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Review Article

A Mini Review on Some Known Medicinal Uses of *Tridax procumbens*

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ABSTRACT

Plants are a valuable source of medication and have a significant impact on global health. Medicinal herbs and plants have long been recognized as valuable sources of medicines and curative remedies. Medicinal plants are considered rich sources of ingredients that can be used for drug development. This has propelled scientists and researchers to investigate the use of medicinal plants for the treatment of various ailments. One of the plants with a wide variety of medicinal purposes is the *Tridax procumbens* plant. It is a highly potent plant that has many health benefits. *Tridax procumbens* is readily available and with all the medicinal benefits, it is still underutilized due to lack of or insufficient awareness. This study is aimed at reviewing the anti-hypertensive, anti-diabetic, wound healing, antimicrobial, antioxidant, hepatoprotective, and cardioprotective potentials of the *Tridax procumbens* plant. Google Scholar, Elsevier, NCBI, and PubMed databases were searched from 2009 to 2023 using specific keywords. Searching was done only using the English language. Thirty-six (36) articles were evaluated in this review. Most of the research articles included in this review supported the claims. It was concluded that this plant has medicinal properties due to the bioactive compounds it contains which help to ameliorate many health conditions.

***Keywords*:** *Tridax procumbens*, Anti-hypertensive, Anti-diabetic, Wound healing, Antimicrobial, Antioxidant, Hepatoprotective, Cardioprotective.

Introduction

Plants are very key sources of medication and contribute to world health.[1] Medicines and curative treatments have long been recognized as great sources of medicinal herbs and plants. Because of the numerous ongoing studies on herbal or medicinal plants, great progress has been made in the pharmacological evaluation of many plants used in traditional medicine.[2]

Phytochemicals are substances created by a plant's inherent metabolic processes. Examples of "secondary metabolites," which are broken down into many categories, include alkaloids, flavonoids, coumarins, glycosides, gums, polysaccharides, phenols, tannins, terpenes, and terpenoids. [3,4] In addition to this, plants also contain a wide range of chemical substances. These may function as assimilation aids or as inhibitors of the adverse effects of the primary active chemicals.

In addition to increased laboratory study into the pharmacological properties of plant products' bioactive elements and their capacity to cure a range of illnesses, there is growing interest in herbal medicines. Medicinal plants are quite effective in treating a wide range of illnesses. It is now being promoted because it is effective, readily available, and because, unlike traditional pharmaceuticals, it has no chance of having unwanted side effects in the body.[5]

Plants produce compounds known as phytochemicals.[6] Phytochemicals, derived from the Greek word which means "plant," are compounds plants produce during either their primary or secondary metabolism.[7,8] Most times, they have a biological effect on the host of the plant and facilitate the development of the plant or serve as a defence against enemies, predators, or infections.[8]

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It has been observed that several plants possess a high level of efficacy in treating many ailments. The *Tridax procumbens* (*T. procumbens*) plant is an illustration of this. *Tridax procumbens* plant as shown in Figure 1 often known as *tridax* daisy or coat buttons, [9] is a species of plant in the family of daisies. It is a typical pest and plant of weed nature. The name "*procumbens*" is used to describe the nature of the stems which are prostrate and trailing and "*Tridax*" to describe the three lobes of the ray blooms. [10]

The plant has three-toothed, yellow-centered ray florets on its white or yellow flowers. They feature arrow-head-shaped leaves with teeth. Its fruit is rigid, having stiff hairs and a white pappus that resembles a feather at one end. In regions with tropical or semi-tropical climates, the plant can be found in meadows, fields, disturbed lands, and croplands.

The value of medicinal herbs and plants as sources of drugs and cures has long been acknowledged. There has been significant headway in the pharmacological evaluation of many plants used in medicine traditionally owing to the number of ongoing research on herbal or medicinal plants Medicinal plants are considered rich sources of ingredients that can be used for drug development. This has propelled scientists and researchers to investigate the use of medicinal plants for the treatment of various ailments. One of the plants with a wide variety of medicinal purposes is the *Tridax procumbens* plant. It is a highly potent plant that has many health benefits such as hepatoprotective, immunomodulatory, anti-diabetic, antioxidant, wound healing, antimicrobial, anti-hypertensive and many more still undergoing trials. *Tridax procumbens* is a plant readily available and with all the medicinal benefits, it is still underutilized due to lack of or insufficient awareness. *Tridax procumbens* has long been used in India as an anticoagulant, a wound healer, a therapy for fungus infections, and an insect repellent. Traditional treatments employed leaf extracts to treat infectious skin problems. Research has also shown that the plant has other medicinal functions such as antioxidant, hepatoprotective, immunomodulatory, anti-diabetic, hair growth promotion, wound healing, antimicrobial, anti-hypertensive, hematopoietic effects, and many more which are to be discussed in this study. This study is aimed at reviewing some of the known therapeutic functions of the *Tridax procumbens* plant.

Phytoconstituents of Tridax procumbens

The *T. procumbens* plant contains a variety of phytochemicals, according to research. Alkaloids, carotenoids, saponins, flavonoids, and tannins were all identified by phytochemical testing as being present in this plant.

Flavonoids: Twenty-three flavonoids are present in *T. procumbens*, according to a recent study. Kaempferol and catechin, as well as their derivatives epigallocatechin, epicatechin, gallocatechin, catechin, and epigallocatechin-3-gallate (EGCG), are examples of anti-oxidants. Others are luteolin, myricetin, isorhamnetin, naringenin, baicalin, biochanin, apigenin, robinetin, etc.[11] The primary flavonoid present in *T. procumbens* L. leaves is kaempferol. Kaempferol and its glycosidic derivatives have been demonstrated in preclinical studies to possess a wide range of therapeutic properties, including cardioprotective, antioxidant, analgesic, anti-inflammatory, anticancer, neuroprotective, hepatoprotective, antimicrobial, anti-diabetic, e.t.c.[12]

Alkaloids: Any class of nitrogenous organic compounds with notable physiological effects on people is referred to as alkaloids. *T. procumbens* has also been found to contain certain alkaloids, according to reports. Thirty-nine alkaloids, primarily Akuamidine (73.91%) and Voacangine (22.33%), were found in the leaves after an aqueous extraction for a phytochemical screening examination. The extract also had tannins and sterols in addition to alkaloids. Proteus mirabilis and Candida albicans were resistant to the antibacterial effects of *T. procumbens*' pedicle and buds, while E. coli and Trichophyton mentagrophytes were resistant to the antimicrobial effects of the buds. [13]

Saponins: The blooms of *T. procumbens* contain compounds such as pB-Sitosterol-3-O-D-xylopyranoside and steroidal saponin. The steroidal glycosides known as saponins have pharmacological and medicinal properties. The sodium-glucose co-transporter-1 (S-GLUT-1) in the male rats' intestines was found to be blocked by saponins from an ethanol extract of *T. procumbens*, according to another study.[13]

Tannins: Water-soluble polyphenols called tannins are naturally occurring in plants. The tannin content of *T. procumbens* has been discussed by several academics. Using acetone water or chloroform water, the tannins in *T. procumbens* leaf extracts were identified. Tannins are present in *T. procumbens*' pedicle and buds. Tannins have anti-microbial, anti-mutagenic, and anti-carcinogenic activities, possibly as a result of their antioxidant abilities. [13]

Carotenoids: Plants use the fat-soluble pigments known as carotenoids, which are abundant in leaves, to attract insects, catch the light, and protect themselves from photooxidative damage. It is believed that carotenoids shield DNA from oxidative stress-related damage. Other types of these secondary metabolites, such as beta-carotene, which can then be biotransformed into vitamin A, a necessary component for sustaining epithelial cells, have been isolated from *T. procumbens*. A lack of vitamin A can lead to immune system and hematopoiesis problems, night blindness, and Xerophthalmia. Carotenoids like beta-carotene and lutein have demonstrated efficacy in lowering UV-induced erythema. The antioxidant qualities of carotenoids and their photoprotective capabilities have also been connected. [13]

Other phytochemicals: *T. procumbens* leaves also include tannins, stigmasterol, caffeine, ferulic acid, lutein, and other advantageous substances. Similarly, the structures of some of the various flavonoids found in *T.procumbens* are shown in figure 2. Studies done in vitro have shown that ferulic and caffeic acids have antibacterial, anticancer, anti-inflammatory, and antioxidant activities. Numerous health advantages include a decreased risk of cardiovascular disease, as well as anti-cancer, anti-diarrheal, anti-obesity, antiviral, antibacterial, antifibrotic, and neuroprotective effects of tannic acid and other hydrolyzable tannins. Ca2+-activated Cl-channel inhibition is one of the molecular mechanisms linked to tannin's medicinal effects. Pharmaceutical effects of stigmasterol include anti-osteoarthritic, anti-hypercholesterolemic, cytotoxic, anti-tumor, hypoglycemic, anti-mutagenic, antioxidant, anti-inflammatory, and analgesic properties. Age-related macular degeneration (AMD), retinitis pigmentosa, uveitis, diabetic retinopathy, age-related cataracts (ARC), retinal detachment, breast and lung cancer, heart disease, and stroke can all be prevented by consuming lutein, a form of xanthophyll carotenoid.[12] The plant also contains a few more primary and secondary metabolites. Specifically, there have been some phytochemicals that have been isolated and identified in *T. procumbens* with many therapeutic potentials. Some of them include (Table 1);

Methodology

Article Search and Selection

Using specified keywords, the Google Scholar, PubMed, NCBI, and Elsevier databases were searched between 2005 and 2023. Keywords such as "*Tridax procumbens"*, "antihypertensive", "wound healing", "antimicrobial", "antidiabetic", "antioxidant", "hepatoprotective", and "cardioprotective" were used to search. The only articles that could be searched were those that were written in English. In the beginning, 52 items in total were chosen. Finally, 36 papers were determined to be appropriate for inclusion in the study based on their applicability. Review papers were also left off the list of chosen articles. Important studies on both people and animals were included. To identify potential new investigations conducted appropriately, the references of the articles were also evaluated.

Figure 1: *Tridax procumbens* plant [6]

Results and Discussion

Medicinal uses of Tridax procumbens

Anti-hypertensive

Hypertension is a health state of high or rising blood pressure usually characterized by pressure in the blood arteries that are consistently elevated. The possibility of the occurrence of disorders of the brain, kidney, heart, etc. can rise resulting from hypertension. More than a billion people globally roughly one in five women and one in four men are hypertensive, which makes it a major contributor to premature death. This disease is more prevalent in low- and middle-income nations. This can be partly attributed to the fact that the risk factors have increased in these populations in the past few decades.[55] Adults are deemed to have normal blood pressure if their systolic readings are less than 140 mmHg and their diastolic readings are less than 90 mmHg. If a person's systolic reading exceeds 140 mmHg, their diastolic reading exceeds 90 mmHg, or if both are higher than these levels, they are said to have high blood pressure.

Much research has described the use of *T. procumbens* in the management of hypertension and regulation of blood pressure. In rats given salt-loaded diets, Jude *et al*.[19] investigated the impact of *T. procumbens* aqueous extract on the body weight, plasma electrolytes, and packed cell volume (PCV). The test and test control groups were fed with 8% salt and 92% feed whereas the controls were fed with 100% feed. The test group was treated with the extracts through their intra-gastric gavages meanwhile the test control and normal control group were given water through the same route. In contrast to the test control group and control group, the intervention group's mean daily weight and PCV increased, according to the results. Moreover, the plasma sodium and chloride levels were lower in the intervention group. There was no significant variation in calcium and potassium levels in plasma. The conclusion reached was that the anti-hypertensive effects of *T.*

procumbens might be facilitated through weight reduction and reduction of sodium and chloride levels in the blood.

Salahdeen *et al*.[20] studied the possible impacts of *T. procumbens* extract (TPE) on the thoracic aorta of rats. The aortic artery was isolated from Wistar albino rats. They were induced with phenylephrine (PE) and potassium chloride (KCl). The animals were then administered varying concentrations of the extract. Changes in arterial tension interactions between extract with cyclic adenosine monophosphate (cAMP) and cyclic guanosine monophosphate (cGMP) inhibitors were also assessed. Results showed that the extract substantially reduced the phenylephrine-induced contraction which was dependent on the concentration. Pre-incubation of cGMP and cAMP inhibitors significantly attenuated the vasorelaxant effect of the TPE. These findings advise that the extract has vasodilatory effects that is dependent on concentration. The mode of action of TPE is quite complex. Blockage or modulation of cGMP and cAMP contributes partly to the relaxing effect of TPE.

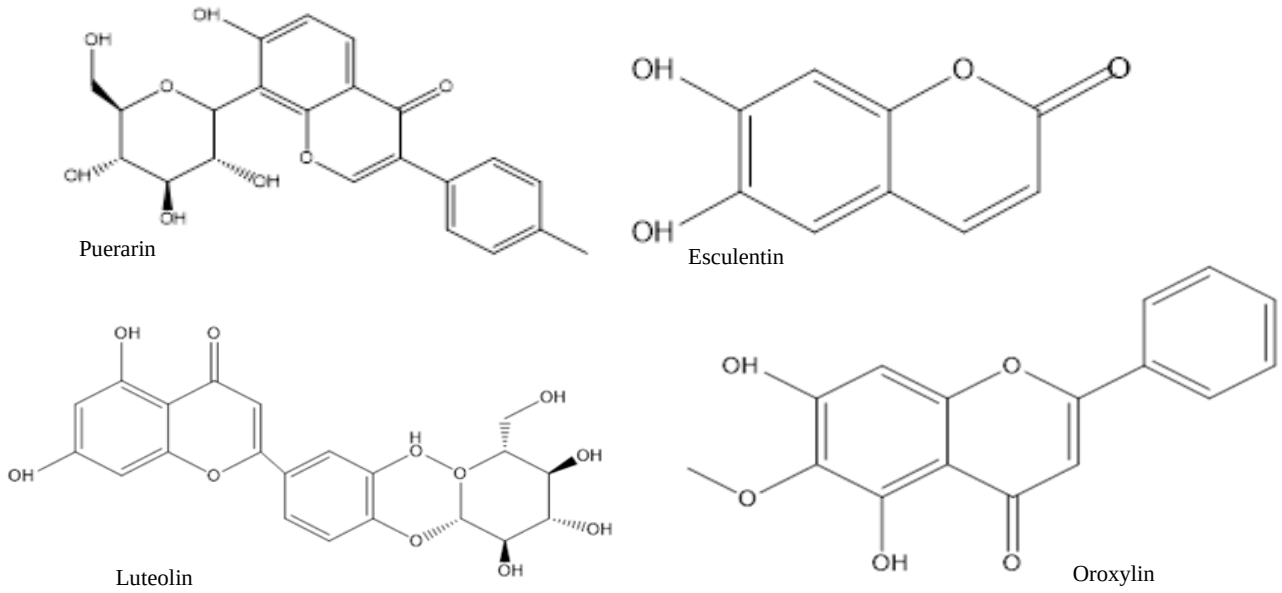
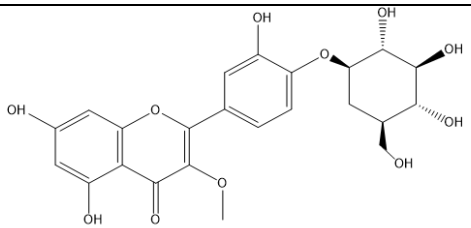
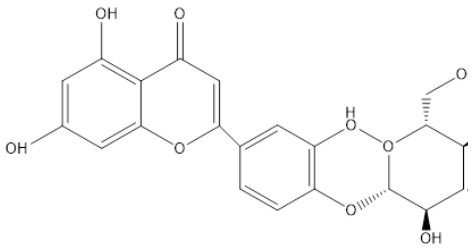
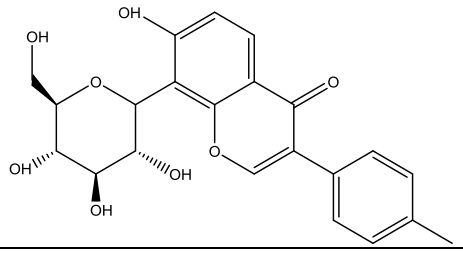
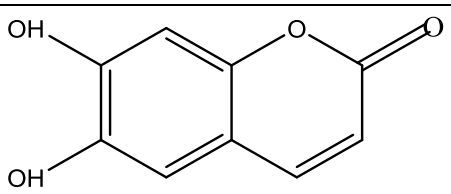
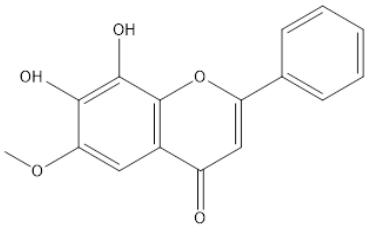
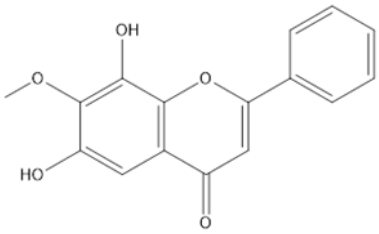
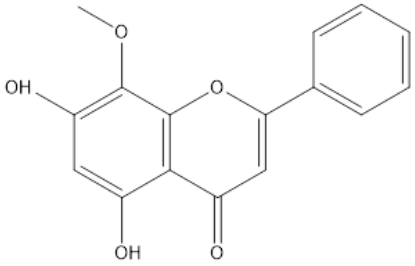
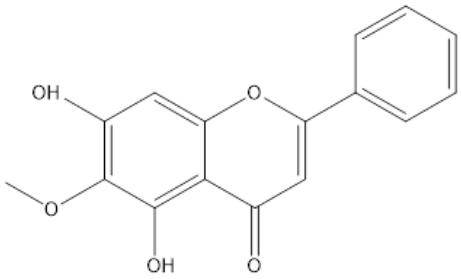
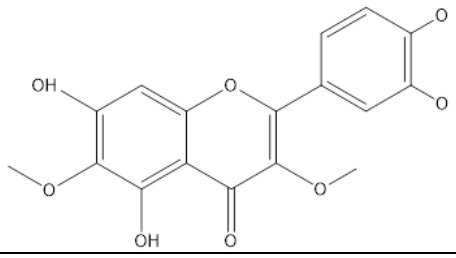


Figure 2: Structure of some flavonoids identified in *T. procumbens* [62]

Table 1: Isolated phytochemicals from *Tridax procumbens*

S/N	Used plant part	Solvent	Analytical method	Phytochemicals	Structure	Activity	Reference
1	Aerial Part	Ethanol	HPLC	3-O-Methylquerecetin-4'-O-β-D-glucopyranoside		Antibacterial	[14,15]
			TLC, IR, ^{1}H-NMR, HR-ESI-MS CD, ^{13}C-NMR	3-O-Methylquerecetin-4'-O-β-D-glucopyranoside (15 mg)		Antioxidant	
2	Aerial Part	Ethanol	HPLC	Luteolin-4'-O-β-D-glucopyranoside		Antibacterial	[14]
3	Whole plant	Ethanol	ID, 2D ^{1}H-NMR, ESI-MS, ^{13}C-NMR	Puerarin		Antioxidant	[16]

4	Whole plant	Ethanol	ID, 2D ^{1}H-NMR, ESI-MS, ^{13}C-NMR	Esculentin		Antioxidant	[16]
5	Flower	Ethanol	UV, IR ^{1}H-NMR, ESI-MS, ^{13}C-NMR	6-methoxy-7,8-dihydroxyflavone		Antioxidant	[17]
6	Flower	Ethanol	UV, IR ^{1}H-NMR, ESI-MS, ^{13}C-NMR	7-methoxy-6,8-dihydroxyflavone		Antioxidant	[17]
7	Flower	Ethanol	UV, IR ^{1}H-NMR, ESI-MS, ^{13}C-NMR	Wogonin		Antioxidant	[17]
8	Flower	Ethanol	UV, FTIR ^{1}H-NMR, ESI-MS, ^{13}C-NMR	Oroxylin		Antioxidant	[17]
9	Whole plant	Ethanol Ehtyl acetate Methanol	^{1}H-NMR	Centaureidin R=H Centaurein R=Gu		Antiinflammatory and antioxidant	[18]

Salahdeen *et al*.[21] evaluated the vasorelaxant effects (endothelium-dependent and independent) of *Tridax procumbens* Linn leaf in the aortic rings of rats. In this experiment, the concentration of *Tridax procumbens* leaf extract resulted in either phenylephrine (PE)-induced relaxation of the aorta or KCl-induced contraction of the aortic rings in the rats. Greater than the one caused by KCl (57%), PE had a calming impact on contraction. The endothelium was not required for the sodium nitroprusside-induced relaxation, and the NOS inhibitor N (gamma)-nitro-L-arginine methyl ester (L-NAME) blocked the extract's ability to relax blood vessels. The sodium nitroprusside-induced relaxation was reduced in rat aorta precontracted with phenylephrine by endothelium ablation. According to the aforementioned findings, mechanisms depending on or unrelated to the endothelium are presumably what help the *T. procumbens* extract's vasorelaxant impact.

Salahdeen *et al*.[22] experimented to evaluate parameters used to determine the efficiency of aqueous leaf extract of *Tridax procumbens* (Linn.) in managing hypertension. The n-nitro-L-arginine methyl ester was used to induce the rats' behavior. The four treatment groups for rats were chosen at random. According to the findings, administering the extract significantly reduced the sustenance of hypertension brought on by L-NAME. Administration of TPE also resulted in a part or complete improvement of some of the hazards caused by L-NAME, which include: (1) An increase in blood pressure and organs weight (2) An increase in blood lipids (3) Histological lesions in the liver, and heart, etc. In conclusion, this study gave some evidence about the effects of

TPE in the management of hypertension and the protection of organs in animal models. Some of the constituents of the extract were implicated in these effects.

Salami *et al*[23] study looked into how the Na+-K+ pump and the Na+-Ca2+ exchanger were affected by T. procumbens extract (TPE) on isolated rat superior mesenteric arteries' ability to relax blood vessels. Wistar rats that had been pre-contracted with phenylephrine (10–7M) were extracted, and different quantities of the TPE aqueous extract (0.5–9 mg/mL) were used. We monitored alterations in arterial pressure and looked at the connection between ouabain, a potential inhibitor of the Na+-Ca2+ exchanger, and TPE. The findings demonstrate that TPE (10-9-10-5M) significantly and concentration-dependently suppresses the cumulative concentration-response curves to PE. The vasorelaxant effects of TPE were abolished by pretreatment with either ouabain or nickel chloride (NiCl2). Additionally, by lowering the extracellular Na+ concentration, TPE lessened the relaxing effect. In a Na+-free solution, which removes the influence of the exchanger's forward mode, TPE-induced vasorelaxation was completely eradicated. The results were found to provide clear evidence that the activation of the Na+-K+ ATPase and stimulation of the forward mode of the Na+-Ca2+ exchanger are what caused the vasorelaxation brought on by TPE in the mesenteric artery

Wound Healing

Tridax procumbens has long been used to cure wounds. By interacting with epidermal, dermal, ECM, soluble proteins, and angiogenesis processes controlled by a variety of cytokines and growth factors, *T. procumbens* improves wound healing.[61] *Tridax procumbens* Linn's aqueous and ethanol extracts were examined by Das *et al*. [24] for their potential role in the healing of wounds. Excision and incision wound models were both assessed. Animals were divided into control and intervention groups. According to the findings, the intervention group's wounds had a much higher tensile strength than the controls. On the 15th day, biochemical tissue indicators such as collagen, hydroxyproline, and hexosamine were considerably higher in the therapy group in the excision wound model. In comparison to the controls, the intervention group's wound area was much smaller. Studies conducted in the past revealed that the formation of a scar results from the removal of the collagen and other cellular "macromolecules" that were produced as part of the acute inflammation that occurs during the healing of a wound. Histopathological assessments showed increased granulation spike and speedy turnover of collagen.

Ravindran *et al*.[25] examined the effects of silver nanoparticles made from *Tridax procumbens* leaf extract in fish. A fish species known as *Pangasius hypophthalmus* was used to test the effectiveness of the nanoparticles on wound healing. They did a comparison of the efficacy of the healing of wounds of the silver nanoparticles from *Tridax procumbens* to that of silver nitrate and the extract of the leaf. Findings showed that using nanoparticles to treat wounds caused collagen to deposit and fibrosis to occur earlier. Also, the fish wound demonstrated improved healing after exposure to the silver nanoparticles. It improved the epithelialization and wound's appearance in comparison to silver nitrate and *Tridax procumbens* leaf extracts.

Tridax procumbens (L.) ethanolic extract's (EETP) impact on wound healing in diabetic and non-diabetic rats was examined by Shrivastav *et al*. [26] Making advantage of the incision, excision, and burn wound models, they created a straightforward EETP ointment to test its potential for healing wounds. The result of the experiment revealed the presence of secondary metabolites like tannin, flavonoids. In the excision model, the treatment group showed a significant contraction of the wound, period of epithelization, and wound index. There were also increases in Hydroxyproline, total protein, and DNA concentration in the healing tissue compared to the controls. It was concluded that the tannin and flavonoids were responsible for wound healing in both conditions (diabetic and non-diabetic).

The effectiveness of a *T. procumbens* ointment formulation in treating wounds was assessed by Deshmukh *et al*. [27] The healing potential of a herbal ointment formulation comprising *T. procumbens* leaf extract was investigated. For 15 days, this ointment composition was applied twice daily to a cutaneous wound. Betadine served as the standard, while blank ointment base served as the control. In contrast to the blank ointment, the results demonstrated that topical application of the ointment containing *Tridax procumbens* increased the pace of wound healing and wound closure on the mice excision wound. The ointment formulation including *T. procumbens* was shown to be effective in treating wounds and should be further researched in light of the plant's potential to treat numerous topical ailments.

Finding a more effective Ayurvedic dosage form for *Tridax* while simultaneously using an all-encompassing approach in keeping with Ayurvedic principles was the goal of Ambulkar *et al*.'[28] research. A model of an excision wound is used in an animal experiment on albino rodents. To measure the rate of constriction and duration of epithelialization, five *Tridax* dosage forms—Ash, Kalka, Oil, Ghana, and Ethanol extract—were created and compared to the control. The outcomes were excellent. The numerous dose formulations of *Tridax* showed exceptional wound-healing skills. There were a few dose forms that showed typical activity at different stages of wound healing. Therefore, *Tridax* is a strong drug with the potential to become a significant wound-healing agent in the future.

Antimicrobial properties

It has also been demonstrated that *Tridax procumbens* has some antibacterial qualities that can inhibit the actions of different kinds of microbes. The antibacterial effects of *T. procumbens* extract on nosocomial infections were investigated by Pai *et al*.[29] Using the agar well diffusion method, aqueous and ethanolic extracts of *T. procumbens* were evaluated on a few bacteria. *Pseudomonas aeruginosa* nosocomial strains from various samples were also evaluated. The aqueous extract was not effective against bacteria. However, *Pseudomonas aeruginosa* was significantly resistant to the ethanolic extract's antimicrobial effects. To compare the activity of the ethanolic extract on bacteria, antibiotics such as augmentin, cefotaxime, and ciprofloxacin were utilized. The antibacterial activity was comparable to that of commercial antibiotics, according to the results. Therefore, it was determined that *Tridax* leaves may be effective in combating infections caused by *Pseudomonas aeruginosa*.

Tridax procumbens Linn (L) extracts were tested for their antibacterial properties against *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella typhi*, *Bacillus cereus*, and *Staphylococcus aureus* by Bharathi *et al*.[30] In this study, methanol and ethyl acetate extracts of *Tridax procumbens* were employed. The disc and agar well diffusion method was used to assess the activity of the extracts against bacteria. When compared to other species, the ethyl acetate extracts were found to have effective suppression against Staphylococcus aureus. Then it was proposed that *Tridax procumbens* leaves might be a source of antibacterial substances. Pandey *et al*. [31] also established the antibacterial activity of *Tridax procumbens* Linn (L) extract against some water-borne pathogens. Acetone, ethanol, and methanol extracts were used in this analysis. The broth micro-dilution method was used to carry out the antibacterial tests. Results showed that extract from acetone was more effective against *E. coli* and *V. cholerae* meanwhile that of ethanol was effective against *Klebsiella pneumoniae* and the effectiveness of that of methanol was observed in only *V. cholerae*.

Research by Tejwaswini *et al*.[32] evaluated the phytochemicals present and the impact of crude and column extracts of Tridax procumbens on microbes. Results of the phytochemical analysis revealed that alkaloids, fumaric acid, fl-sitosterol, carotenoids, tannins, saponins, and flavonoids (catechins and flavones) were present. The plant extracts showed good antimicrobial activity since most of the microorganisms are showing resistance to various compounds. The antimicrobial activity was found to be better in crude extracts than in column extracts. This study suggested the need for the use of natural compounds as antimicrobial agents.

A methanol extract of *Tridax procumbens* was reported to prevent many infections seen on human skin, according to a 2014 study by Policegoudra *et al*.[33] Major human skin pathogens with low minimum inhibitory concentrations (MIC) values, such as *Candida albicans*, *Trichophyton rubrum*, *Trichophyton rubrum*, *Microsporum fulvum*, and *Microsporum gypseum*, shown improved antifungal activity when the extract was administered.

Syed *et al*[34] investigated the cytotoxic, antibacterial, and antioxidant properties of *Tridax procumbens* leaves. Drying of the leaves was carried out, and numerous organic solvents were used to extract them. The leaves included a variety of compounds, including alkaloids, polyphenols, tannins, and carbohydrates. The antibacterial qualities of the extracts were assessed with the use of disc diffusion methods. Several organic solvent extracts, including methanol, ethanol, and ethyl acetate extracts, showed outstanding efficacy against the bacterial strains under research, according to the data. The antioxidant activity of the *T. procumbens* leaf methanol extract was substantially higher. The plant leaf extract under investigation was more potent against breast cancer cell types than it was against human lung cancer cells. Plant extract at 250 g/ml slowed the growth of human lung cancer cells by 84±2%.

In the investigation conducted by Andriana *et al*.[35] *T. procumbens* was extracted using a variety of liquids. Additionally, it was separated into various fractions using column chromatography (CC), with methanol and chloroform serving as the eluents, and its antibacterial, antioxidant, and xanthine oxidase (XO) inhibitory characteristics were examined. Both extracts and fractions were used to evaluate the bactericidal activity. Several *T. procumbens* extracts were examined in an antibacterial activity experiment against the bacterium strains *E. coli*, *S. aureus*, *P. mirabilis*, and *B. subtilis*. In every bacterial strain, the EtOAc extract demonstrated the highest inhibitory effects (minimum inhibitory activity = 25-10 mg/mL). E. coli and S. aureus were both inhibited by hexane extract, while only S. aureus was by chloroform extract. Gram-positive (*P. mirabilis* and *E. coli*) and negative (*B. subtilis* and *S. aureus*) bacteria were used to test *T. procumbens'* antibacterial activity. On four different bacterial strains, the studied fractions' levels of inhibition varied. The F4-5 fraction (MIC = 15–25 mg/mL) was the best option for preventing the growth of all tested microorganisms. All fractions displayed lower inhibitory values than the positive controls, ampicillin, and streptomycin. Streptomycin and ampicillin both had MIC values of 0.156 mg/mL and 0.0012-0.039, respectively.

Antidiabetic properties

Elevated blood glucose, also referred to as blood sugar, is a characteristic of diabetes, a metabolic disorder that is chronic. Diabetes over time can seriously harm the kidney, blood vessels, eyes, nerves, heart, and cardiac function. Adults are typically affected by type 2, the most prevalent form of diabetes. It begins to show up when the body either stops producing enough insulin or develops a resistance to it. In countries with all income levels, the prevalence of type 2 diabetes has increased dramatically for exactly three decades. Many plants are potent in the management of diabetes. Amongst them is *Tridax procumbens*. Aqueous, alcoholic, and petroleum ether extracts of *Tridax procumbens* were shown by Bhagwat *et al*.[36] to have anti-diabetic benefits in Wistar rats. The results showed that taking the extracts by mouth considerably reduced blood sugar levels. This is an indication of the potential of *T. procumbens* to manage diabetes.

In the study by Pareek *et al*.[37] oral intake of sub-chronic and acute doses of *Tridax procumbens* extracts significantly lowered fasting blood glucose levels in rats having diabetes; however, no such reduction was observed in normal rats. When evaluated against the reference drug Glibenclamide, the effects of *T. procumbens* on diabetes were comparable.

Petchi *et al*.[38] assessed the effects of *Tridax procumbens* ethanolic extracts in diabetic rats induced with streptozotocin. The extracts were analyzed to determine their phytochemical content. The extracts were administered to the rats having diabetes then glibenclamide was used for comparison. The analysis of phytochemicals indicated that compounds such as tannins, alkaloids, phenolics, flavonoids, and saponins were present. The extracts and glibenclamide reversed the streptozotocin-induced hyperglycemia to the normal level. A drastic weight reduction occurred in the intervention group in comparison with the controls.

Table 2: Findings from the studies

Author	Year	Subjects	Activity	Results
[19]	2010	Animals (Rats)	Antihypertensive	Increase in mean daily weight and PCV. Lower plasma sodium and chloride levels.
[20]	2016	Rat organ	Antihypertensive	Substantial reduction in the phenylephrine-induced contraction.
[21]	2012	Rat organ	Antihypertensive	Concentration-dependent relaxation of the aorta.
[22]	2017	Rats	Antihypertensive	Inhibition of hypertension sustenance. Partial or complete improvement of some of the hazards caused by the toxicant, which include: (1) Increase in Blood pressure and organs weight (2) Increase in blood lipids (3) Histological lesions in the liver and heart, etc.
[23]	2021	Rat organs	Antihypertensive	Significantly inhibited the cumulative concentration-response curves in a concentration-dependent manner. Lowered the extracellular Na+ concentration, which diminished the relaxing effect. A Na+-free solution fully eliminated vasorelaxation.
[24]	2012	Rats	Wound healing	The wounds in the intervention group had tensile strengths that were noticeably higher than those in the controls.

				Collagen, hydroxyproline, and hexosamine were higher in the therapy group in the excision wound model. The area of the wound was smaller in the intervention group. Increase granulation spike and speedy turnover of collagen.
[25]	2019	Fish	Wound healing	Deposition of collagen and formation of fibrosis. Enhanced healing of the wound in the fish. Improved epithelialization and wound appearance.
[26]	2020	Rats	Wound healing	Presence of secondary metabolites like tannin, and flavonoids. Significant contraction of the wound, period of epithelization, and index of the wound. Increases in Hydroxyproline, total protein, and DNA concentration in the healing tissue in comparison with the controls.
[27]	2018	Mice	Wound healing	Increased wound healing pace and wound closure.
[28]	2020	Rats	Wound healing	Excellent wound healing property.
[29]	2011	Bacteria	Antimicrobial	Comparable antimicrobial activity with antibiotics.
[30]	2012	Bacteria	Antimicrobial	Effective suppression against Staphylococcus aureus
[31]	2016	Bacteria	Antimicrobial	Effective antibacterial activity
[32]	2011	Bacteria	Antimicrobial	Good antimicrobial activity
[33]	2014	Human skin pathogen	Antimicrobial	Improved antifungal activity
[34]	2020	Bacteria, Human cell lines	Antimicrobial, cytotoxic, antioxidant	Excellent efficiency against bacterial strains. Higher efficacy against human lung cancer cells Good antioxidant activity.
[35]	2019	Bacteria	Antimicrobial	Strong antibacterial activity
[36]	2008	Rats	Antidiabetic	Significantly reduced the rats' blood sugar levels
[37]	2009	Rats	Antidiabetic	Reduced fasting blood glucose in diabetic rats comparable with glibenclamide.
[38]	2013	Rats	Antidiabetic	Reversed the streptozotocin-induced hyperglycemia to the normal level comparable with glibenclamide.
[39]	2014	Rats	Antidiabetic	Extracts inhibited alpha-amylase activities.
[40]	2015	Human	Antidiabetic	Significant reduction in fasting and post-prandial blood glucose concentrations. Strong antioxidant capacity.
[41]	2021	Rats	Antidiabetic	Decrease in weight gain and a lack of a rise in blood sugar and lipid levels.
[42]	2022	Rats	Antidiabetic, Antioxidant	A substantial decline in blood glucose concentrations. Improvement in oxidative stress biomarkers.
[43]	2010	*In vitro*	Antioxidant	Antioxidant activity comparable to the standards employed, gallic and ascorbic acids
[44]	2009	*In vitro*	Antioxidant	High antioxidant power

[45]	2017	*In vitro*	Antioxidant	Presence of alkaloids, tannins, polyphenols, glycosides, flavonoids, saponins carbohydrates. Strong antioxidant activity.
[46]	2021	*In vitro*	Antioxidant	Antioxidant activity was comparable with ascorbic acid.
[47]	2018	Rats	Hepatoprotective	Markedly normalized the abnormal values in liver function and antioxidant parameters in a dose-dependent manner.
[48]	2018	Rats	Hepatoprotective	Modulated liver enzyme activity. Improved the histological profile of the rat organs.
[49]	2021	Rats	Hepatoprotective	All abnormal values of serum hepatic biomarkers and antioxidant enzymes were returned to normal.
[50]	2005	Rats	Hepatoprotective	Restored altered serum hepatic biomarkers and antioxidant enzymes to normal.
[51]	2010	Rats	Hepatoprotective	Restored altered serum hepatic biomarkers and antioxidant enzymes to normal.
[52]	2020	Rats	Cardioprotective	Modulated all the alterations in total cholesterol, low-density lipoprotein cholesterol (LDL-C), lipid peroxidation (LPO), triglycerides, and very low-density lipoprotein cholesterol (VLDL-C), high-density lipoprotein cholesterol (HDL-C), Paraoxonase (PON)and reinstated altered lipoproteins and lipids levels to normal.
[53]	2019	Rats	Cardioprotective	Significantly altered inflammatory biomarkers.
[54]	2021		Cardioprotective	Improved the adverse effects of doxorubicin in the rats using the cardiac integrity and oxidative stress biomarkers

To evaluate *T. procumbens'* in vitro anti-diabetic efficacy, Sonawane *et al*.[39] performed a test. The in vitro alpha-amylase inhibitory activity of *Tridax procumbens* whole plant extracts in petroleum ether, chloroform, and methanol was evaluated. Comparing the % inhibition value to quercetin and normal acarbose, it was discovered that the extracts had inhibited alpha-amylase activity. From the results, it was seen that methanol extract could reduce glucose levels postprandially through the inhibition of α-amylase. The inhibitions observed in pet ether and chloroform extracts were lower.

A study carried out by Desai *et al.*[40] was aimed at evaluating the lowering effects on blood glucose concentration resulting from the administration of *Tridax procumbens* in patients with Type 2 diabetes. The extracts contained phenolics, flavonoids, and carotenoids, according to a chemical examination. The results of the microbial analysis showed that there were no microorganisms, aflatoxins, pesticide residues, or heavy metals present. Leaf extract was found to have significant potential as an antioxidant. Fasting and post-meal blood glucose levels significantly decreased after ingesting the extracts.

In the study conducted by Amagbegnon *et al*.[41] the hydro-ethanol extract gotten from the plant's leaves and stems as well as its fractions were used to determine the plant's preventative and therapeutic benefits against obesity, hyperglycemia, and hyperlipidemia. The hydro-ethanolic extract was decanted to generate four fractions with hexane, dichloromethane, diethyl ether, and ethyl acetate. For 28 days, the rats given a fatty and sweet diet developed hyperlipidemia and hyperglycemia. Results showed that the diet considerably enhanced the lipid levels, weight, and glycemia of the rats. Contrarily, rats that were administered 500 mg/kg of *Tridax procumbens* extract showed less weight growth and no blood sugar or cholesterol levels rise. The fatty and hyperglycemic rats received the ethyl acetate fraction of *Tridax procumbens* extract for 14 days at a dose of 50 mg/kg of body weight, but their blood sugar and triglyceride levels remained unchanged.

In the Kakkar *et al*. [42] investigations, Wistar rats were given four weeks of intraperitoneal administration of 45 mg/kg of streptozotocin (STZ) to induce DN. The blood glucose levels were assessed after the rats' tails were clipped. Additionally, evaluated were body weight and urine volume. Several inflammatory cytokines, including tumour necrosis factor (TNF)- α and interleukin (IL)-β, were found to be oxidative stress generators, including superoxide dismutase (SOD), thiobarbituric acid reactive substances (TBARS), catalase (CAT), and others. Protein kinase C (PKC-) and vascular endothelial growth factor (VEGF) were also assumed to be angiogenic markers. The acetone test for cold allodynia, Eddy's hot plate for hot allodynia, the Rota rod for grip strength, and the Tail flick technique for hyperalgesia were also used to evaluate behavioural aspects. Turkey was added as a post hoc analysis using the GraphPad Prism software, and a one-way analysis of variance (ANOVA) was performed for the statistical evaluation of the data. TP was administered to DN rats for a month, and as compared to untreated DN rats, it significantly lowered blood glucose levels. The biochemical marker results demonstrated that the DN had greatly improved. While the blood level of antioxidant defense enzymes was increased in the TP-treated rats with DN, the activities of TBARS were drastically reduced. TP reduced DN-induced increases in blood levels of TNF- α and IL-6. Additionally, PKC- β and VEGF concentrations had decreased as a result of the TP therapy. The restoration effects of TP on DN rats were

demonstrated by this study's findings to be possibly due to the anti-inflammatory and antioxidative antiangiogenic responses.

Antioxidant properties

Oxygen-containing molecules called free radicals have an unbalanced distribution of electrons. They easily react with other molecules owing to their odd number. Because they interact with other molecules so quickly, free radicals can produce enormous chemical chain reactions in the body. These reactions are referred to as oxidation. They have the potential to be advantageous or unfavourable. Antioxidants are substances that stop oxidation. They are also known as "free-radical scavengers." To defend human cells and organ systems from free radicals, a sophisticated antioxidant system exists. When free radical generation outnumbers antioxidant defence, oxidative stress ensues.[56]

The antioxidant capacity of *Tridax procumbens* was investigated by Habila *et al*.[43] The 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay and the Folin-Ciocalteu method was used to analyze *Tridax procumbens* for its capacity to reduce and determine the total phenolics. The analysis's findings showed that *T. procumbens* has a smaller amount of antioxidant activity than the two standards used—gallic and ascorbic acids. The reductive potential of *T. procumbens* was found to be extremely high. *T. procumbens* contained 12 mg/g GAE of total phenol. It was shown that plants are abundant in natural antioxidants.

In a different investigation, Agrawal *et al*.[44] used the DPPH method to test the antioxidant activity of different methanolic extract fractions. Comparing the activity of ethyl acetate and n-butanol fractions as an antioxidant showed substantial improvement.

The antioxidant capacity of *Tridax procumbens* was also demonstrated by Singh *et al*.[45] Initial phytochemical analysis of *Tridax procumbens* extract in ethanol, methanol, and aqueous extracts showed that alkaloids, tannins, polyphenol, glycosides, flavonoids, saponins carbohydrates were present. Ethanol extracts have higher antioxidant activity *in vitro* than methanol and aqueous extract. These outcomes demonstrate the extracts' antioxidant properties which may be the basis for some of *Tridax procumbens'* medicinal applications.

The antioxidant activity was chosen since the goal of the research by Suryawanshi *et al*. [46] was to identify novel plant directions. The maceration procedure with chloroform, water, and ethanol was used to extract the potency of the plant's shade-dried leaves. To evaluate the antioxidant qualities of the resulting extracts, the reductive capacity of ferric chloride and the scavenging activity of nitric oxide were used. Using a nitric oxide scavenging technique (20 mg), the alcoholic extract showed better antioxidant activity than ascorbic acid at dosages of 600 mg/ml, 800 mg/ml, and 1000 mg/ml. A ferric chloride scavenging model showed that the antioxidant activity of the aqueous and alcoholic extracts at 400 g/ml and 600 g/ml concentrations was comparable to that of 20 g of ascorbic acid.

Hepatoprotective

Wagha and Shinde's study examined how *Tridax procumbens* Linn (Asteraceae) (TP) normalized liver damage induced by rifampicin (RIF) using several biomarkers and indicators of hepatotoxicity in male rats.[47] The albino rats received a daily dose of 50 mg/kg of rifampicin. This led to an increase in the serum Aspartate aminotransferase (AST), Alanine aminotransferase (ALT), and Alkaline phosphatase (ALP) activities and there was also a reduction in the activities of catalase (CAT) and superoxide dismutase (SOD) in liver samples indicating the occurrence of hepatotoxicity in the animals. The levels of thiobarbituric acid reactive substances (TBARS) increased in the RIF-induced toxicity indicating lipid peroxidation (LP). Liver Glutathione, serum total protein, and tissue glycogen were however reduced in the RIF group in comparison with the normal controls. Administration of *T. procumbens* extracts reversed all the abnormalities caused by RIF in the rats. For 10 days, treatment with the extract significantly and dose-dependently normalized the aberrant readings. The values gotten from the groups of rats given the extracts were comparable to the counterparts in the normal control group. This serves as evidence of the hepatoprotective efficacy of the plant extract. *T. procumbens* extracts were most effective at a dose of 400 mg/kg.

Chang human hepatoma cell line was utilized by Saheegh *et al* [48] to assess the antioxidant and hepatoprotective properties of *T. procumbens* L methanol extract in the toxicity brought on by isoniazid-rifampicin in male Wistar rats. Using the MTT test, the hepatotoxic effects of isoniazid-rifampicin on Chang hepatic cells were assessed, as well as the hepatoprotective effects of the methanol stem, leaves, and flower extracts of *T. procumbens*. The rats were divided into six groups of six rats each, and all treatments were given for 14 days. Controls were given normal saline (1 ml/kg). Other groups were given isoniazid-rifampicin at varying doses. For comparison, oral silymarin was provided, while extracts from the plant's various sections were given to others. Results showed that isoniazid-rifampicin significantly reduced cell viability, whereas cytotoxicity was not observed with the extracts. Liver enzymes in the serum were also increased significantly ($p<0.05$). The organs' histopathological profile supported the results of the biochemical assays. It was seen that the leaves were more effective than the stem and flowers and isoniazid-rifampicin damages the liver.

In studies carried out by Chandra and Shanmugapandiyan,[49] the effectiveness of methanolic *Tagetes erecta* and *Tridax procumbens* extracts against liver damage caused by isoniazid and rifampicin (INH-RIF) was assessed. The rats were randomly shared into seven groups while they received treatments for 28 days: there was a normal control group, and another group was given 50mg/kg of INH-RIF intraperitoneally. There were groups given methanol *Tagetes erecta* extracts at 200 and 400 mg/kg respectively. Another group was given methanolic *Tridax procumbens* extracts 200 and 400 mg/kg and finally a group was administered silymarin for comparison. Hepatic indicators in the serum were substantially higher ($p<0.05$). Antioxidants including SOD, CAT, Gpx, GSH, and lipid peroxidation levels in liver tissues were also considerably ($p<0.05$) elevated. All abnormal values were returned to normal resulting from administration of both extracts at the two doses. The study showed that both plants have potent hepatoprotective effects on liver injury which is facilitated by their ability to stabilize membrane and their antioxidant effects.

The protective effects of aerial parts of *Tridax procumbens* on the liver were also examined[50] against rat hepatitis brought on by d-galactosamine/lipopolysaccharide (d-GalN/LPS). The activities of some liver marker enzymes, bilirubin levels in the serum, and other parameters were employed to evaluate the hepatic damage caused by d-GalN/LPS given at a dose of 300 mg/kg body weight (30 mg/kg). The rats were first treated with *Tridax procumbens* ethanolic extract which restored the parameters that were altered back to normal. Histopathological evaluation of liver slices was done in addition to the biochemical observations. The study's findings demonstrated that *Tridax procumbens* might significantly reduce the damage to hepatocellular tissues caused by d-GalN/LPS.

In the work carried out by Wagh and Shinde, [51] the protective effect of *Tridax procumbens* L., was evaluated against liver damage induced by paracetamol (acetaminophen) in male albino rats. A notable increase in the level of serum hepatic biomarkers and enhanced lipid peroxidation indicated the liver damage that the paracetamol caused at a dose of 2g/kg B.W. On the other hand, liver tissue showed decreased activity of catalase (CAT) and superoxide dismutase (SOD). An increase in serum bilirubin levels was also observed. Paracetamol poisoning also led to a significant reduction in hepatic glycogen, glutathione, and total serum protein levels. Ethanolic extract of *Tridax procumbens L.* orally administered at varying doses (100, 200, 300, and 400 mg/kg body weight (B.W) for seven days, restored all abnormal parameters to normal. This proved the hepatoprotective potency of the plant against liver damage induced by paracetamol.

Cardioprotective

The study was conducted by Ramachandran *et al*.[52] to determine the effects of *Tridax procumbens* Linn's hydro-alcoholic extract (THAE) on lipoproteins, lipids, and antioxidant activity in rats with isoproterenol-induced myocardial infarction. By administering ISO twice within 24 hours at a dose of 85mg/kg, myocardial infarction was produced. Rats were orally given the extracts for 20 days at 100 and 200 mg/kg, with ISO taking place on days 21 and 22 at intervals of 24 hours. Results showed that due to ISO intake, there was a marked increase in the concentration of low-density lipoprotein cholesterol (LDL-C), total

cholesterol, lipid peroxidation (LPO), triglycerides, and very low-density lipoprotein cholesterol (VLDL-C) were intraperitoneally markedly increased while there was a significant high-density lipoprotein cholesterol (HDL-C) decrease. Following ISO treatment, the activity of the enzyme paraoxonase (PON) was also markedly reduced. Oral pre-treatment with the extracts modulated all the alterations in all these parameters and reinstated altered lipoproteins and lipids levels to normal. Also, the extract significantly reduced the serum antioxidant enzyme levels. According to the study, pre-treatment with THAE in rats that have had ISO injections dramatically reduced myocardial infarction.

In a different study, Shanmugapriya and Maneemegalai[53] focused on the cardioprotective qualities of *T. procumbens*. Using an animal model, this study assessed the synergistic cardioprotective efficacy of ethanolic *Tridax procumbens* leaf extracts and *Boerhavia diffusa* root extracts. To treat myocardial infarction in rats, ethanolic extract (150 + 150 mg/kg BW) was administered along with isoproterenol to Wistar male albino rats. Inflammatory markers including c-reactive protein (CRP), myeloperoxidase, and some others in tissue samples, blood, and plasma were used to evaluate cardioprotection. Findings revealed a significant increase in inflammatory biomarkers in isoproterenol-treated rats. By inhibiting cardiac necrosis, the combination of *Tridax procumbens* leaf and *Boerhavia diffusa* root extracts significantly altered the parameters. This study succinctly described the protective effect of both plants against myocardial infarction and indicated that the combined treatment with ethanolic extracts of both plants was more effective.

Chromolaena odorata and *Tridax procumbens'* aqueous leaf extracts may be able to reduce doxorubicin-induced cardiotoxicity, according to research by Ikewuchi *et al*. [54]. Their effects on markers of oxidative stress, cardiac ATPase, creatine kinase, lactate dehydrogenase activities, cardiac integrity markers and oxidative stress biomarkers in rats treated with doxorubicin were noted. To cause cardiotoxicity, doxorubicin was administered intraperitoneally at 15 mg/kg B.W. Metformin was also given orally to another group at a dose of 250 mg/kg B.W while both extracts were administered at doses 50, 75, and 100 mg/kg B.W for 14 days. Results showed that the plasma levels of LDH, Creatine kinase, and AST were markedly elevated in the intervention group in comparison with the other groups ($p < 0.05$). The amounts of calcium, chloride, salt, cholesterol, and triglycerides in the heart were also considerably ($p < 0.05$) greater in the intervention group when compared with other groups. But the Test control group (Doxorubicin group) had significantly ($p < 0.05$) lower ascorbic acid, magnesium, reduced glutathione, and potassium in the heart, and significantly lower activities of some antioxidant enzymes in the heart than the experimental group. The plant extracts improved the adverse effects of doxorubicin in the rats using various biomarkers. It was determined that the extracts had a similar impact on cardiotoxicity as metformin.

Conclusion

All plant species used in herbal therapy are referred to as medicinal plants, and they are regarded as the foundation of conventional medicine. They are constantly used in the creation of pharmaceutical medications because they contain a variety of chemical elements (mostly secondary metabolites) responsible for their curative/protective properties. The therapeutic use of medicinal plants, commonly referred to as alternative medicine, has been used since ancient times. Today's biological study has demonstrated that this form of phytotherapy will continue to be used by humans for some time.[58-60] Natural resources are necessary for human sustenance. Humans rely on plants for food, medicine, housing, and clothing, making them an essential resource for living things. Their use necessitates the transmission of expertise and information from one generation to the next.[61] It is impossible to overstate how effective plants are in the management and treatment of various ailments. Therefore, it is advised that a more natural approach to treating ailments, such as using plants, be used. From the review carried out, it was seen that *Tridax procumbens* offers numerous positive health effects such as wound healing, management of health conditions such as hypertension, diabetes, and antioxidants, antimicrobial, hepatoprotective, and cardioprotective effects as shown through numerous studies in table 2. These effects were attributed to the metabolites present in the leaves. It is advised that more research be done to determine the plant's precise mechanism of action in the treatment of certain ailments as well as its pharmacokinetics.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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