**Graphical Abstract:**

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**Book Chapter**

**An overview of endangered medicinal plant *Desmodium gangeticum*: Medicinal, Health, Regeneration and Nanoparticle Synthesis related aspects**

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**An overview of endangered medicinal plant *Desmodium gangeticum*: Medicinal, Health, Regeneration and Nanoparticle Synthesis related aspects**

**Abstract**

*Desmodium gangeticum* (DG) is an important endangered medicinal plant found mainly in shrub of tropical regions of India and exploited for its medicinal applications. Each part of this plant is highly medicinal and is being utilized to cure several diseases such as fever, gout, asthma, bronchitis, liver diseases, cancer, etc. Due to the presence of wide variety of active compounds, this herb has been overexploited for medicinal purposes and categorized as endangered. As *D. gangeticum* is experiencing a surge in popularity in Indian region and many pharmaceuticals all over the world utilized it as drug, it is relevant to understand its medicinal importance for various purposes. The aim of this study is to analyze and cumulate all relevant reports of *D. gangeticum* until July, 2024. The current chapter covers nearly all aspect of medicinal importance of *D. gangeticum* incuding *in vitro* and *in vivo* pharmacological activities like antileishmanial, immunomodulatory, antiasthmatic, smooth muscle relaxant, anti-inflammatory, anti-ulcer, cardio-protective, antidiabetic, antiamnesic, antiviral, antioxidant and hepatoprotective etc., were systematically reviewed. Importance and need of *in vitro* regeneration, conservation and molecular analysis of this endangered plant were also discussed. Domestication, cultivation and strict laws are the need of the hour to save these species from extinction. Modern approaches in mechanisms of action, including a study of gene expression profiling could suggest the most up-to-date challenges for the future research of *Desmodium*.

**Key words:** *Desmodium gangeticum*; health; medicinal; *in vitro* regeneration; phytochemicals,

**Abbreviations:** DG: *Desmodium gangeticum*, SOD: Superoxide Dismutase, CAT: Catalase, GPx: Glutathione Peroxidase, GSH: Glutathione, DPPH: 2,2-diphenyl-1-picrylhydrazyl, LPO:lipid peroxidation, NO: nitric oxide, HOCl: hypochlorous acid, ISO: isoproterenol, ROS: reactive oxygen species, EAC: Ehrlich Ascites Carcinoma, HPLC: High-Performance Liquid Chromatography, HPTLC: High-Performance Thin-Layer Chromatography, TGA: Thermo Gravimetric Analysis, SEM: Scanning Electron Microscopy, FTIR: Fourier Transform Infrared Spectroscopy, UV Vis: UV–Visible Spectrophotometry, XRD: X-ray diffractometry, MIC: minimum inhibitory concentration, MMPs: Matrix Metallo Proteinases, LDH: Lactate Dehydrogenase, PEG: Polyethylene glycol, RAPD: Random Amplified Polymorphic DNA, SSR: Simple Sequence Repeat, ITS: Internal Transcribed Spacer, PCR-RFLP: Polymerase Chain Reaction-Restriction Fragment Length Polymorphism

**Introduction**

*Desmodium gangeticum* (DG) (Hindi, Shalparni) is an endangered perennial medicinal shrub, belongs to family Fabaceae. The plant is employed as a bitter tonic and in treatment of inflammatory conditions due to vata disorder (Chopra et al., 1956; Bakshi et al., 2001). This plant is also implicated for abcesses, acne, asthma, bronchitis and liver diseases (Trout, 2004). The leaves and stem of ‘shalaparni’ are used in many countries for treatment of fever, skin diseases, anxiety states (Iwu, 1992) and for antimicrobial activity (Lagudu and Owk, 2016), etc. *D. gangeticum* is one of the ingredient of Dasamula (DM) kwatha, which is used as a one of important Ayurvedic prepration for health (Aparana et al., 2012). The aqueous extract of this species has been reported to show severe antiwrithing activity, moderate central nervous system (CNS) depressant activity and antileshmanial activity (Jabbar et al., 2001; Mishra et al., 2005). The root extract has also shown antiasthmatic effect (Vedpal et al., 2016). Diagnostic indices for the identification/validation of the *D. gangeticum* raw material and standardization of its formulations for quality control parameters such as examination of morphological and microscopical characters, fluorescent profile for pharmacognostical evaluation was carried out (Vedpal et al., 2016). A comparative pharmacognostical investigation of *D. gangeticum* and *D. laxiflorum* were performed. This study involved the macroscopy and microscopy of roots of both plants as per standard procedures. Root powders of both *Desmodium* species used in the experimental study to ascertain its Rasa by dilution method. Both the species show the same Rasa and Anurasa i.e., Madhura and Kashaya and almost same morphological and microscopical characters like prismatic crystals, starch grains etc. Thus with the help of this study outcome *D. laxiflorum* can be used as substitute of *D. gangeticum* (Vaghela et al., 2012). Comparative phytochemical study of root versus small branches of *D. gangeticum* using HPTLC-UV detection method was performed.The phytochemical fingerprint profiling of root and small branches of *D. gangeticum* were found similar and thus with this study outcome small branches may be utilized instead of root and vice-versa after comparison and confirmation of same pharmacological activities (Verma et al., 2015). The authentication of the crude samples of *D. gangeticum* were done using different physicochemical parameters and other aspects such as TLC and heavy metal studies. DG exhibits a set of diagnostic characters, which will help to identify this plant as a drug. This study revealed that estimation of heavy metals is highly essential for raw drugs or plant parts used for the preparation of compound formulation drugs. The periodic assessment is essential for quality assurance and safer use of herbal drugs (Meena et al., 2010). Major variations observed in anatomical, physicochemical and phytochemical characters in *D. gangeticum* due to change in season and region. Phytochemical changes due to various seasons and different regions were studied by performing HPTLC densitometric quantification of lupeol in methanol extract of roots. This study indicated that seasonal variation is associated with the vegetative and reproductive stages of the plant and it has direct influence with the variation in chemical constituents of the plants (Jayanthy et al., 2013).

**Synonyms**

1. Latin Name: *Desmodium gangeticum*
2. Hindi: Shalparni, Sarivan, Salpani
3. Sanskrit: Anshumati, Dhruva, Dirghamuli, Pivari, Shalaparni
4. Bengali: Shalaparni
5. Marathi: Salavan
6. Gujrati: Shalavan
7. Telagu: Gitanaramu
8. Tamil: Pullati
9. Malayalam: Orila

**Scientific Classification**

1. Kingdom: Plantae
2. Sub Kingdom: Trachebionta
3. Superdivision:Spermatophyta
4. Division: Magnoliophyta
5. Class: Magnoliopsida
6. Subclass: Rosidae
7. Order: Fabales
8. Family: Fabiacae
9. Genus:*Desmodium*
10. Species: *gangeticum*

**Distribution:**

*D. gangeticum* is a small perennial shrub of tropical regions growing throughout India. It is distributed in lower Himalayan regions and throughout India as well as from tropics of Africa to Indomalaysia (Gaur, 1999). It is also found in Ceylon, Burma, Malay Peninsula and Islands, China, Philippines and Tropical Africa (Anonymous, 1952; Hooker, 1973). It is cultivated throughout the tropics ascending to 5000 feet elevation in the Himalayas (Iyer and Kolammal, 1978).

**Description:**

It is erect, diffusely branched, 90-120 cm in height with a short woody stem and numerous prostate branches covered with soft grey hairs. Its leaves are unifoliate, ovate to ovate-lanceolate, membranous and mottled with grey patches. The flowers are white, purple or lilac in elongated lax, terminal or axillary racemes. The fruit in form of pod is thin, flat, curved having 6 to 8 nodes.Fruits are moniliform, 6-8 jointed, glabrescent pods, joints of pods separately pubescent with hooked hairs, joint separating when ripe into indehiscent one seeded segments. Seeds are compressed and reniform (Joy et al. 1998).The root is tap root which is poorly developed, light yellow and smooth (Iyer, 1953; Duthie, 1994). The root bark is yellowish white in colour and has a leathery texture. Its flowering–fruiting season is duringthe months of March to December (Fig 1).



**C**

**A**

**B**

Fig. 1. Images of *D. gangeticum* (A) The complete plant, (B) Plant with flowers and pods, (C) Roots

**Agrotechnology**

*Desmodium* can grow in a variety of climates and soils, but it prefers tropical and subtropical climatic conditions, whereas, waterlogged and highly alkaline soils are not suitable for this plant. Light sandy loam is preferred for commercial cultivation of *Desmodium*. It is propagated through seeds, which are either planted directly in the field or seedlings are raised in nursery beds and then transplanted. Transplanting always gives better results in commercial cultivation, as it gives assured crop stand. Planting is done at a spacing of 40x20cm on flat beds or ridges. Organic manures are applied at the time of land preparation and thoroughly mixed with the soil. A small quantity of phosphatic and nitrogenous fertilizers are also applied for better crop growth. The inter-row spaces between plants, both in the field and nursery should be kept free from weeds by frequent weeding and hoeing as the plant suffers from weed competition, especially during early stages of growth. Manual hand weeding is usually done. Irrigation of seedlings just after planting is good for crop establishment. Although it can be cultivated as a rainfed crop under humid tropical conditions, irrigation every month is beneficial during summer. The root is the economic part and harvesting can be commenced after 8-9 months. About 500-700 kg roots can be harvested from a hectare of land per year (Joy et al. 1998). Bioproduction of indoleacetic acid through a *Rhizobium* sp. isolated from the root nodules of *D. gangeticum* using tryptophan precursor in culture. With the help of this study the possible relationship between the rhizobial IAA production and legume-rhizobia symbiosis were discussed (Bhattacharyya and Basu, 1997).

**Traditional and medicinal uses**

*D. gangeticum* is the chief of the ten ingredients in the *Dasamula kwatha* of Ayurvdic medicine (Prayagadatta, 1966). Roots are useful in vitiated conditions of *vata*, anorexia, dyspepsia, haemorrhoids, dysentery, strangury, fever, gout, inflammations, cough, asthma, bronchitis, cardiopathy and debility. The unani preparation “*Arq dashmul*” contains extract from its roots. It is considered a curative for leucorrhoea and for pains due to cold (Warrier et al., 1995). Its roots as well whole plant were used for treatment of snake bites and scorpion stings. This activity were reported in Khagan valleyMansehra KPK and Pakistan due to occurrence of variety of active compounds i.e., Gangetin, Gangetinin, Desmodin, Flavones, Flavonols, Isoflavones, Pterocarpans, Indole-3-Alkylamines, AmideAlkaloids, Phenylethylamine, Alkaloids, Steroids, Β-Amyrone,4 Dihydroxybenzoic Acid,Vanillic Acid (Bhatterjee,2000; Butt et al.,2015).

The plant is used as an antipyretic in India (Lans, 2006). Water decoction of root and aerial parts of this plant traditionally possesses anti-inflammatory, anti-nociceptive as well as analgesic activities (Rathi et al., 2004). In the Indian system of medicine it is used as a bitter tonic, febrifuge, digestive, anticatarrhal, antiemetic, in the management of inflammatory conditions of chest and various other inflammatory conditions due to vata disorder (Chopra et al., 1956 and Bakshi et al., 2001) and in treatment of abcesses, acne, cataract, dysentery, eye diseases, fever, gout, asthma, bronchitis, infections and liver diseases (Trout, 2004). In west tropical Africa, its bark is used as laxative, leaf and root for fevers, skin diseases, anxiety states, kidney ailments and as diuretic, roots are used as abortifacient, antidotes for venomous stings, pain killer, tumors and cancers (Iwu, 1993). Its roots as well as leaf is higly medicinal and various reports are present to show medicinal status of these parts. In Uganda,its root were chewed to cure prematureejaculation (Tabuti et al., 2003). In Satpuda Hills, its root powder was mixed with honey andapplied frequently to treat mouth ulcer (Kosalge and Fursule, 2009). In Uttar Pradesh, the leaf paste was applied externally alongwith the leaves of Aloe vera to preventhair fall (Singh and Singh, 2009). In Assam, the paste of leaves was layered on theinfection to cure eczema (Saikia et al., 2006). In Java, decoction of leaves is used for stones of the gall bladder and kidneys, in Malay root decoction is used for diarrhoea, fever and applied to the gums for toothaches, and the leaves are used externally for headaches. In Southern Nigeria, leaf is used for urinary problems and root is considered as astringent and diuretic, is used for abdominal tumors, asthma, diarrhea, fever, nasal polyps, dysentery and worms as well as anti-catarrhal and febrifuge (Iwu et al., 1994). A study of Nigeria reported that swallowing of *D. gangeticum* leaf by chimpanzee, provides them self-medication (Fowler et al., 2007). The plant also utilized for making paper and its leaves as fodder (Ambasta, 1986).

Table 1: Traditional use of *D. gangeticum* plant

|  |  |  |
| --- | --- | --- |
| Part | Traditional use | Reference |
| Leaves | fevers, skin diseases, anxiety states, stones of the gall bladder and kidneys, and as diuretic | Iwu, 1993; Iwu et al., 1994 |
| Bark | laxative | Iwu, 1993 |
| Root | anorexia, dyspepsia, haemorrhoids, dysentery, strangury, fever, gout, inflammations, cough, asthma, bronchitis,snake bites and scorpion stings | Richard et al., 1983; Iwu et al., 1994; Raman Namboodiri, 2004 |
| Whole plant | bitter tonic, febrifuge, digestive, anticatarrhal, antiemetic, gout, asthma, bronchitis, infections and liver diseases | Nadkarni, 1976; Bakshi et al., 2001; Trout, 2004 |

**Commercial Potential of *D. gangeticum***

This plant has high commercial value, and the domestic demand has been estimated as about 678.4 t/year (Anonymous, 2005). Large scale and unrestricted exploitation of *D. gangeticum* to meet its ever increasing demand by the Indian pharmaceutical industries coupled with limited cultivation and insufficient attempts for replenishment of natural populations has led to marked depletion in its population as a result of which it is now listed as a rare species by the International Union for Conservation of Nature and Natural Resources (Pandey et al., 1993; Oommen et al., 2000). The Department of Indian Systems of Medicine and Homeopathy, Ministry of Health and Family Welfare, Government of India, has formulated a Central Scheme for Cultivation and Development of Medicinal Plants. *D. gangeticum* is one of the species identified for promoting cultivation in order to reduce pressure on its natural populations and to meet the shortage in biomass availability to the pharmaceutical industry (Rawat and Sharma, 1998).

**Phytochemical Screening**

Dry and finely powdered leaves (5 kg) of *D. gangeticum* were extracted with methanol (6×5 L) for 36 h using a Soxhlet apparatus at 60-70°C. The residue (536 g) obtained after *in vacuo* concentration was further fractionated in n-hexane (2 L×2), chloroform (1 L×1), and ethyl acetate (1 L×3) using a mechanical stirrer followed by concentration under reduced pressure to afford crude residue of 152 g, 34 g and 92 g, respectively (Figure 1). Systematic chemical investigation of the methanolic leaf extract enabled isolation of known glycoside, 2-(hydroxymethyl)phenyl hexopyranoside (DG-1), also known as ‘salicin’ whichis conventionally isolated from the willow bark [50]; this is the first report of isolation of salicin from leaves of *D. gangeticum*.

**Chemical compounds in *D. gangeticum***

*D. gangeticum* is used in ‘Ayurvedic’ preparations like ‘Dashmoolarishta’ and ‘Dashmoola kwaath’ for the post-natal care to avoid secondary complications (Prayagadatta, 1966). The bioactivity studies of the individual ingredients of Dashamularishta were done with the aqueous extracts of the individual ingredients. Among the components of it, *D. gangeticum* exhibited no toxicity to the brine shrimp (BST) nauplii, but moderate toxicity to thewheat rootlet growth (WRG) and lettuce seed germination (LSG). It exhibited total inhibition to the growth of PPR virus (Jabbar et al., 2004). The sterols *N*,*N*-dimethyltryptamine, 5-methoxy-*N*,*N* dimethyltryptamine, their oxides and other derivatives have been isolated from aerial parts (Behari and Varshny, 1986). Three pterocarpenoids, namely, gangetin, gangetinin and desmodin, are the major chemical constituents of the roots (Ghosal and Banerjee, 1969;Purushothaman et al., 1971; Ingham and Dewick, 1984). Gangetin, a pterocarpan, shows anti-fertility activity by affecting alkaline phosphatase activity in uterine fluid (Purushothaman et al., 1975). Phytochemical screening has revealed that this plant contains alkaloids such as tryptamines, phenethylamines and their N-oxides (Muzaffer et al., 1982), pterocarpanoids such as gangetin, gangetinin, desmodin, and desmocarpin; phospholipids, (Rastogi et al., 1971) sterols (Mukat and Varshney, 1986) and flavonoid glycosides like 4,5,7-trihydroxy-8- prenylflavone-4’-O-α-L-rhamnopyranosyl-(1-6)-β-D-glucopyranoside (Yadava and Tripathi, 1998) and 8-C-prenyl-5,7,5’-trimethoxy-3’,4’-methylenedioxy flavones (Yadava and Reddy, 1998). The following compounds, glycosphingolipid, 5-methoxy N, N-dimethyl tryptamine, kaempferol 7-O-β-D-glucopyranoside, 5-methoxy N,N dimethyltryptamine N-oxide, rutin, quercetin 7-O-β-D glucopyranoside and uridine triacetate were shown *In vitro* antileishmanial activity (Meena et al., 2010).

Meena et al., (2010) reported that *D. gangeticum* have high water content and it was easily deteriorated due to fungus. The loss on drying at 105 °C in fruits was found to be 4.9%. Total ash value of plant material indicated the amount of minerals and earthy material present in the plant material. Analytical results showed total ash value content was 3.45%. The negligible amount of acid-insoluble siliceous matter present in the plant was 0.63%. The water soluble extractive value was indicating the presence of sugar, acids and inorganic compounds. The alcohol soluble extractive values indicated the presence of polar constituents like phenols, alkaloids, steroids, glycosides, flavonoids.It contains various classes of bioactive principles such as flavonoid glycosides, pterocarpanoids, lipids, glycolipids, lactones (Avasthi and Tewari, 1955a, b, c) and alkaloids (Ghosal and Bhattacharya, 1972; Mishra et al., 2005).Several phytochemical components have been isolated from *D. gangeticum*. The extraction were done with various chemicals including alcohol, petroleum ether, ether resin, chloroform, ethyl acetate, amyl alcohol etc. at each step of fractionation different active compounds were isolated and identified from precipitate and filterate. The isolation of these principles has been described and a preliminary study of their physical and chemical properties is reported (Avasthi and Tewari, 1955a, b, c).In the consequent study from the seeds of *D. gangeticum* many phytochemicals were isolated (Avasthi and Tewari, 1955a, b, c).Srivastava et al. (2017) reported that *D. gangeticum*leaves showed the presence of variety of active compounds including alkaloids, tannins, phenols, flavonoids, terpenoids, tannins, whereas saponins and volatile oils was absent (Table 2).

The roots of *D. gangeticum* form one of the ingredients of a famous ayurvedic preparation of Dasmoola Kwatha, which is considered as an antipyretic alternative and bitter tonic. The aqueous extract of root exhibit anti-inflammatory, antibacterial and antifungal activities (Trout, 2004 & Rathi et al., 2004). It acts as a potent antiulcer agent, which is effective in all models, mainly due to its more cryoprotective effect in comparison to anti-secretory effects (Dharmani et al., 2005). From the roots of *D. gangeticum* seven alkaloids which represents three structural types-carboxylated and decarboxylated tryptamines and β-phenylethylamine were extracted and characterized.Along with this three new pterocarpenoids-gangetin, gangetinin and desmodin were also isolated and identified from roots and whole plant(Anonymous, 1971; Purushothaman et al., 1975; Kirubha et al., 2011). A novel pterocarpan, gangetial, has been extracted from the chloroform extract of the roots of *D. gangeticum* (Varaprasad et al., 2009).

Earlier chemical studies on the *D. gangeticum* revealed the presence of alkaloids, pterocarpenoids, flavones and isoflavanoid glycosides (Purushothaman et al., 1971). The sterols N, N-dimethyltryptamine, 5-methoxy-N,N dimethyltryptamine, their oxides and other derivatives have been isolated from aerial parts of this plant, while pterocarpenoids are the major constituents of the root. Gangetin, a pterocarponoid from *D. gangeticum* has been shown to possess anti-inflammatory and analgesic activities (Ghosh and Bhattacharya, 1972). *D. gangeticum* is supposed to be a candidate medicinal plant to have anti-oxidant activities in its aerial parts (Govindarajan et al., 2003).

Salicin is a glycoside, which acts as a precursor compound for the synthesis of acetyl salicylic acid. This glycoside consists of a carbohydrate molecule (sugar) and a non-sugar component (aglycone). White Willow Bark and Meadowsweet are traditional sources of salicin, which has analgesic as well as anti-inflammatory properties. Salicylic acid, released from salicin in the body, provides anti-inflammatory and pain-relieving actions (Pilotto et al., 2004). In this study, salicin was isolated from *D. gangeticum* leaves. Further, molecular modeling and docking studies showed that salicin has a much higher affinity for COX2 than that for COX1 (Srivastava et al., 2013). Schematic representation of steps involved in screening,identification, extraction and characterization of phytochemicals of *D. gangeticum* with wide variety of biological activities is shown in Figure 2.

**Table 2.** Qualitative analysis of the phytochemicals of crude extracts of *Desmodium gangeticum* leaves.

|  |  |
| --- | --- |
| **Phytochemicals** | ***Desmodium gangeticum*** |
| Alkaloids | + |
| Carbohydrates | + |
| Saponins | - |
| Phenols | + |
| Flavonoids | + |
| Terpenoids | +  |
| Tannins | + |
| Volatile oils | - |

 + Presence of the compound.
 - Absence of the compound

*Desmodium gangeticum*

(leaves, bark, root, whole plant)

Screening, identification, extraction and fractionation in suitable solvent for complete solubilization

Bioactivity characterization and structure elucidation with specific technique.

Bioactivity screening for various properties majorly anticancer, antimicrobial, antidiabetic, anticancer, etc.

Optimization of suitable bioassay

**Fig 2:** Schematic flowchart showing exraction, isolation, and characterization of phytoconstituents present in various parts of *D. gangeticum* with specific biological activities

**Table 3:** Active compounds present in various parts of *D. gangeticum*

|  |  |  |  |
| --- | --- | --- | --- |
| **S.No.** | **Plant part** | **Name of the compound** | **Reference** |
| **1.** | Whole plant | Aminoglucosyl glycerolipid-isolated first time,trans-5-hexadecenoicacid, 1-tritriacontanol, 1-heptadecanol, β-sitosterol, β -amyrone,gangetin, glycosphingolipid, 5-methoxy N,N-dimethyl tryptamine,8-C-prenyl-5,7,5’-trimethoxy 3’,4’-methylene dioxy flavone,salicylic acid, 5-O-methylgenistein-7-O- β -d-glucopyranoside, 3,4-dihydroxy benzoic acid, kaempferol-7-O- β-d-glucopyranoside,5-methoxy N,N-dimethyl tryptamine Nb-oxide, β-sitosterol-3-O-β-d-glucopyranoside, rutin, quercetin-7-O- β-D-glucopyranosideand uridine triacetate | Misra et al., 2005 |
| **2.** | Aerial parts | Indole-3-alkylamines, Kaempferol, Quercetin, Rutin, Caffeic acid, Cholorogenic acid, Salicylic acid, Protocatechuic acid, Gallic acid | Niranjan and Tewari, 2008; Deshpande and Bhalsing, 2014 |
| **3.** | Roots | Benzaldehyde, 4 – methoxy,1,2, 3 – Benzenetriol, 2-Propenal, 3-(4-hydroxy-3-methoxyphenyl)- , 4-(1E)-3-Hydroxy-1-propenyl)-2-methoxyphenol, N,N-Dimethyltryptamine, Hexadecanoic acid, methyl ester, 7-Hexadecanoic acid, n-Hexadecanoic acid, 3,5-Dimethoxy-4-hydroxycinnamaldehyde, 9,12-Octadecadien-1-ol,methyl ester, 11-Octadecenoic acid, methyl ester, Heptadecanoic acid, 16-methyl-, methyl ester, 9.12-Octadecadienoic acid, Octadecanoic acid, 12-Ethylsophoramine, E,Z-1,3,12-Nonadecatriene, Stigmasterol, Gamma Sitosterol,a new pterocarpan-gangetial | Varaprasad et al., 2009; Hemlal and Subban, 2012 |

**Proven and possible health benefits of *D. gangeticum***

**Anticancer**

Cancer is a group of diseases with uncontrolled growth of abnormal cells in which cells are aggressive,invasive, and sometimes metastatic,anywhere in a body. Cancer may affect otheranimals and plants, other than humans. *D. gangeticum*crude leaf extracts as well as its isolated compound salicinhave shown marked anticancer activity. Screening and identification of salicin compound from leaves of *D. gangeticum* and its *in vivo* anticancer activity and docking studies with cyclooxygenase (COX) proteins from *Mus musculus*. Salicin have positive effect on EAC bearing mice, which significantlyincreased the life span of treated animal as compared to the EAC control. Molecular modeling anddocking studies revealed the binding orientations of salicin into the active sites of COX-1 and COX-2 enzymes. Thus this study successfully discovered novel anticancerinhibitor from medicinal plant *D. gangeticum*(Srivastava et al., 2013). In another study Srivastava et al. (2015) reported comparative dose dependent anticancer activity of crude leaf extracts (methanol-MEDG and ethylacetate-EADG) and isolated compound salicin of *D. gangeticum*against EAC tumor model in swiss albino mice. Hematological profile, such as RBC, WBC, lymphocyte counts and hemoglobin content reverted to near normal level in MEDG, EADG and salicin treated mice. The biochemical parameters GSH, SOD and CAT increased where as LPO decreased in treated mice shwing marked anticancer activity, which approaches that of standard drug 5-fluorouracil. Thus, the *D. gangeticum* crude extracts and isolated compound have marked anticancer activity.

**Antioxidant**

The antioxidants properties of plant sources has been remarkably used in conventional therapy. *D. gangeticum*is supposed to be a candidate medicinal plant to have anti-oxidant activities in its aerial parts. Various studies have been performed for analyzing antioxidant activities of *D. gangeticum*. The flavonoids and alkaloidal fractions of methanolic extract have evaluated under *in vitro* condition for antioxidant potential. The antioxidant potential were assessed using DPPH, NO, HOCl, LPO assayes. The results observed represents potent antioxidant activity of flavonoids fraction (Govindarajan et al., 2003; 2007).The phenolics fraction of *D. gangeticum* upon activityguided fractionation and isolation showed maximum potency. The isolation of two potentantioxidant compounds, caffeic acid and chlorogenicacid fromactive phenolic fraction were done with Solidphase extraction followed by preparative HPLC. The antioxidantpotential of these compounds were evaluated in adjuvant-induced arthritic rats. The antioxidant assay revealed marked increase in SOD, GSH and CAT whereas a decrease in theLPO content upon administration of *D. gangeticum*extract (100 mg kg–1) and its phenolics (50 mg kg–1)in arthritic rats, thereby indicating the extracts antioxidantproperty under arthritic conditions (Govindarajan et al., 2006). The comparative antioxidant activities of phenolic components of the crude extracts of 10 different *Desmodium* species including *D. gangeticum* were evaluated and reported by Tsai et al., 2011. Aerial as well as root extract contain phenols and other phytochemical compounds, responsible for antioxidant activity as well for its efficacy in different ayurvedic formulations (Niranjan and Tewari, 2008).In the Indian system of medicines and Ayurvedicpreparations, *D. gangeticum* was used fortreatment as well as management of ischemic heart disease (Kirtikar and Basu, 1987). The aqueous extract of this species has been reported to show free radical scavenging activity in case of severe myocardial infraction (Kurian et al., 2005). Kurian and Paddikkala (2009) reported that feeding the aqueous extract of *D. gangeticum* to rat, improved the antioxidant capacity of heart and reduced the degree of lipid peroxidase after ischemic perfusion. A similar effect was observed when rats were given ethylacetate extract of *D. gangeticum*roots (Kurian et al., 2010).Kurian et al., (2010) reported that *D. gangeticum* root extract mediates the cardio-protection in ischemic reperfusion injury model in rat heart through negative inotropic and chronotropic effect by stimulating the G coupled receptors similar to the action of acetylcholine.The chloroform extract of *D. gangeticum* roots exhibited the hepatoprotective activity against carbon tetrachloride induced liver damage in rats (Prasad et al., 2005).

The free radical scavenging effect of *D.gangeticum* (DG) root aqueous extract was investigated under *in vitro* and *in vivo* conditions in different antioxidant models. The rats were divided into three groups namely control, reperfusion control, and drug treated. The aqueous extract of DG root exhibitedpromising free radical scavenging effects that were reduce the oxidative stress demonstrated by ischemic reperfusion injury (IRI) (Kurian et al., 2009). Inhibitory activity of Acetylcholinesterase (AChE) and antioxidant activity of methanolic extract of *D. gangeticum* were evaluated. Ellman method and DPPH free radical scavenging test were performed for Acetylcholinesterase inhibitory activity and antioxidant activity measurement respectively. Thus, the results exhibited that DG extract havemarked scavenging activity (Ranjan and Kumari, 2017). The methanolic root extract of *D. gangeticum* (DG) was investigated for total phenolic content as well as for antioxidant potential. This study analysed the role of oxidative stress in cardiomyoblast hypertrophy and its modulation by use of DG in traditional system of medicine. H9c2 cell line to β-adrenergic receptor agonist, isoproterenol (ISO) was used to induce hypertrophy for 96 hours. Analysis of reactive oxygen species (ROS) generation, mitochondrial transmembrane potential (ΔJm), and integrity of permeability transition were performed in ISO, *Desmodium*and ISO-cotreated cells (Sankar et al., 2013).Theroot extract of *D. gangeticum* (DG) showed markedcardioprotective activity against ISO-induced left ventricular cardiac hypertrophy (LVH) in adult Wistar rats.Heart weight (HW) body weight (BW) ratio (HW/BW) an indicator of hypertrophic growth, was considerably reduced in DG root post-treated LVH rats as compared with that for the non-treated LVH rats. With DG,The altered levels of ventricular LPO, collagen, MMPs-2 and -9, and antioxidant enzymes in the ISO-treated animals reverted back to near normal. Additionaly, the anti-hypertrophic activity of DG was comparable to that of the standard drug losartan (10 mg/kg).Thus, the aqueous root extract of DG showed anti-hypertrophic activity *in-vivo* by inhibiting ISO-induced ROS generation and MMP activities (Hitler et al., 2014). The aqueous and alcoholic rootextracts of *D. gangeticum*and its substitute *Pseudarthria viscida* were reported with marked antioxidant activities viz., DPPH, NO andreducing power properties. The standard antioxidantwas ascorbic acid (100 μg/ml) and analysis was done with UV-Vis spectrophotometer. Due to marked antioxidant properties, these plants could be used for pharmaceutical applications (Kirubha et al., 2013). Screening and identification of free radical scavenging properties of methanolic extract of few important medicinal plants viz., *D. gangeticum*, *Eclipta alba*, *Ocimum sanctum*, *Piper longum*, *Solanum nigrum* and *Amaranthus caudatus* were done. Among all the selected plants, *D. gangeticum* antioxidant activities werehighest.The Free radical scavenging activity (IC50), Ascorbic acid content and Carotenoids content were highest in case of *D. gangeticum* whereas total phenol was highest for *O. sanctum* (Veeru et al., 2009). Myocardial necrosis caused significant alterations in the lysosomal enzymes and biochemical variables, which further causemyocardial ischemic reperfusion injury. *D. gangeticum* preconditioned heart tissues reproduced thelysosomal enzymes and electrolytes contentof perfusate and cardiac tissuesto near normal levelunder *in vitro*condition (Shabi and Upadhayay, 2012).

Effect of DG chloroform root extract was evaluated on isolated rat heart and *in-vitro* antioxidant models. Langendroff apparatus was used to induce ischemia reperfusion injury experimentally. Various antioxidant models i.e., DPPH, super oxide, hydroxide and nitric oxide scavengingassays were utilized to evaluate the free radical scavenging potential under *in vitro*condition. The DG extract was used as a pre-conditioning agent against myocardial ischemia reperfusion injury to evaluated cardio-stimulatory effects. The improved antioxidant status of the myocardium indirectly predicts reduced oxidative stress mediated by ischemic reperfusion with evident reduction of infarct size determined by cardiac marker protein. These findings indicate that DG chloroform root extract may possess therapeutic potential against ischemia reperfusion injury (Srivats et al., 2012).

The pharmacological mimetic action of methanolic root extract ofDG on ischemia reperfusion injury in isolated perfused rat heart by stimulating muscarinic receptors were evaluated. For evaluation of ischemic post condition (POC) mimetic action of DG methanol root extractin an isolated rat heart withLangendroff perfusion technique were used and compared withstandard drugs acetylcholine (Ach) and atropine (Atr) as agonist and antagonist respectively. DG methanol root extract mimics its action similar to that of Ach, the myocardial protection mediated by the extract was superior to Ach, due to the presence of antioxidants in the crude extract.Thus, DG methanol root extract provides myocardial protection towards IRI by stimulating muscarinic receptors (Kurian and Paddikkala, 2012).

In ischemia reperfusion injury cases*D. gangeticum*aqueous root extract revealed protective effect on mitochondrial and sarcoplasmic ATPase. The isolated rat hearts in both drug and control group were subjected to warm ischemia (37°), followed by reperfusion with the Langendorff perfusion system. The aqueous root extract of *D. gangeticum* at a dose of 50 mg/kg body weight was found to be effective in the rat heart for the management of ischemic reperfusion injury. Physiological parameters were significantly (P<0.05) improved in drug treated rat hearts. Creatine phosphokinase in coronary perfusate found to be declined. Moreover, sarcoplasmic ATPase and mitochondrial enzymes were significantly (P<0.05) improved in drug treated rat hearts. In fact, histological analysis of the myocardium also suggested an improved ultra structure in *D. gangeticum* treated rat heart. These results suggest that DG aqueous root extract can preserve the mitochondrial and sarcoplasmic ATPase in the myocardium, resulting in the improvement of cardiac function after ischemia reperfusion injury (Kurian and Paddikkala, 2010).

Anti ischemia reperfusion property of *D. gangeticum* (DG) chloroform root extract was measured in frog and evaluated in isolated rat heart. Langendroff apparatus was used to induce ischemia reperfusion injury in rat and was perfused with Kreb Hanseleit buffer through aorta. Various parameters such as heart rate, coronary flow and Left Ventricular Pressure (LVP) along with biochemical enzymes level were recorded. The activity of LDH in coronary effluent and creatine kinase and LDH contents in myocardial tissues were measured. Administration of DG root chloroform extract was effectively reduce the release of lactate dehydrogenase in coronary effluent and improve cardiac functions. GSMS and atomic absorption analysis of DG root extract, confirm the presence of bio-molecules that can stimulate the release of calcium in heart. This study reported DG chloroform root extract can protect the myocardium against the damages induced by ischemia reperfusion in rats and the effect of the extract may be related to calcium releasing property (Kurian et al., 2010).

The*in vitro* and *in vivo* free radical scavenging property of the aqueous extract of *D. gangeticum* (DG) root on experimentally induced ischemic reperfused rat heart were studied. The free radical scavenging potential was evaluated *in vitro* by using different antioxidant models such as DPPH, super oxide scavenging activity, hydroxide scavenging activity and nitric oxide scavenging activity. Aqueous extract of DG at 50 or 100 mg/kg body weight was administrated once daily for 30 days orally in Wister rats to assess the *in vivo* free radical scavenging potential. Further, isolated heartwere subjected to ischemic reperfusion injury. During this study,lipid peroxide products (thiobarbituric acid reactive substances) were significantly increased whereas, the enzymes (superoxide dismutase, catalase, glutathione peroxidase and glutathione reductase) in the myocardial tissue homogenate showed a significant decrease during ischemia and ischemic-reperfusion. Pre treatment of rats with DG (50 or 100mg/kg b.wt.) orally for 30 days daily caused a significant effect in the activity of antioxidant enzymes. The *in vitro* antioxidant study showed lipid peroxidation (LP), scavenge hydroxyl and superoxide radicalsinhibition. Administration of DG to normal rats did not have any significant effect on any of the parameter studied. The results of our study showed that DG possesses activity to scavenge the free radical generated during ischemia and ischemic-reperfusion (Kurian et al., 2008).

**Antimicrobial**

Root extract in aqueous form revealed striking antibacterial and antifungal activities (Rathi et al., 2004). Methanolic extract of leaves of *D. gangeticum* have the maximum degree of antimicrobial activity than aqueous, chloroform, hexane extracts and this may be due to the presence of phytochemicals viz. alkaloids, tannins, flavonoids and saponins (Lagudu and Owk, 2016). Antibacterial activity of various solvents against various pathogens were reported under *in vitro* condition with maximum efficacy of methanolic extracts (Karthikeyan et al., 2012).Antibacterial properties of hexane, chloroform and aqueous extracts of roots of some medicinal plants including*D. gangeticum*used in the traditional medicine were studied on *Bacillus pumilis* and *Eschericia coli* by disc diffusion method (Sini and Malathy, 2005).

The methanolicroot extract of *D. gangeticum*and *Pseudarthria viscida* (L) were evaluated for chemical composition. 43 and18compounds have been identified from *P. viscida*and *D. gangeticum*extracts respectively. Stigmasterol was quantified from both extracts by HPTLC method (105.15 µg/ml and 20.9 µg/ml respectively). *In vitro*antimicrobial (antibacterial and antifungal) activities including zone of inhibition and MIC of these extracts were evaluated and Ampicillin (30 µg/disc) and mystatin (20 µg/disc) were used as standard for antibacterial and antifungal activity respectively (Hemlal and Subban, 2012).

**Anti-asthmatic**

The root extract of *D. gangeticum*were reported with anti-asthmatic activity due topresence of alkaloids, carbohydrates, glycosides, phytosterol and flavonoids. The extracts were shownsignificant decreased in WBC count, tissue MDA and protein content in comparision to sensitized control II (Ovalbumin) treated rats (Vedpal et al., 2016).

**Antiulcer and Antinociceptive**

*D. gangeticum* acts as a potent antiulcer agent, which is effective in all models, mainly due to its more cryoprotective effect in comparison to anti-secretory effects (Dharmani et al., 2005). The root powder of this plant mixed with honey and applied frequently to treat mouth ulcer. The lesion number and ulcer index notably reduced against ethanol induced acute gastric ulcer in mice with oral administration of ethanolic extract of rootof *D. gangeticum* in a dose dependent manner. The highest dose (150 mg/kg) of the extract provoked a marked increase in protein and glutathione levels, when compare to control.Furthermore, gastric juice, free acidity and total acid output were inhibited in a dose-dependent mannerat p<0.05 level (Ayyavu et al., 2012).

Antinociceptive potential of methanolicstem extract of *D. gangeticum*was evaluated in acetic acid-induced gastric painwith consequent abdominal constrictions in Swiss albino mice. The extract was administered in dose-dependent manner and significant reduction of acetic acid-inducedabdominal constrictions in mice was observed. At the highest dose tested of the extract, namely 400 mg/kg body weight, theextract caused 52.6% inhibition of abdominal constrictions, when compared to control mice. Thus, it is validated to be use this plant in folk medicine for treatment of pain (Jahan et al., 2010).

**Anti-inflammatory and Analgesic**

Inflammation is a very common disease in all over the world, every third person is suffering from inflammatory disease; inflammation can develop in any stage of life. There are several options for the treatment of inflammation. Various drugs are available in the market which is related to allopathic medicine system. Due to fewer side effects and less toxicity herbal drugs gain more market value. Desmodium gangeticum

(DC) commonly known as salpan (Fabaceae). In India, Desmodium gangeticum (L.) DC has a considerable reputation as a bitter

tonic, febrifuge, digestive, anti-emetic, antipyretic and anti-catarrhal. It is also widely used in Ayurveda for the treatment of neurological

disorders. In the present study an attempt was made to screen the anti-inflammatory activity of various extract of Desmodium gangeticum.

Gangetin, a pterocarponoid from *D. gangeticum* has been sown to possess anti-inflammatory and analgesic activities (Ghosh and Bhattacharya, 1972; Ghosh and Anandakumar, 1983).The aqueous extract of root exhibit anti-inflammatory activity (Trout, 2004). Root as well as aerial parts of aqueous decoction under *in vivo*mice model showed remarkable anti-inflammatory and anti-nociceptive activity using carrageenan and acetic acid induced writhing (Rathi et al., 2004). Whole plant juice of *D. gangeticum* carries anti-inflammatory activity in form of anti-rheumatic and anti-osteo arthritic activity (Sharma et al., 2009). Gangetin, a pterocarpens, isolated from n-hexane extract of root of *D. gangeticum*exhibitedremarkable anti-inflammatory activity in both exudative and proliferative phases of inflammation in rat model at dose of 50 and 100 mg/kg body weight(Amritpal et al., 2008). Whole plant ethanolic extract of *D. gangeticum* in rat using Carrageenan-induced paw oedema method showed anti-inflammatory activity at 100 and 200 mg/kg dose level (Yasmeen and Sujatha, 2013).Nagarkar et al. (2013) reported comparative of anti-inflammatory activities of various medicinal plants including *D. gangeticum*, which are ingredients ofAyurvedicDashamoola. The result obtained have significant anti-inflammatory activity, which rationalizes the folk use of formulations. Ethanolic extract of leaves of *D. gangeticum* were evaluated for anti-inflammatory and antinociceptive activities using thermal and chemical method against Carageenan induced paw oedema. The oral administration of DG extract at 50, 100,200mg/kg dose and positive control morphine (5mg/kg i.p.) and aspirin (300mg/kg o.p.)inhibited acetic acidinducedwrithing. Most effectively 300 mg/kg DG extract inhibited acetic acidinducedwrithing comparable to that of aspirin. Thehighest dose of the DG extract increases the latency period by 37.65% in Eddy’s hot-plate and28.26% (P < 0.05) in tail fick test. From all the experiemnetal methods evaluated 200mg/kg dose was found effective and equipotent to standard drugindomethacininhibitingcarageenan induced paw oedema. Thus study reported ethenolic extractof *D. gangeticum*have anti-inflammatory and antinociceptive properties and to be used aspotential therapeutic against pain andinflammatory diseases (Sargar et al., 2010).

*D. gangeticum* is known for its marked anti-inflammatory activity. A new aliphatic enone, (17Z,20Z)-hexacosa-17,20-dien-9-one (3), and one new bisindole alkaloid, gangenoid (6), along with seven known compounds were isolated from the roots and aerial parts of this medicinal plant. All the compounds except two were isolated from this plant for the first time, with known chemotaxonomic importance. Structures of compounds, 3 and 6 were determined on the basis of their detailed spectroscopic analyses (NMR, IR and mass). In addition, compounds 3 and 6 were investigated for their effects on lipopolysaccharide-stimulated macrophages for the production of pro-inflammatory cytokines such as tumour necrosis factor-α and interleukin-6 (Yadav et al., 2013).The detection of gangenoid, an anti-inflammatory alkaloid from roots of *D. gangeticum* were reported using two simple and accurate methods i.e.; HPLC and HPTLC (Yadav and Gupta, 2014).

**Anti-diabetic**

For treatment of type 2 diabetes mellitus with the dried crushed roots of *D. gangeticum* and *Pseudarthriaaqueous* decoction is prescribed thrice daily after meal by tribal people (Dilip and Janardhan, 2012).Methanolic extract of aerial parts of *D. gangeticum* (100 and 250 mg/kg) for 3 weeks showed a significant antidiabetic activity in rats by stimulating insulin secretion from MIN6 and pseudoislets cells of pancreatic islet. It plays a major role to maintain the lipid profile of the rats by reducing cholesterol and triglycerides level and increase in high density lipoproteins (HDL) significantly (p < 0.05). This supports the traditional use of *D. gangeticum* as anti-diabetic drug (Govindarajan et al., 2007). Renal protective effect of *D.gangeticum* in Streptozotocin induced diabetic rats were reported. Enzymatic (SOD, CAT, GPx) as well as non-enzymatic (GSH) antioxidants level were enhanced in such treated mice. Thus the ethanolic whole plant extract of this plant have marked antidiabetic as well as antioxidant activities (Yasmeen et al., 2011). Diabetes induced Wistar male ratInsulin-DG mix was found optimum and DG extract was shielding to insulin when utilized in prescribed combination and delivered orally. The molecular interaction between DG and insulin were demonstrated by FTIR and NMR. This combination was helpful to overcome painful subcutaneous injections (Gandhi et al., 2016).Oral delivery of insulinhave several difficultiesconcerningwith physical and chemical hormonestability and its absorption and metabolism in the human body. The aqueous extract of *D. gangeticum* (DG) root(0.1 mg/ml) were used to study oral delivery of human insulin (40 IU/ml) in ratio 1:1(v/v), in normal as well steptozotocin (STZ)-induced diabetic rats. Incorporation of insulin along with DG extractin normal and STZ-induced diabetic rat, caused decrease in plasma glucose level and increase in plasma insulin withpossible absorption of insulin through GI tract. Thus, DG extract mixed insulin was evidenced as suitable drug for oral delivery of insulin, even though exact compound ofprotective oraldelivery should be identified (Kurian et al., 2009). Combinatorial therapy of insulin with herbal formulation of *D. gangeticum* in oral administration found effective to reduce blood glucose levels in STZ-induced diabetic rats under *in vivo* condition.This mixed formulationhas a substantial antihyperglycemic, antioxidant andcardioprotective activities. Thus this herbal formulation is one the best possible candidate for oral delivery of insulin for diabetes treatment (Gandhi et al., 2016).

The antidiabetic effect of various extracts of *D. gangeticum*was evaluated on normal and streptozotocin (STZ)-nicotinamide induced type-2 diabetic animals. Type-2 diabetes was induced in Wistar albino rats of either sex by the administration of STZ-nicotinamide (40, 110 mg/kg b.w., respectively) intraperitoneally. *D. gangeticum* (100 mg/kg b.w.) extracts in different solvents (viz. pet. ether, benzene, chloroform, acetone, ethanol and water) were administered to diabetic rats for 21 days. The effect of extracts on blood glucose, lipid profile (TC, TG, LDL-C and HDL-C) and body weight was studied in diabetic rats. *D. gangeticum* extracts significantly reduced the elevated blood glucose, TC, TG, LDL-C level. Reduced HDL-C level and body weight in diabetic animals were found to be elevated significantly by the *D.gangeticum* extracts. But among all the extracts aqueous extract exhibited the best antidiabetic, antihyperlipidemic activity and positive effect on weight of diabetic rats. The results of our study suggest that the aqueous extract of *D.gangeticum* possesses a promising effect on STZ-nicotinamideinduced type-2 diabetes (Bisht and Bhattacharya, 2013).

**Anti-venom**

Paste of the root of *D. gangticum*is given orally to the victim of snake bite once or twice. It is claimed that the patients are being cured by this treatment. Sour things should be avoided (Maheshwari et al., 2003). Used as antidote to snakebite and scorpion sting (Verma et al., 1999).

**Antileishmanial and immunomodulatory activities**

Visceral leishmaniasis (VL), which is commonly called as Kala-azar, is the utmost threating disorder among various forms of leishmaniasis complexes. Its causing agent is an obligate intracellular protozoan parasite*Leishmania donovani*, belonging to the family Trypanosomatidae. Antileshmanial activity of some medicinal plant extracts including *D. gangeticum* were evaluated using Radiorespirometric Microtechnique (RAM) based on *in vitro* inhibition. The methanolic extracts of various plant including *D. gangeticum*were found effectiveat dose of 50 µg/ml or less against visceral leshmaniasis through catabolism of 14CO2, from a battery of 14Csubstratesby promastigotes (Iwu et al., 1992).

Glycolipids viz. Aminoglucosylglycerolipid and glycosphingolipid, isolated from the roots of *D. gangeticum* indicated marked antileishmanial and immunomodulatory activities *in vitro* by increasing nitric oxide (NO) production and provided resistance against infection established in peritoneal macrophages by the protozoan parasite *Leishmania donovani* (Pushpesh et al., 2005).

The ethanolic extract and itsaqueous fractions, n-hexane, n-butanol extracts of *D. gangeticum* were evaluated chemo-prophylactically and chemotherapeutically against experimental visceral leishmania in hamsters at a dose of 250 mg/kg for seven days. The results of this study revealed highest prophylactic efficacy (41.2±5.3% inhibition) in n-butanol fraction and moderate efficacy (66.7±6.1% inhibition) in ethanol extract (Singh et al., 2005). Activity-guided isolation of pure compounds from this plantresulted in the isolation of nineteen compounds out of which eight compounds were tested for their antileishmanial activitiesby *in vitro*assays(Misra et al., 2005). *D. gangeticum*crude extract as well as its fractions (hexane, n-butanol and aqueous) were evaluated againstexperimental visceral leishmaniasis. The butanol fraction had moderate antileishmanial activity against *L. Donovani* infectionin hamsters whereas crude ethanolic, hexane and aqueous fractions wereshowed insignificant inhibition of parasite multiplication. Among all the extracts n-butanol fractionhave the highest efficacywith significant (P < 0.001) non-specific resistance to peritoneal macrophages against *Leishmania* infection whereas methanolic, hexane and aqueous fractions indicated no activity (Nasib et al., 2005).

**CNS activity**

The aqueous extract of *D. gangeticum*showed noanalgesic activity in the hot plate method, but it showedsevere anti-writhing activity in the acetic acid-induced abdominal writhing assay (Jabbar et al., 2001). The effects of this extract on locomotion were compared with some standard CNS drugs.Total alkaloids of this species have also shown CNS activity.Alkaloid Fraction (AF) at 25 or 50 mg/kg, p.o. was used to evaluate antianxiety, anticonvulsant, antidepressant, locomotorand hypnotic activities with well recognized models.AF revealedsubstantial antianxiety activity as compare to control using elevated plus maze model but the activity was not comparable to the standard drug, diazepam(2 mg/kg, p.o.).AF was found to be devoid of hypnotic activity as it could not potentiateduration of sleep in mice treated with thiopentone sodium. AF of *D. gangeticum* roots exerts mild CNS depressionwithout causing sedation and possesses strong antidepressant activity (Mahajan et al., 2017).

**Antiamnesic (nootropic) activity**:

Aqueous extract of *D. gangeticum* (50, 100 and 200 mg/kg) showed potent anti-amnesic effects in mice against scopolamine (0.4 mg/kg, i.p.) induced interoceptive behavioral models. The study was compared with Piracetam (200 mg/kg, i.p.), standard nootropic agent (Joshi and Parley, 2006). Pretreatment with aqueous extract of *D. gangeticum* (100, 200 mg/kg, p.o.) for seven successive days, reversed scopolamine induced amnesia in mice. Study revealed that the plant increased mice brain acetylcholine content and decreased acetyl cholinesterase activity in a similar fashion to the standard cerebro-protective drug piracetam. Hence, aqueous extract of *D. gangeticum* can be used to delay the onset and reduce the severity of the symptoms of dementia and Alzheimer’s disease (Hanumanthachar and Milind, 2010).

To screen antiamnesic activity of *D. gangeticum* powder, extraction were done using solvents in increasing order of polarity viz., n-hexane, chloroform, methanol and water. For evaluation of amnesiaelevated plus maze (EPM) were performedand statistically compared with the standard memory enhancing drug, piracetam.A standardized procedure was adopted to prepare alkaloidal fraction from *D. gangeticum* roots, which was also evaluated for antiamnesic activity at the doses of 25 or 50 mg/kg, p.o.The antiamnesic activity shown by the chloroform extract and alkaloidal fraction of the plant was statistically equivalent to the standard drug. It is concluded that alkaloids are responsible for antiamnesic activity of *D. gangeticum* roots (Mahajan et al., 2015).

**Wound Healing**

The majority of Indian medicinal plants have large number of active compounds which make them suitable to be used as drug with wound healing properties either in traditional medicines such as Ayurveda or in morden medicines. Jain et al. (2006) investigated the wound healing potential of the aqueous extract in rat model with different kinds of wounds. In comparision to control group the DG extract mixed ointment had better efficacy in term of wound clousure time, tensile strength, contracting and regenerating ability, which were comparable to standad drug.

**Sun Protection and Skin Treatment**

The sunscreen efficacy is represented in terms of SPF (sun protection factor) value. The leaf extract of *D.gangeticum*had SPF value of 7.276, thereforeit was reported to block UV B by 83%-88%. It also has high vitamin C content (52.6 mg/l) which inhibits thesunburn. Due to presence of theseeffective compounds, with clinical correlation for developing *D. gangeticum* based sunscreen (Das et al., 2016).

**Hepatoprotective activity**

Hepatotoxicity can be caused as a side effect, due to high dose of paracetamol. Antihepatotoxic activity of *D. gangeticum*against paracetamol induced toxicity in Albino Wistar rats were evaluated. For determination of hepatotoxicityvariation in serum ALT, ALP, AST, LDH, GGT, protein and bilirubin were measured and with this plant extract the level were decreased.The results of the rats treated with*D. gangeticum* were compared to standard silymarin. Thus, the plant extract was effective against paracetamol induced hepatotoxicity in ananimal model (Venkatachalam and Muthukrishnan, 2013).

**Need of *in vitro* regeneration**

Large scale and unrestricted exploitation of *D. gangeticum* to meet its ever increasing demand by the Indian pharmaceutical industries coupled with limited cultivation and insufficient attempts for replenishment of its wild stock has led to marked depletion in its population and now it is listed as a rare species by the International Union for Conservation of Nature and Natural Resources (Pandey et al., 1993; Oommen et al., 2000). Thus there is urgent need for *in vitro* regeneration, propagation as well as conservation of this plant by various means. Plant tissue culture is one of the most important tool for multiplication and conservation of this important medicinal herb. Ahuja et al., (2008) reported effect of range of different cytokinin from seedling germinated nodal explant and 0.5 mg/l BA concentration was found optimum for regeneration.Efficient protocol for direct shoot regeneration of *D. gangeticum* from cotyledonary node explants on full and half-strength Murashige and Skoog (MS) and Gamborg’s (B5) media supplemented with BA, kinetin (KIN) and TDZ were reported. Out of all the cytokinins, 4.44 µM BA was found optimum (Srivastava et al., 2013). Comparative evaluation of multiplication from seed and field derived nodal explants along with parameters like season of explant collection, type and strength of culture media and type of explant used were reported by Srivastava et al. (2014). In the same study, extraction, isolation and characterization of bioactive compounds were also reported. Synergistic effect of BA (8.90 μM)and NAA (2.68 μM)for mass multiplication of seedling derived nodal explant and leaf derived calli were reported with regeneration efficacy of 29.1 and 26 shoots/culture respectively (Srivastava et al., 2015). Regeneration and mass multiplication protocol through axillary bud multiplication using nodal explant with 2 passage cycles to achieved upto 33 shoots (Puhan and Rath, 2012). Efforts on propagation of this plant by seed, stem cuttings, node and cotyledonary node explantshave been reported (Vishwakarma et al., 1999; 2003; Behera &Thirunavoukkarasu, 2006; Vishwakarma et al., 2009).High frequency of multiple shoot induction approximately 100/culture in 0.5 mg/L BAP supplemented media was reportedand genistein and daidzeincontent concentration was also evaluated in *D. gangeticum*. The difference in content of Genistein and Daidzein due to prsenece of different concentrations of BAP. Maximum Genistein 6.273 µg/g DW and Daidzein 8.224 µg/g DW content was found at 0.5 and 0. 52 mg/lit BAP respectively in stem derived from shoot biomass (Patil et al., 2016).The optimizationof the maximum callus production of*D. ganageticum* were done using response surface methodology (RSM) with different combination of growth hormones (IAA, IBA, BAP, and Kinetin). Models were developed with the selected parameters using Central composite design (CCD). The regression analysis (R2) of RSM exhibited 97%. By use of statistical modeling improved yield of callus was achieved. Comparative analysis of antioxidant activities of the intact plant compared with callus by superoxide scavenging, Hydroxy radical scavenging activity, Lipid peroxide assay, Nitric oxide radical inhibition activity (Kumar et al., 2014). From immature leaf explants on MS medium supplemented with 2,4-D 4.0 mg/l in combination with 6-benzylaminopurine (BA; 0.8 mg/l). For callus regeneration, various concentrations of BA (1.0–5.0 mg/l) or thidiazuron (TDZ; 1.0–5.0 mg l−1) alone or in combination with indole-3-acetic acid (IAA; 0.2–1.0 mg l−1) were used. Highest response of shoot regeneration was observed on MS medium fortified with TDZ (4.0 mg l−1) and IAA (0.5 mg l−1) combination. Here, 100% cultures responded with an average number of 22.3 shoots per gram calli. MS medium fortified with IBA was found optimum for rooting. (Cheruvathur et al., 2013)

**Synthesis of nanoparticle and their applications**

The leaf extract of DG was used for synthesis of silver nanoparticles, that were cost-effective, novel, safe, reliable and follow ”green” chemistry to produce environment-friendly condition. The crystalline nature of these particles were evaluavated by using XRD & EDX studies whereas their morphology were characterized using UV-vis, TEM, FTIR analysis and FESEM. The FTIR studies demonstarated these particles were of flavanoidal nature, that adsorbed on metal surface by interaction with carbonyl groups. The DG leaf extract act as reducing & capping agents. The method adapted for this synthesis was done at reduced-time at room temperature without any complexity accomplished. The method was used for large scale production of silver nanoparticles (Ghosh et al., 2019).

Copper oxide nanoparticles (CuO NPs) were synthesized with *D. gangeticum*(DG) root extracts and its biological activity were explored. Synthesis of these particles were done by reduction process, then purified, dried. Confirmation of these nanoparticles through UV visible spectroscopy and characterization were done through FTIR, SEM and TGA. Biologically synthesized CuO NPs were less toxic and have substantial antioxidant activity, thus these were safer for biomedical applications (Guin et al., 2015). Comparative analysis of titanium dioxide nanocrystals by both chemical as well as biological method and Titanium tetra isopropoxide utilized as precursor. In this study, DG aqueous root extract was used for biological method. Characterization of these nanocrystals were done through UV-Vis, XRD, FTIR, Zeta potential, antioxidant and antimicrobial evaluation.These TiO2nanocrystals synthesized from biological route were less toxic and having more antioxidant and antimicrobial activity (Banu et al., 2014).Silver nanoparticle (AgNP) were synthesized using silver nitrate and aqueous root extract ofDG*.* These particles were further characterize through UV-Vis*,* FTIR, XRD, TGA, SEM. These AgNPs particles have less cytotoxicity against LLC-PK1 cells and shown more antimicrobial as well as antioxidant activity as compare to DG extract and precursor silver nitrate (Vishnu et al., 2014). Comparative analysis of chemical (hydrazine hydrate) and green (aqueous DG root extract) AgNPsfor biological activity and toxicity were evaluated. Characterization were done through UV Vis, XRD, FTIR, TGA, SEM and Zeta analyzer. For biological activity evaluation was done through free radical scavenging activity (DPPH, SOD, total phenol), antimicrobial determination through disc diffusion method and cytotoxicity by LDH assay. These characterize AgNPs shown less cytotoxicity and more antimicrobial and free radical activities (Vishnu et al., 2015). Eco-friendly Ni nanoparticles were synthesized using NiCl2 precursorand aqueous root extract of DG. These particles were characterize using UV Vis, XRD, FTIR, TGA, SEM techniques. These particles were showing less cytotoxicity and more antioxidant as well antibacterial potential. Iron oxide nanoparticles (FeO NPs) were synthesized using aqueous root extract of DG. Characterization were done through UV Vis, XRD, FTIR, TGA, SEM. Biological evaluation of these particles were done through free radical scavenging activity, antimicrobial and cytotoxicity through LDH assay. All these biological activities were significant in these particles as well as safer than chemically synthesized particles (Santoshiet al., 2015).

The biological activity and toxicology of chemical and green routes synthesized nickel nanoparticles (NiNP) were compared. NiNP chemical synthesis was mediated by PEG and hydrazine hydrate as stabilizing and reducing agent, respectively, whereas *D. gangeticum* aqueous root extract was used to synthesize NiNP without any stabilizing and reducing agent. Nickel nanoparticles synthesized by both methods were characterized (UV-Vis, XRD, FTIR, zeta potential and vibrating sample magnetometer) and compared. The nature of the NP synthesized by both methods having no significant difference. Although, green synthesized NiNP exhibited reduced size and better monodispersity compared to chemical synthesized one. On comparative evaluation of antioxidant, antibacterial activities and toxicity under*in vivo* and *in vitro* suggests green route synthezise NP were nontoxic and reliable (Sudhasree et al., 2014).

Synthesis of Ni nanoparticles using NiCl2 as precursor and aqueous extract of *D. gangeticum* root as the reducing agent. Characterization of NP for its average size, morphology, functional moieties and thermal stability by UV-Vis, XRD, SEM, FTIR and TGA respectively. Cytotoxicity was evaluated with LDH assay against LLC PK1 cell lines.The biological activity as well as toxicity of these NP was evaluated and found to possess the good antioxidant and reduction potential with significant antibacterial activity (Sudhasree et al., 2015).

Eco-friendly and green synthesis of Titanium dioxide nanocrystals using Titanium tetraisopropoxide as precursor and *D. gangeticum* (DG) root extract which avoid adverse effects of chemical by products in biomedical applications. Characterization of synthesized nanocrystals were done using UV–vis, XRD, SEM, FTIR and TGA. Antioxidant assay, antimicrobial test and reducing potential assay were performed to evaluate their biological behavior. TiO2 nano crystals possessed higher DPPH radical scavenging activity than that of their precursor and had better antimicrobial activity gainst Gram positive bacteria. Cytotoxicity study was done using LDH assay against the LLC-PK1 cellline and TiO2 nanocrystals were found to be safe for further biological applications (Jamuna et al., 2014).

Comparative analysis of silver nanoparticles (AgNPs)synthesizedthrough chemical and green route (aqueous extract of *D. gangeticum* root).Nephro-toxicity of these AgNPs were evaluated in rat proximal epithelial cell lines and renal mitochondria.AgNPs (100 mg/kg) were administered orally to the wistar rats. The renal architecture of both AgNPs and its exposure towards renal epithelial cells and renal mitochondria also confirm the toxic similarities between the AgNPs produced from two routes (Vasanth and Kurian, 2017).

For synthesis of silver nano particles *D. gangeticum*aqueous leaf extract was used. Stable nanoparticles were synthesized with silver nitrate and aqueous leaf extract combination. These particles were characterized with UV-Vis, SEM, TEM, FTIR, EDAX. Further, these biologically synthesized nanoparticles were found to be highly toxic against pathogenic bacteria Escherichia coli, thus implying significance of the present study in production of biomedical products. (Thirunavoukkarasu et al., 2013)

To evaluate the renal toxicity of various aqueous root extracts of *D. gangeticum* on isolated mitochondria, cells and wistar rattitanium dioxide nanoparticles (TiNPs) were synthesixed from green and chemical route. TiNPs were synthesized with aqueous roots of this plant and titanium tetraisopropoxide asprecursor. TiNPs were characterized using UV–vis, XRD and evaluated its renal toxic impact in different experimental models viz., Wistar rats (100 mg/kg b.wt.; oral), LLC-PK1 cells (100 mg/mL) and isolated renal mitochondria (0.25, 0.5 and 1 mg/mL). these synthesized nanoparticles represented less nephrotoxicity, determined by elevated serum renal markers like urea (62%), creatinine (35%), aspartate aminotransferase (61%) and alanine transaminase (37%) and the result was in agreement with cellular toxicity calaculated through other standard tests viz; MTT assay and LDH activity. The study concluded with biochemical findings in renal tissue and epithelial cell (LLC-PK1)supported by histopathology examination and isolated mitochondrial activity exhibitedminor toxicity with TiNPs synthesized through green route (TiNP DG) than TiNP Chem (Ansari and Kurian, 2017).

**Genetic Diversity Analysis**

Usually *D. gangeticum* is utilized in Ayurveda formulations for the treatment of different neurological as well as other disorders. Mohan et al., (2021) reported that the pharmaco-chemical features like organoleptic, DNA sequence, physicochemical, proximate, phytochemical, UV, and FTIR profling, ADME-PK properties, and soil chemistry of *D. gangeticum* revealed its unique and diagnostic peculiarities. DNA barcoding demonstrateed that the sequence was 99.77% similar to *D. gangeticum* (KP094638) having 100% query coverage. The soil analysis showed the presence of moderately high content of NPK and suffcient amount of all essential macro- and micronutrients (S, Fe, Mn, Cu, Zn, and B). The phytochemical profling revealed that the ethanolic extract of the aerial part contained glycoside, amino acid, phenols, alkaloids, favonoids, and coumarins, while the ethanolic root extract of the plant revealed the presence of glycoside, amino acid, phenols, alkaloids, favonoids, coumarins, and triterpenoids. FTIR results indicated that the plant extracts are mainly rich in phenolic derivatives.

Pharmacognostic evaluation including ash values, extractive values, powder characteristic, examination of morphological and microscopical characters, foreign matter, bitterness value and HPTLC profile was done to use these as diagnostic indices for the identification/validation of the raw material and standardization of its formulations in fixing quality control parameters (Kawale et al., 2012).

Irshad et al. (2009) analyzed and compared authentic samples of *Desmodium* species viz., *D. gangeticum* (L.) DC., *D. velutinum* (Willd.) DC. and *D. triflorum* (L.) DC with commercial samples of different origin. For genomic analysis using RAPD marker, out of twenty primers used,eleven gave 223 RAPD fragments. RAPD profiles of three species showed very low similarityindex (0.21–0.39), whereas market samples showed high similarity of 0.82–0.89 withauthenticated *D. gangeticum*.

Genetic diversity analysis among accessions of *D. gangeticum*with SSR and ITS regions intended to carry out the relationships among different available accessions and study biodiversity conservation. This study were used for molecular characterization and population conservationalong with authentication of *D. gangeticum*(Ahmad et al., 2016).

Genetic relationships among accessions of four species of *Desmodium* and allied genera (*Dendrolobiumtriangulare*, *D.gangeticum*, *D.heterocarpon* and *Tadehagi triquetrum*) with RAPD markers were evaluated.Average Jaccard’s similarity coefficients (JSCs) were found in*D. heterocarpon* and *T. triquetrum* and moderate to high levels were found in *D. triangulare* (P% = 52.9 and JSC = 0.61) and *D. gangeticum*(P% = 34.5 and JSC = 0.49) (Heider et al., 2009).

Identification of medicinal plants utilized in Ayurvedic drug Dasamulawere done with PCR-RFLP.ITS regionwereamplified withPCR for six out of ten plants of Dasamulaincluding *D. gangeticum*.RFLP was carried out by restriction digestion of amplified ITS region using BamHI, HindIII, MspI, MboI, EcoRI, EcoRV, HinfI, AluI. RFLP showed species-specific variation in the number and size of digested DNA fragments. MspI and EcoRV proved to be the best enzymes as it could generate unique pattern for all the six plants. Variations in the ITS region among the species can be used for conclusive identification of these plant species (Biswas and Biswas, 2013).

The *in vitro* regenerated plants were successfully transferred to the field and total DNA was extracted from the leaves of the acclimatized plants of *D. gangeticum*. RAPDanalysis were done with 13 arbitrary decanucleotide primers, which revealed the genetic homogeneity in all the ten plants regenerated from callus with parental plant. The resultsproposing that shoot regeneration from callus could be used for the true-to-type multiplication of *D. gangeticum* plant. (Cheruvathur et al., 2013)

Comparative molecular characterization of *D. gangeticum* DC. and *D. laxiflorum* DC. through RAPD analysis was done. In this study with the help of 10 primers both species DNA were amplified.The binary scoring of these primers indicated 60-65% of analogous characters between species of the same genus. Thus, this study reported development of DNA markers of both the species for their authentication as well as for the categorization of *Desmodium* genus and *D. laxiflorum* can be used as an alternative for *D. gangeticum*and vice versa (Singh et al., 2016).

Thirty *D. gangeticum* accessions were assessed for genetic variability, heritability and genetic advance for four yield attributing traits collected from differentparts of India. The analysis of variance for mean squares for different characters was foundto be highly significant for most of the characters under study except for lamina width,petiole length and internode length. This study concluded, that the analysis of different components of variability studies such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (broad sense) and expected genetic advance over mean showed sufficient amount of variability in the germplasm lines of *D. gangeticum*. According to this study, minor influence of environment on the expression of these traits and hence, selection for yield could prove effective and improvement may be possible through recurrent selection programme(Nandanwar et al., 2017).

**CONCLUSION / SUMMARY**

Plants have been an invaluable source of medicinal compounds since ancienttimes, and different plant parts are important ingredients in traditional medicinesystems. Even in the modern system of medicine, a number of biologically activecompounds and formulations are based on plant products. In the wake of hugedemand of herbal drugs world over, medicinal plants are being harvested by thepharmaceutical industries in large quantities, mostly by illegal means, well over theregeneration capacity of the natural populations. As a result of overexploitationand lack of systematic cultivation, many plant species are now listed as threatenedor endangered. *D. gangeticum* is one such endangered medicinal plantthat is widely used in the traditional system of medicine. Due to its medicinalimportance, endangered status, and huge commercial demand for its biomass, *D. gangeticum* has been selected as a target species to review it’s all medicinal aspects.

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