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Phytochemical and pharmacological aspects of *Tephrosia* genus: A brief review

Vimal John Samuel[1*], Agasa Ramu Mahesh[2], Vedigounder Murugan[2]

[1]Department of Pharmacology, College of Pharmaceutical Sciences, Dayananda Sagar University, Bengaluru, India.
[2]Department of Pharmaceutical Chemistry, College of Pharmaceutical Sciences, Dayananda Sagar University, Bengaluru, India.

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ABSTRACT

Tephrosia, the plant genus belongs to the family Fabaceae. It belongs to the major group of angiosperms (flowering plants) that comprises more than 350 species which is widely distributed in the regions of tropical and subtropical countries of the world. Since the herbal medicine is in demand due to its fewer associated side effects, the genus *Tephrosia* is extensively used for the treatment of large number of diseases in traditional medicines. The main aim of this review is to summarize and document the phytochemical and pharmacological activities performed on *Tephrosia* genus. To promote the continual use of these plants and in order to plan for the future studies, it becomes important to provide a basis by combining a number of available information into a single data covering the different aspects of the plant.

INTRODUCTION

From many decades, plants have been used for the ailment of diseases. Traditional medicines refer to innumerable approaches such as animal- and mineral-based medicines, spiritual therapies, knowledge and beliefs in incorporating plant to treat, diagnose and prevent illness of the well-being. Most of the modern medicine currently used for various treatments has many undesirable effect and unpredictable pharmacological action; hence, the need to search for the newer drugs with lesser or no side effects is obligatory (Muazu and Kaita, 2008; Roger and Brian, 1996). *Tephrosia* genus belongs to the family Fabaceae (Leguminosae) and subfamily Paplilionaceae, which contains about more than 350 species of the genus. The plants in this genus are chiefly distributed in the regions of tropical, subtropical, and arid regions of the world (Al-Ghamdi, 2013). The plants are erect herbs, or it is in the form of soft or woody shrubs. Based on several studies conducted by the taxonomist, *Tephrosia* was classified into four sections, namely, *Mundulea*, *Brissonia*, *Craccoides*, and *Reineria*, out of which *Mudulea* and *Reineria* were represented in India. Later, the genus has been classified into three subgenera which includes *Marconyx* (includes *T. tenuis*), *Brissonia* (includes *T. candida*), and *Reineria* (includes rest of the species of *Tephrosia)* (Lakshmi *et al*., 2008).

Phytochemical investigations revealed the presence of a number of phytoconstituents. The bioactivity associated with the plant has been studied extensively, indicating the phytoconstituents present in the *Tephrosia* genus manifested various biological activities such as anti-diabetic, anti-ulcer, anti-diarrheal, wound healing, anti-inflammatory, insecticidal, anti-viral, anti-protozoal, anti-fungal, anti-plasmodial, and many other activities (Chen *et al*., 2014). Several literature surveys showed a very few or no reviews were available which correlates the data of phytochemical, pharmacological, and molecular properties of the genus *Tephrosia* together. Thus, the main purpose of this review is to cover completely and provide up-to-date knowledge of pharmacological and phytochemical research work carried out on this genus.

**Corresponding Author*
Vimal John Samuel, Department of Pharmacology, College of Pharmaceutical Sciences, Dayananda Sagar University, Bengaluru, India.
E-mail: vimalalina @ gmail.com

CHEMICAL CONSTITUENTS OF *TEPHROSIA* GENUS

Various research studies have been carried out to study the chemical constituents of the variety of plants belonging to genus *Tephrosia*. Many of the organic compounds belonging to different classes have been isolated. Among many of the organic compounds isolated, some have been used for their pharmacological properties and some of them are still unknown for their effects. It was found that flavonoids were the most commonly isolated and identified compound in the genus, the other main classes of compounds include rotenoids, terpenoids, sterols, essential oils, and fixed oils. Not many research studies have been carried to indicate the presence of essential oil and fixed oil. For many of the taxonomists, *Tephrosia purpurea*, *Tephrosia toxicaria*, *Tephrosia candida*, *Tephrosia elata*, and *Tephrosia villosa* have been a sign of interest. Also, there are works done on the stereochemistry of the compounds, for example, a flavonoid from *Tephrosia pumila* called as Praecansone, exists in two isomers (Dagne *et al*., 1988). The various chemical constituents isolated from some of the *Tephrosia* genus are described in Table 1.

Many of the isolated compounds have been studied for their pharmacological actions. There are many chemical components mentioned under the Table 1 that are not studied under the genus *Tephrosia* but the literature survey suggested their presence in other genera. For instance, Pseudosemiglabrin, Flemichapparin, Caryophellene oxide, deguelin, pongamol, and lupeol possess platelet aggregation antagonism, anti-fungal, anti-cancer, anti-convulsant, and anti-inflammatory activities, respectively.

PHARMACOLOGICAL ACTIVITIES OF PLANT FROM GENUS *TEPHROSIA*

Hepatoprotective activity

The hydro-alcoholic extract of aerial parts of *T. purpurea* was studied for its hepatoprotective activity against arsenic induced hepatotoxicity which causes acute hepatic injury and hepatocellular necrosis, thereby causing leakage of cellular enzyme (Gora *et al*., 2014). The stem of *T. purpurea* were extracted using methanol and investigated for its hepatoprotective activity (Verma *et al*., 2017). The ethyl acetate fraction of ethanolic extract of *T. purpurea* was investigated for its hepatoprotective activity against carbon tetrachloride induced hepatocellular injury. In all the above investigations, it was observed that the extracts significantly reduced the serum alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, total bilirubin and also reduced necrosis and inflammation when compared with the toxic group. It was also observed that there was also a higher lipid peroxidation (LPO) and lower glutathione levels. These activities were due to the presence of polyphenolic compounds and flavonoids in the extracts of *T. purpurea* (Shah *et al*., 2011). The methanolic extract of *Tephrosia calophylla* also possesses hepatoprotective activity due to the presence of flavonoids (Adinarayana *et al*., 2011).

Anti-diabetic activity

The anti-diabetic activity of methanolic extract of *T. calophylla* was carried out both by *in-vitro* and *in-vivo* methods against alloxan-induced diabetes in albino Wistar rats. The results showed that there was a significant reduction in the blood glucose levels when compared with the diabetic control group. The extract was also effective in reducing the serum concentrations of serum glutamic oxaloacetic transaminase, triglycerides (TG), total cholesterol (TC) and urea, and increased insulin level. *Tephrosia calophylla* could also inhibit the *in-vitro* α-glucosidase and α-amylase activity (Ramesh and Rani, 2018).

The flavonoid rich fraction of the ethanolic extract of *T. purpurea* was used to evaluate the anti-diabetic activity (Bhadada and Goyal, 2016). The extract was well effective in providing the beneficiary effects on diabetes-induced cardiovascular complications as well as in the treatment of cataract and these activities may be attributed due to the presence of flavonoid, quercetin, and rutin present in this genus (Bhadada *et al*., 2016). The anti-diabetic activity of the silver nanoparticles using aqueous extract of *Tephrosia tinctoria* was tested and the results showed significant free radical scavenging ability, inhibition of carbohydrate digestive enzymes (α-Glucosidase and α-amylase), and enhancement of glucose uptake rate (Rajaram *et al*., 2015).

Anti-inflammatory activity

Literature survey revealed the anti-inflammatory activity of ethanolic extract of the *T. purpurea* root using carrageenan-induced model. It was found that the inflammation was significantly reduced in the extract treated when compared with the inflamed group rats (Praveena *et al*., 2011). The ethyl acetate extract of *T. sinapou* was evaluated for the anti-inflammatory activity. The anti-inflammatory activity was proven by inhibiting the recruitment of total leukocytes and neutrophils, induced by a variety of inflammatory stimulus. This action may be attributed due to the presence of flavonoid and phenolic components present in the extract (Martinez *et al*., 2012). (-)-pseudosemiglabrin which is a major phytoconstituent isolated from *Tephrosia apollinea* possesses anti-inflammatory activity that was confirmed by measuring the levels of interleukin-1 (IL-1), tumor necrosis factor-α (TNF-α), and nitric oxide (NO) in *in-vitro* method. *In-vivo* activity was confirmed by the potential inhibition of granuloma tissue, thereby lowering the production of cytokines (Hassan *et al*., 2016).

Anti-nociceptive activity

Ethyl acetate extract of *T. sinapou* possessed anti-nociceptive effect when tested against acetic acid, phenyl-p-benzoquinone, formalin, and complete freund's adjuvant-induced writhing response by causing mast cell activation leading to the release of inflammatory cytokines (TNF-α, IL-1β, and eicosanoids) resulted in inhibition of inflammatory overt pain-like behavior in mice. The analgesic property was due to the presence of phenolic compound, thus proving promising anti-nociceptive activity (Martinez *et al*., 2012). The ethanolic extract of *Tephrosia falcliformis* root was screened for anti-inflammatory activity by three different models. The result revealed the reliving effect through peripheral action of the extract (Kumar *et al*., 2007).

Wound healing

Upon many literature surveys, researchers have even found the cutaneous wound healing (a complex physiological process) activity of ethyl acetate extract of *T. purpurea*. The extract

Table 1. Chemical constituents from some of the plants of genus *Tephrosia*.

Species	Class	Chemical constituents	References
Tephrosia aequilata	Flavonoid	3,4:8,9-Dimethylenedioxypterocarpene, obovatin methyl ether, (E)-praecansone A, Demethylpraecansone B.	(Atilaw *et al*., 2017)
Tephrosia apollinea	Flavonoid	(−)-Semiglabrin, (−)-Pseudosemiglabrin, (+)-Glabratephrinol, (+)-Glabratephrin, Appollinine (7-methoxy-8- [3″-(2″,5″-dihydro-5″,5″-dimethyl-2″-oxofuryl)]-flavone, Lanceolatin-A, Semiglabrinol, Tephroapollin C, D, E, F, G.	(Ahmed Hassan *et al*., 2014)
Tephrosia barbigera	Flavonoid	Isopongaflavone, Barbigerone	(Touqeer *et al*., 2013)
Tephrosia bidwilli	Flavonoid	Tephrocarpin, (-)-6a*R*; 11a*R*-maackiain, (-)-6a*S*; 11a*S*-pisatin, (-)-6a*R*; 11a*R*-4-methoxy-maackiain, acanthocarpan	(Ingham and Markham, 1980)
Tephrosia bracteolata	Flavonoid	Isopongaflavone, Trans-tephrostachin, Trans anhydrotephrostachin	(Babayemi and Bamikole, 2006)
Tephrosia calophylla	Coumestan	Tephcalostan, Tephcalostan B, C, D	(Devi *et al*., 2017; Ganapaty *et al*., 2009)
	Flavonoid	7-O-methylglabranin, Calophione A	
		kaempferol 3-O-β-D-glucopyranoside	
		(2S)-5-hydroxy-7,4'-di-O- (gamma, gamma dimethylallyl)flavanone, 6-Hydroxy-E-3-(2,5-dimethoxybenzylidine)-2',5'-dimethoxyflavanone, Kaempferol 3-O- β -D-glucopyranoside, Tephrowatsin C, Afrormosin,	
Tephrosia candida	Flavonoid	Candidin, 6-Hydroxykaempferol 4'-methyl ether, Candidol, Tephrocandidin A, Tephrocandidin B, Candidone, Ovalichalcone, Dehydrorotenone, 12 α-Hydroxy-*β*-toxicarol, Candirone, Candidachalcone, Tephrone, Tephrospirolactone, Tephrospiroketone I, II	(Hegazy *et al*., 2011)
	Sterol	β -Sitosterol	
	Sesquiterpenes	1*β*-Hydroxy-6,7*α*-dihydroxyeudesm-4(15)-ene	
	Acid	Caffeic acid	
	Rotenoid	α-Toxicarol,	
		12 α-Hydroxyrotenone, Amorpholone	
Tephrosia cinerea	Flavonoids and Phenolics	Demethylapollinin 7-*O*-*β*-D-glucopyranoside, Apollinin, Glabatephrin, Semiglabrin, Pseudosemiglabrin, Cineroside A	(Arriaga *et al*., 2008; Maldini *et al*., 2011)
		3′-O-methyl-quercetin 3,7-Di-O-rhamnopyranoside, Quercetin 3,7-di-O-rhamnopyranoside, 3-O-β-xylopyranosylquercetin 7-O-α-Rhamnopyranoside, 3-O-α-arabinopyranosylquercetin 7-O-α- rhamnopyranoside, 5-O-methylgenistein 7-O-β-D-glucopyranoside, Quercetin 3-O-β-glucopyronoside, Quercetin 3-O-α-rhamnopyranoside, Kaempferol, 7-O-methylquercetin	
	Sesquiterpene	Caryophyllene oxide, Teclenone B	
	Lignan	Pinoresinol	
Tephrosia crassifolia	Flavonoid	Crassifolin, Crassichalcone	(Gomez-Garibay et al.,1999)
Tephrosia elata	Flavonoid	Isopongaflavone, Tephrosin, 8-(3,3-dimethylallyl)-5,7- dimethoxy flavanone, Obovatin methyl ether, Elatadihydrochalcone, Obovatachalcone, (*S*)-elatadihydrochalcone	(Muiva *et al*., 2009)
Tephrosia elongata	Flavonoid	Elongatin	(Smalberger *et al*., 1975)
Tephrosia emoroides	Flavonoid	Emoroidone, 5-Methoxyisolonchocarpin, Emoroidocarpan, Emoroidenone	(Machocho *et al*., 1995)
Tephrosia falciformis	Flavonoid	7-Hydroxy-8-(γ,γ-dimethylallyl)flavanone, Falciformin.	(Khan *et al*., 1986)
Tephrosia fulvinervis	Flavonoid	Fulvinervin C, A, B	
	Rotenoid	α-Toxicarol, Deguelin, Munduserone, Cis-12 α-hydroxymunduserone, (-)-Maackiain	(Dagne *et al*., 1989)
Tephrosia hamiltonii	Flavonoid	5,7-Dimethoxy-8-(2, 3-epoxy-3-methylbutyl)-flavanone, 2-Methoxy-3,9-dihydroxy coumestone, Pongamol, Flemichapparin-B	(Falak and Shoeb, 1987; Rajani and Sarma, 1988)
		flemichapparin-C	
Tephrosia hildebrandtii	Pterocarpan	Hildecarpidin, Hildecarpin	(Lwande *et al*., 1986)
	Flavonoid	methylhildardtol B, Hildgardtol B, Hildgardtene, Methylhildgardtol A, Hildgardtol A, Trans-tephrostachin, Trans-anhydrotephrostachin	
Tephrosia hookeriana	Flavonoid	Hookerianin, (−)-semiglabrin, Lanceolatin A, Tephrorianin	(Prabhakar *et al*., 1996)
Tephrosia leiocarpa	Flavonoid	Tephroleocarpin A, Tephroleocarpin B	(Gomez-Garibay et al., 1991)
Tephrosia lupinifolia	Flavonoid	Lupinifolinol, Lupinifolinol triacetate, Lupinifolin, 5,4'-*O*,*O*-dimethyl-lupinifolin, Lupinifolin diacelate	(Smalberger *et al*., 1974)
Tephrosia madrensis	Flavonoid	5,7-dimethoxy-8-prenylflavan	(Gomez-Garibay et al., 1983)

Continued

Species	Class	Chemical constituents	References
Tephrosia major	Flavonoid	2',6'-dihydroxy-3'-prenyl-4'-methoxy-*β*-hydroxychalcone	(Gomez-Garibay et al., 2002)
	Sterol	β-sitosterol, stigmasterol	
	Triterpene	Lupeol	
Tephrosia maxima	Flavonoid	Maxima flavanone A, Maxima isoflavone A, B, C, D, E, F, G, H, J	(Sandhya *et al*., 2011)
Tephrosia multijuga	Flavonoid	Multijugin, Multijuginol	(Vleggaar *et al*., 1975)
Tephrosia pentaphylla	Flavonoid	Dihydrostemonal, 9-Demethyldihydrostemonal, 6-Acetoxydihydrostemonal	(Dagne *et al*., 1989)
	Rotenoid	Villosin, Sumatrol, Rotenone, α-Toxicarol	
		cis-12α-hydroxyrotenone, 6-Hydroxyrotenone	
Tephrosia polyphylla	Flavonoid	4′-Demethyltoxicarol isoflavone, Toxicarol isoflavone, 7-Methylglabranin	(Dagne *et al*., 1992)
Tephrosia procumbens	Rotenoid	Rotenone, sumatrol, praecansone A, B, obovatin	(Venkataratnam *et al*., 1987)
		7-ethoxy-3,3′,4′-trihydroxyflavone;	
		Fisetin 7-ethyl ether	
		7,4′-dihydroxy-3′-methoxyisoflavone	
Tephrosia pumila	Flavonoid	Pumilanol, Pumilaisoflavone A, B, C, D β-hydroxychalcone, Praecansone-A	(Dagne *et al*., 1988)
Tephrosia purpurea	Flavonoid	Tephrosin, Pongaglabol, Purpureamethide, Pongamol, Karanjin, Lanceolatin B, (+)-Tephrorins A, B, (+)-Tephrosone, Purpurenone, (+)-Purpurin, Purpuritenin, Lanceolatin B, (+) Purpurin, Quercitin, (−)-Purpurin dehydroisoderricin, (−)-Maackiain pseudosemiglabrin, (−)-semiglabrin, Terpurinflavone, (-)-Isolonchocarpin, 7,4‘-Dihydroxy-3‘,5‘-dimethoxyisoflavone, (+)-Tephropurpurin	(Khalafalah *et al*.,2010; Lodhi *et al*., 2006; Peng *et al*., 2014)
		(−)-3-hydroxy-4-methoxy-8,9-methylenedioxypterocarpan	
		(−)-medicarpin	
		3‘-methoxydaidzein desmoxyphyllin B, 3,9-Dihydroxy-8-methoxycoumestan, Isoglabratephrin, Tephropurpulin A, Rutin, Serratin 7-O-β-D-glucopyranosyl-(1→4)-O-β-D-galoctopyranoside	
Tephrosia semiglabra	Flavonoid	Glabratephrin, Semiglabrinol, Semiglabrin	(Smalberger *et al*., 1973)
Tephrosia sinapou	Flavonoid	Toxicarine, Tephrowatsin A, Quercetol B, Flamichapparin B, 7-O-Methylglabranine,	(Martinez *et al*., 2016)
	Rotenoid	Tephrosin, rotenolone, rotenonone, villosone, 6a,12a-dehydrorotenone, 6-Oxo-6α,12α-dehydrodeguelin, 6-Oxo-6α,12α-dehydro-α-toxicarol	
	Coumarin	2,3-dihydro-p-coumaric acid	
Tephrosia spinosa	Flavonoid	Spinochalcone A, B, C, Spinoflavanones A, B, flemistrictin A, 3′,5′-Diisopentenyl-2′,4′-dihydroxychalcone, Fulvinervin A, Eupalitin 3-O-b-D-galactopyranoside	(Rao and Prasad, 1992)
Tephrosia tinctoria	Flavonoid	7-O-methylglabranin, 5,7-Di-O-prenylbiochanin A, 2′-Hydroxy-7-methoxyflavonol, Tephrowatsin C, Flemichapparin B, Kaempferol-3-O-β-D-glucopyranoside dehydrorotenoid, Dehydrodeguelin, 2¢-Hydroxy-7-methoxyflavonol	(Lakshmi *et al*., 2010; Reddy *et al*., 2014)
Tephrosia toxicaria	Flavonoid	Iso-obovatin, Obovatin, α-Toxicarol, Sumatrol	(Ribeiro *et al*., 2006)
		6α,12 α-dehydro-β-toxicarol, 6α,12α-dehydro-α-toxicarol, (2S)-5-hydroxy-7-methoxy-8-[(E)-3-oxo-1-butenyl] flavanone, isoliquiritigenin, genistein, chrysoeriol	
	Coumarin	Marmesin	
	Triterpene	Lupenone	
	Rotenoid	4′,5′-Dihydro-11,5′-dihydroxy-4′-methoxytephrosin, 11-hydroxytephrosin	
Tephrosia tunicata	Flavonoid	Tunicatachalcone	(Andrei *et al*., 2000)
Tephrosia viciodes	Flavonoid	Enantiomultijugin	(Gomez-Garibay et al., 1992)
Tephrosia villosa	Flavonoid	(2S)-5,4′-dihydroxy-7-O-[(E)-3,7-dimethyl-2,6-octadienyl] flavanone, (2S)-5,4′-dihydroxy-7-O-[(E)-3,7-dimethyl-2,6-octa-dienyl]-8-C-[(E)-3,7-dimethyl-2,6-octadienyl] flavanone, 7-O-methylglabranin, 12 α-dehydro-6-hydroxysumatrol, Tephcalostan, Villosin, Villosone, Villol, Villinol, Tephrinone,	(Madhusudhana *et al*., 2010)
	Triterpenoid	Lupenone	
	Triterpene	Lupeol	
	Sterol	Stigmasterol	
Tephrosia viridiflora	Flavonoid	Viridiflorin	(Gomez-Garibay et al., 1985)

Continued

Species	Class	Chemical constituents	References
Tephrosia vogelii	Sesquiterpene	(1β,6α,10α)-guai-4(15)-ene-6,7,10-triol,	(Stevenson *et al*., 2012)
	Rotenoid	Deguelin, Tephrosin, Toxiconol, Tephrosal,	
	Flavonoid	Pyranosyl(7→6)-*β*-galactopyranoside-7-*O*-*α*-rhamnopyranoside, Pyranosyl(1→2) [*α*-rhamnopyranosyl(1→6)-*β*-galactopyranoside, Rhamnopyranosyl (1→2)[(3-*O*-*E*-feruloyl)-*α*-rhamnopyranosyl(1→6)]-*β*-galacto-pyranosides, (2*R*,3*R*)-3-hydroxy-5-methoxy-6",6"-dimethylpyrano-[2",3":7,8]flavanone, (2*S*)-4'-hydroxy-5-methoxy-6",6"-dimethylpyrano[2",3":7,8]-Flavanone, (2*S*)-7-hydroxy-5-methoxy-8-prenylflavanone, (2*S*)-5-methoxy-6",6"-dimethy1-4",5"-dihydrocyclopropa[4",5"]furano[2",3":7,8]flavanone, (2*S*)-5,7-dimethoxy-8-(3-methylbut-1,3-dienyl)flavanone, Quercitin,	
Tephrosia woodii	Flavonoid	Oaxacacin, Mixtecacin	(Chen et al., 2014)

was prepared and applied externally in the form of ointment (5%w/w) to rats. The study showed the extract processed healing action which was reflected by the improved collagen (predominant extracellular protein in granulation tissue of wounds) maturation by increased cross-linking and increased levels of hydroxyproline, a major constituent of collagen which serves as the indicator of replacement of collagen tissue, thereby promoting rapid wound healing process (Lodhi *et al*., 2006). Since flavonoids have been reported to have anti-oxidant and anti-inflammatory properties, *T. purpurea* is also believed to act as a health promoting substance and are reported to have important role in healing of wound (Lodhi *et al*., 2016).

Anti-oxidant activity

Chloroform and methanolic extract of *T. calophylla* was investigated for its anti-oxidant activity using albino Wistar rats. The result revealed an increase in the levels of catalase, superoxide dismutase and decrease in LPO which can be attributed due to its anti-oxidant mechanism. Flavonoid present in the extracts was responsible for its anti-oxidant mechanism (Ramesh and Rani, 2018). It was also discovered that the ethanolic extract of *T. purpurea* possessed anti-oxidant activity in an *in-vitro* study where it exhibited free radical scavenging in 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay and anti-lipid peroxidation properties in carbon-tetrachloride-induced LPO assay. Macrophages have been involved in the inflammation process and during the inflammation there is an increased production of superoxide ions. Many reports suggested the mild anti-inflammatory activities of *T. purpurea.* Based on these reports, researchers concluded that it may be possible that the inhibition of superoxide generation is related to anti-inflammatory activity of *T. purpurea* (Soni *et al*., 2006). The ethanol ether extract of *Tephrosia vogelii* seeds also showed anti-oxidant and free radical scavenging and this was mainly due to the presence of flavonoid present in the extracts (Li *et al*., 2010). The chloroform extract of leaf and aerial parts of *T. villosa* showed anti-oxidant activity when examined by DPPH assay method. This may be attributed due to the secondary metabolites like phenols, glycosides, tannins, reducing sugars, terpenoids, flavonoids present in the extract (Mani *et al*., 2017). *In-vitro* anti-oxidant activity of the different parts (Leaf, Stem, and Root) of *T. tinctoria* was studied by extracting with various solvents like hexane, chloroform, ethyl acetate, and ethanol. Among the various fractions tested using DPPH assay, the ethyl acetate fraction of stem of *T. tinctoria* exhibited maximum anti-oxidant activity (Rajaram and Suresh, 2011). *Tephrosia apollinea* was used to evaluate the anti-oxidant, anti-angiogenic, and cytotoxic activities. The results supported the ethnobotanical uses of the plant *T. apollinea* to cure the oxidative stress and paraneoplastic symptoms caused by the cancer (Hassan *et al*., 2014). The various organic extracts of leaf, stem, and root of *T. apollinea* were assayed for radical scavenging, total anti-oxidant capacity, anti-lipid peroxidation, and reduced glutathione, and was found to be ameliorating the oxidative stress developed during the generation of reactive oxygen species (Rizvi *et al*., 2018). The anti-oxidant and cytotoxic properties were evaluated using DPPH, ferric reducing anti-oxidant power (FRAP), reducing power assay, and anti-hemolytic assay of four major parts of methanolic extracts of *T. purpurea* including leaves, root, stem, and seed are investigated and compared. The results revealed that, among the four extracts studied, leaves extract showed the highest anti-oxidant activity, and there was no significant difference observed in anti-hemolytic activity. Leaves extract showed effective cytotoxicity on colorectal cancer cells and also had the higher total phenolic and flavonoid content, thus proving higher anti-oxidant and cytotoxic activities of leaf extract when compared with other extracts (Padmapriya *et al*., 2017).

Anti-ulcer activity

The ethanolic extract of *T. calophylla* leaves is reported to have anti-ulcer activity, when investigated using pylorus ligation, ethanol induced, and indomethacin-induced ulcer models. The extract was tested at two different doses. The results revealed that in all the three models, the extract showed dose dependent reduction in gastric volume, free acidity, ulcer index, and total acidity, thus proving the potential anti-ulcer activity. This activity is may be due to anti-secretory property of flavonoids present in the extract (Divya *et al*., 2011). The aqueous extract of roots of *T. purpurea* was evaluated for anti-ulcer activity using different models of gastric and duodenal ulceration in rats. The results suggested that the extract possesses significant anti-ulcer property which could be either due to cytoprotective action of the drug or by strengthening of gastric and duodenal mucosa, and thus enhancing mucosal defense (Deshpande *et al*., 2003).

Purgative activity

An investigation was carried out to analyze the stimulant effect on the Gastro Intestinal Tract (GIT) smooth muscles of methanolic extract of *T. vogelii.* This was demonstrated on the isolated rabbit jejunum which increased the contractions of intestinal smooth muscle. The extract, potentiates the contractile effect of acetylcholine (ACh) on intestinal smooth muscle by acting through the muscarinic cholinergic receptors, involving the mobilization of extracellular calcium ions. This result strongly provides the evidence for the purgative activity of *T. vogelii* (Dzenda *et al*., 2007; 2015).

Anti-hyperlipidemic activity

Different parts of the plant like stem, root, leaves, and whole plant also (excluding leaves) extracts of *T. purpurea* were screened for the anti-hyperlipidemic activity. It decreased the TC, TG, low-density lipoprotein, very low-density lipoprotein, and increased high-density lipoprotein levels, thus providing a significant evidence that the plant extract processes anti-hyperlipidemic activity by the inhibition of β-Hydroxy β-methylglutaryl-CoA (HMG-CoA) reductase enzyme (Dalwadi and Patani, 2014).

Anti-cancer activity

Tephrosia purpurea exhibited better anti-cancer activity when tested using human MCF 7 cell lines (estrogen receptor dependent and carries the tumor suppressor p53 gene), an *in-vitro* method. Mainly due to the presence of flavonoids, this genus exhibits the chemo preventive role which effects proliferation and angiogenesis (Gulecha and Sivakuma, 2011). The other species, *T. apollinea* also demonstrated the anti-cancer activity. After carrying out many investigations, it is evident that the plants are a good source of anti-cancer agents. A prenylated flavone, isoglabratephrin was isolated using bioassay guided technique from the aerial parts of *T. apollinea*. The three human cancer cell lines, namely, prostate (PC3), pancreatic (PANC-1), colon (HCT-116), and one normal cell line (human fibroblast) were used for the study. It was observed that the isoglabratephrin displayed inhibitory activity against proliferation of PC3 and PANC-1 by inducing chromatin dissolution, nuclear condensation, and fragmentation, thus providing an evidence to treat human prostate and pancreatic malignancies (Hassan *et al*., 2017).

Anti-fungal activity

Tephrosia purpurea exhibited anti-fungal activity. This was found against 61 endophytic fungus strains with different colony morphologies isolated from the leaves, stem, and root of *T. purpurea*. Anti-fungal activity when measured by dual culture testing, out of 61 isolates, depending on the colony morphologies, the isolates exhibited broadest anti-fungal spectrum of activity, hence proving promising anti-fungal activity of the bioactive components present in *T. purpurea* (Luo *et al*., 2015). *Tephrosia hildebrandtii* showed anti-fungal activity against *Cladosporium cucumerinum*. The activity was found to be related to a chemical constituent isolated from its roots (Lwande *et al*., 1985). *Tephrosia tinctoria* also showed activity against *Aspergillus niger* and *Candida albicans* (Lakshmi *et al*., 2010).

Anti-bacterial activity

Tephrosia purpurea was found to possess anti-bacterial activity. The ethanolic extract from the roots was tested against three standard cultures *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*. The extracts were subjected to the minimum inhibitory concentration agar dilution method (Touqeer *et al*., 2013). Various studies were conducted on different kinds of microorganisms and those studies suggested that the methanolic extract of *T. purpurea* exhibited anti-microbial activity when tested on *Bacillus subtilis*, *S. aureus*, and *Micrococcus luteus*, the Gram-positive bacteria and the Gram-negative including *E. coli*, *Pseudomonas aeruginosa*, and *Salmonella typhimurium.* Also, the root extracts of *T. purpurea*, showed anti-microbial activity against *P. aeruginosa* and no activity against *S. aureus* and *E. coli.* The chloroform root extract of *T. calophylla* were tested for anti-bacterial and anti-fungal activity and showed moderate activity. The activity of the extracts increased with increasing concentrations (Abayasekara *et al*., 2009; Ramadevi, *et al*., 2014). The study was conducted to analyze the anti-bacterial activity of the bark of *T. vogelii* when tested using *Bacillus cereus*, *E. coli*, *Salmonella typhi*, *Streptococcus pyogenes*, *Serratia marcescens*, *Serratia liquefaciens*, *Enterobacter aerogenes*, and *Staphylococcus epidermidis* (Hu *et al*., 2011). The various extracts of *T. villosa* roots showed a moderate anti-bacterial and anti-fungal activity (Ganapaty *et al*., 2008).

Anthelmintic activity

The ethanolic extract of *T. calophylla* roots was screened for anthelmintic activity at various concentrations against adult Indian earthworm, *Pheretimaposthuma*, as it shows anatomical and physiology resemblance with intestinal round worm's parasite of human beings. The results obtained in this study proved that the efficacy of ethanolic extract *T. calophylla* taken at the dose of 100 mg/ml showed significant anthelmintic activity and it is a dose dependent activity which may be due to the presence of flavonoids (Devi *et al*., 2017). In another study, the methanolic and aqueous leaf extract of *T. purpurea* also demonstrated in *in-vitro* anthelmintic activity (Manjula *et al*., 2013).

Larvicidal activity

Extensive work has been done on *Tephrosia* as an agent to control the population of insects harmful to animals and plants. The larvicidal activities of *T. egregia* extracts and its major component, dehydrorotenone, were tested against *Aedes aegypti* larvae. The hexane extract of stems of *T. egregia* showed potent larvicidal activity (Arriaga *et al*., 2009). The larvicidal activity of petroleum ether and ethyl acetate extract of *T. purpurea* was tested against the larvae of *Culex quinquefasiciatus* thus proving to be the most promising, more selective and biodegradable agent (Kumar *et al*., 2012). The ethanol extract of roots, stems, leaves, and pods and some fractions of *T. toxicaria* were tested for lavicidal activity with the larvae of *A. aegypti*. It was found that rotenoids from *T. toxicaria* were responsible for larvicidal activity (Santiago *et al*., 2012). The extracts of *T. villosa* and *T. pumila* also possess larvicidal activity and therefore can be used to control mosquitoes (Kidukuli *et al*., 2015). The oil obtained from *Tephrosia cinerea* showed larvicidal activity against *A. aegypti* larvae (Arriaga *et al*., 2008). Flavonoids from the seedpods of *T. elata* and *Tephrosia aequilata* were found to possess anti-plasmodial and larvicidal activity. *Tephrosia elata* showed significant anti-feedant activity against *M. testulalis*, *S. exempta* and *E. sacchariana* (Atilaw *et al*., 2017; Muiva *et al*., 2009).

Miscellaneous activities

The anti-feedant activity is attributed due to the presence of rotenoid compounds. The roots of *Tephrosia hidebrandtii* also possess anti-feedant activity against the pest, *Maruca testulalis* (Lwande *et al*., 1985). The naturally occurring novel compound, benzofuran was isolated from the plant *T. purpurea* confirmed its suppressive activity toward H_1 Histamine receptor gene expression (Shill *et al*., 2015). The prenylated flavonoids isolated from *T. apollinea* was tested for its toxic and anti-feedant activities against three major coleopteran pests of stored grains and the results revealed that there was a significant reduction in the relative growth rate, consumption rate, and efficiency of conversion of ingested food by all insects (Nenaah, 2014). The three flavonoids were isolated from the *T. tinctoria* roots and was tested for *in-vitro* anti-protozoal activity using cell line L-6 (rat skeletal muscle myoblasts). The flavonoids showed the potential to inhibit the parasitic protozoa namely, Trypanosoma, Leishmania, and Plasmodium. Out of the three flavonoids studied, 2-hydroxy tephrosin and tephrinone exhibited moderate activity against both *Tephrosia brucei* and *Tephrosia cruzi*, mild activity against *Leishmania donovani* and no activity against *Plasmodium falciparum* (Ganapaty *et al*., 2009b). When the ethyl acetate extracts of leaf, stem, and root of *T. tinctoria* were compared with the leaf, stem, and root callus revealed that it has potent anti-oxidant and anti-proliferative activity and the callus culture can be used to produce the bioactive compounds due to the endemic nature of the plant. The apoptotic cell death was observed through DNA fragmentation analysis in HepG2 cells treated with *T.tinctoria* (Rajaram *et al*., 2013). The HPTLC analysis, anti-oxidant, and anti-gout activity of *T. purpurea* extract were investigated by 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid), DPPH, FRAP radical scavenging assays, and anti-gout activity by cow milk xanthine oxidase. The results showed significant xanthine oxidase inhibitory activity and revealed an inhibition greater than 50% and IC_{50} values below the standard thus proving their active constituents are useful against inflammation and gout (Nile and Park, 2014). Aqueous extract of *T. purpurea* was used to investigate the cardiovascular complications and cataract associated in streptozotocin induced diabetic rats. The data obtained from the study suggested that the extract prevents not only the streptozotocin-induced metabolic abnormalities but also cardiovascular abnormalities and reduces the risk of development of cataract (Bhadada and Goyal, 2015). A novel benzofuran, 4-methoxybenzofuran-5-carboxamide (MBCA) from *T. purpurea* and its chemical synthesis was investigated for its anti-allergic activity and the mechanism was evaluated, works on the mechanism of MBCA on phorbol 12-myristate-13-acetate or histamine induced upregulation of H_1R gene expression in HeLa cells (Shill *et al*., 2016). The efficacy of *T. purpurea* in the prevention of generation of free radicals and in preventing various diseases like cataract in the lens of selenite-induced cataract models. Morphological evaluation of the *T. purpurea* treated rats lens revealed the normal transparent lens, reduction in nuclear opacity, improvement in the insoluble proteins, protein sulfydryl, total nitrate, calcium levels, decreased malondialdehyde levels but also prevented the loss of reduced glutathione levels (Bhadada *et al*., 2016).

CONCLUSION

The present extended review on the genus *Tephrosia* shows number of phytoconstituents like flavonoids, terpenoids, sterols, rotenoids, etc which is present in different species and also their diverse pharmacological activities such as hepatoprotective, anti-diabetic, anti-oxidant, anti-hyperlipidemic, anti-ulcer, anti-bacterial, anti-fungal, larvicidal, anti-inflammatory, wound healing, anti-cancer, and anti-feedant activities of few species. Among all the phytoconstituents, flavonoids were the major constituent isolated from most of the species. Hence, the present review summarized the significant research works conducted on the *Tephrosia* genus, and its phytoconstituents and biological uses which can be further studied to explore potent bioactive molecules in search of newer herbal drugs.

CONFLICT OF INTEREST

All the authors declared there is no conflict of interest.

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