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Review Article

PHYTOCHEMICALS AND PHARMACEUTICAL POTENTIAL OF *DELONIX REGIA* (BOJER EX HOOK) RAF A REVIEW

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ABSTRACT

Traditionally *Delonix regia* (Boj.) Raf. has been used in various ailments such as chronic fever, antimicrobial, constipation, inflammation, arthritis, hemoplagia, piles, boils, pyorrhea, scorpion bite, bronchitis, asthma and dysmenorrhoea. However, there is little experimental evidence for its traditional use. In this review an attempt has been made to gather and compile the scattered traditional information along with the experimental evidence on the beneficial properties of *Delonix regia* (Boj.) Raf. The plant shows diverse therapeutic prospective such as antifungal, antibacterial, antioxidant, antiemetic, larvicidal, hepatoprotective, anti-diarrhoeal, anti-inflammatory, antimalarial, anthelmintic, antiarthritic, wound healing and anticarcinogenic potential. It possess copious phytochemicals, *viz.* saponins, alkaloids, carotene, hydrocarbons, phytotoxins, flavonoids, tannins, steroids, carotenoids, galactomannon, lupeol, β-sitosterol, terpenoids, glycosides and carbohydrates, in leaves, flowers, bark and roots. Though *Delonix regia* (Boj.) Raf. has been widely used in traditional medicines in various ailments, yet studies need to be conducted to explore the potential phyto-constituents of this plant for the prevention of various other diseases and to further unravel, characterize, patent and commercialize the protective components from different parts of this plant for the benefit of humans.

Keywords: *Delonix regia*, Phytochemicals, Antioxidants, Traditional Medicines, Pharmaceutical potential.

INTRODUCTION

The generic name, 'Delonix', is derived from Greek words-delos (visible), and onyx (claw), due to the conspicuously clawed petals. The specific name, 'regia', is from the Latin word 'regis' (royal, regal, magnificent). It is called as chura, radha (in Bengali), royal, flamboyant, poinciana (in French), gul mohr, shima, sunkesula (in Hindi), mayirkonrai, panjadi (in Tamil), flamboyant flame tree, gold mohur, flame tree, peacock flower, gul mohr and royal poinciana (in English).

The plant Delonix regia belongs to family Fabaceae, sub-family Caesalpinioideae. It is a tree (10-15 m high, girth of upto 2 m) with many branches and umbrella shaped crown. It has biparinnate, alternate, light green, feathery leaves, 10-25 pairs of pinnae, each having 12-40 pairs of small leaflets. Near the end of the twig are present 15-30 cm long corymbs, which are borne laterally, each having loosely arranged slightly fragrant orange-red flowers, which literally cover the tree from May to June. Petals (5-6.5 cm, 2-3 cm wide) are broadly spoon shaped. The tree is native to Madagascar and has been widely planted for the last 150 years as a garden and avenue tree in both dry and moist regions of tropical India. It is distributed in the countries like Brazil, Burkina Faso, Cyprus, Egypt, Eritrea, Ethiopia, India, Jamaica, Kenya, Mexico, Nigeria, Singapore, South Africa, Sri Lanka, Sudan, Tanzania, Uganda and United States of America. Light is required for its growth but under shade, it grows weakly and sparsely. It grows in areas with both high and scanty rainfall. Trees are deciduous only where the dry season is long and pronounced [1, 2].

There is ample literature that emphasizes the traditional use of this plant in countries such as India, Bangladesh, Zambia and Cameroon. Though some workers have also explored its bioactivities; yet there is meager experimental evidence for its traditional use. The phytochemicals in this plant possess diverse biological activities including protection against various pathogens. The enormous significance of the phyto-constituents in *Delonix regia* cannot be ignored and comprehensive insight into their function in various fields and the mechanisms operating behind them is essential. The present review focuses on the beneficial bioactivities of *Delonix regia* such as antifungal, antibacterial, antioxidant, antiemetic, larvicidal, hepatoprotective, anti-diarrhoeal, anti-inflammatory, antimalarial, anthelmintic, antiarthritic, wound healing and anticarcinogenic potential, along with their experimental evidence and mode of action.

Traditional use

The Shaiji community in Southwestern Bangladesh used the flowers of *Delonix regia* for curing chronic fever [3]. 250 g of flower were boiled in 1.5 l of water (1/2 h) and 2 ml of the boiled mixture was taken morning and evening successively for some days. During the study on the traditional medicines and herbal plants of Nigeria the flowers of *Delonix regia* possessed antibacterial activity [4]. The medicinal plants were used to cure wounds in Darikal Gaon of Tezpur, in Assam (North-East India). 19 sp. of plants belonging to 16 families were used in diseases and ailments; *Delonix regia* being one of them. The leaves of *Delonix regia* were crushed and applied on wounds [5]. The leaves of *Delonix regia* (Boj. Ex. Hook) Raf. have been used to treat constipation, inflammation, arthritis and hemiplagia; in Koothanoallur and Marakkadai, Thiruvarur district of Tamil Nadu, India [6].

The leaves and fruits were used in piles and helminthiasis in the areas of Pirojpur district, Bangladesh [7]. The investigation conducted on Sylhet district, Bangladesh revealed the use of leaves and fruits in piles and boils. Fruits eaten for piles and crushed leaves and fruits applied to boils [8]. The bark used as traditional fever remedy in Zambia [9]. *Delonix regia* has been used by the tribal belts in Birbhum district, West Bengal, India [10]. *Delonix regia*, an ethnomedicinal plant possessed antibacterial activity [11]. The different parts of *Delonix regia* were used by the tribes of Chhatarpur district, Madhya Pradesh, India [12] for the treatment of diseases. The seeds were used in pyorrhea; the roasted and crushed leaves were wrapped in a cloth and inhaled just after scorpion bite; infusion of flowers was used in bronchitis, asthma and malarial fever. The leaves were also used in rheumatism and as purgatives. The plant has antirheumatic and sparmogenic potential. The bark showed antiperiodic, febrifuge potential; aqueous and ethanol extract of flowers were used against round worms [13].

Delonix regia has been reported to be used by the people of Patan district, North Gujarat (India) in traditional medicines [14]. It is also present in the list of traditional plants used by people of Bangangte region, Western Cameroon in the treatment of peptic ulcer [15]. The usage of *Delonix regia* in traditional medicines was confirmed in a survey of Chittoor district in Andhra Pradesh, India. The people of Yanadi (a tribal community in Andhra Pradesh, India) used flowers of *Delonix regia* in the treatment of dysmenorrhoea [16]. The water

extracts of flowers were also used in traditional healthy beverages in several African counties. It is a part of local medicine and traditional bioproducts [17].

Experimental evidence for traditional use
Pharmaceutical potential

The floral extracts of *Delonix regia* were used by the local people of Chittoor district, Andhra Pradesh, India for treating fungal infection [18]. The zone of inhibition for ethanol extract was found to have diameter of 13 mm against *Candida albicans* in agar well diffusion assay. Tetracycline and DMSO were used as positive and negative controls, respectively. The antimicrobial evaluation by other workers is shown in table 1. The plant also possessed gastroprotective [19], antiemetic [20], larvicidal [21, 22], hepatoprotective [23, 24], anti-diarrhoeal [25, 26], anthelmintic [27], antiarthritic [28], antiulcer [29], biotermicidal [30], glucose tolerance [31], wound healing [32], anti-inflammatory [33], antimalarial [34, 35] and anticancer potential [24] as shown in table 2.

The database of antidiabetic plant sp. was made, *Delonix regia* being one of them [36]. Leaf extract of *Delonix regia* were used as antidiabetic [37]. The assessment on the wound healing medicinal plants was conducted [38]. Significant anti-inflammatory and analgesic (pain killing) activity was shown by the flavonoid-rich fraction of flowers of the plant in the studies conducted at the Indian Veterinary Research Institute (IVRI), using various experimental models [39]. The plant decoction (AM-1), formulated from *Jatropha curcas*, *Gossypium hirsutum*, *Physalis angulata* and *Delonix regia* was used to treat malaria [40]. The AM-1 was found to eliminate the malarial parasites (*Plasmodium falciparum* and *Plasmodium malarie*) from the peripheral blood of patients with malaria. The flowers of the plant were also reported to be used in the formulation and evaluation of sunscreen [41].

Table 1: Pharmacological activities of different parts of the plant *Delonix regia* (Boj.) Raf

Activity	Plant part	Extract type	Dose/Conc.	Strains/Organism studied	Control	Results	Reference
Antimicrobial	Leaves, flowers and bark	Absolute ethanol, absolute methanol, absolute acetone, 80% methanol, 80% ethanol, 80% acetone and deionised water		*Pseudomonas stutzeri, Pseudomonas aeruginosa, Escherichia coli* (bacterial strains) and *Aspergillus oryzae, Aspergillus niger, Fusarium solani* (fungal strains).	Amoxicillin and flumequine (positive bacterial and fungal standards); whereas respective solvents were taken as negative standards.	80% methanol extract of leaves and flowers showed MIC of 20±0.8 and 23±1.3 mg/ml, respectively against *Pseudomonas stutzeri*.	[42]
	Flowers and seeds	Metabolite rich fractions such as flavonoids, anthraquinones and sterols	0.4 g/ml	*Aspergillus niger, Aspergillus flavus, Rhizopus bataticola* and *Fusarium auxisporum*.	Clotrimazole	Acetone extract showed 23 and 18 mm zone of inhibition against. *Aspergillus niger*.	[43]
	Leaves	Ethanol	20 g/50 ml	*Lactobacillus sp., Streptococcus mitis*, *Candida albicans* and *Aspergillus niger*.		23.25 mm and 22.62 mm diameter against *Aspergillus niger* and *Streptococcus mitis* respectively.	[44]
	Flowers	Ethanol	6.25, 12.5, 25 and 50 mg/ml	*Escherichia coli* and *Pseudomonas aeruginosa*	Streptomycin (10 mg/ml), Amphotericin (10 µg/disc)	MIC values of 50 and 25 mg/ml.	[45]
	Root bark	Methanolic	100 mg/ml and 200 mg/ml	*Esherichia coli, Pseudomonas aeruginosa, Klebseilla pnenomia* (Gram negative) and *Staphylococcus aureus*, *Staphylococcus pnenomia, Bacillus subtilis* (Gram positive)	Ampicillin (50 µg/ml)	16 mm and 21 mm zone of inhibition against *Staphylococcus aureus.*	[46]
	Stem Bark	Petroleum Ether, CCl_4 and dichloromethane	15 µg mm^{-2}	*Esherichia coli, Bacillus subtilis, B. cereus, B. megaterium, Staphylococcus aureus, Sarcina lutea, Pseudomonas aeruginosa, Salmonella typhi*, *Salmonella paratypi, Shigella boydii, S. dysenteriae, Vibro minicus V. parahemolyticus*; *Candida albicans, Aspergillus niger, Sacharomyces cerevisiae*	Kanamycin (1.06 µg mm^{-2})	9-14 mm, 11-13 mm and 9-20 mm, zone of inhibition.	[47]
	Stem bark	Methanolic	100, 250, 500, 1000,	*Pectobactereium carotovorum* subsp.	Tetracycline	11, 10, 6, 13, 15 mm diameter.	[48]

			2000 and 4000 µg/ml	*Wasabiae*, *Pectobacterium carotovorum* subsp. *Carotovorum*, *Pectobactereium carotovorum* subsp. *Atrosepticum*, *Dickeya dianthicola*, *Dickeya chrysanthemi*			
	Leaves and flowers	Methanol	20 mg/ml in 25% DMSO	*Staphylococcus aureus*, *Salmonella typhi*, *Candida albicans* and *Crytococcus neoformans*.	Streptomycin and fluconazol	1.3, 1.1, 3.9 against *Staphylococcus aureus*; 1.5, 1.4, 3.6 against *Salmonella typhi*, respectively. 1.6, 0.8, 3.9 against *Candida albicans*; 1.6, 1.2, 4.1 against *Crytococcus neoformans* by DLME, DFME and fluconazole.	[49]
	Leaves and seeds	petroleum ether, chloroform and ethanol	20 ml	*Bacillus subtilis*, *Escherichia coli*, *Enterobacter aerogenes*, *Micrococcus luteus*, *Pseudomonas aeruginosa*	Chloramphenicol	Petroleum ether extract of leaves showed maximum zone of inhibition (24 mm diameter), whereas chloroform extract of seeds showed 35 mm against *Escherichia coli*; followed by 34 mm against *Pseudomonas aeruginosa*.	[50]
	Leaves	Methanol	1.6, 3.125, 6.25, 12.5, 25 mg/ml	*Escherichia coli*, *Klebsiella pneumonia, Pseudomonas aeruginosa*, *Bacillus subtilis*, *Staphylococcus aureus* and *Streptococcus epidermidis*,	Streptomycin	MIC value of 100, 50, 100, 25, 50 and 100 mg/ml.	[51]
	Flowers	70% ethanol	100 mg/ml	*Staphylococcus aureus*, *Salmonella typhi*, *Salmonella typhimurium*, *Salmonella paratyphi*, *Escherichia coli*, *Shigella dysenteriae* and *Pseudomonas aeruginosa*; five filamentous fungi, *Aspergillus niger*, *Alternaria alternata*, *Fusarium chlamydosporium*, *Rhizoctonia bataticola*, *Trichoderma viridae* and a yeast, *Candida albicans*	Chloramphenicol	Maximum zone of inhibition against *Shigella dysenteriae* (16-20 mm). 25-30 mm against *Alternaria alternate* and *Fusarium chlamydosporium* (fungal strains).	[52]
Gastroprotective	Flowers	70% ethanolic	100, 250 and 500 mg/kg. p. o	Wister albino rats	Lansoprazole	Antiulcer activity in a dose dependent manner.	[19]
Antiemetic	Leaves	Methanolic	150 mg/kg body weight	Male chicks	Chlorpromazine (150 mg/kg body weight)	96.74% antiemetic activity.	[20]
Larvicidal	Flowers	Methanol	0.25%, 1%, 4%	3rd instar larvae of Teak defoliar *Hyblaea puera* Cramer	Respective solvents and tween 20 used as controls.	84% and 100% mortality at 1% and 4%.	[21]
	Flowers	Acetone	0.5, 1.0 and 2.0 mg/ml	3rd instar larvae of *Aedes aegypti*	DMSO	LC_{50} and LC_{95} were found to be 1.07 and	[22]

						3.02 mg/ml, respectively	
Glucose tolerance	Leaves	Methanolic	400 mg/kg	Hyperglycemic mice	Glibenclamide	42.46% activity	[31]
Wound healing	Flowers	Aqueous and ethanolic	5% and 10%	Albino rats albino rats by using incision and excision wound models	5% w/w povidine ointment (excision wound model) and normal saline (incision wound model)	Increase in the wound breaking strength, percentage of wound contraction, increased hydroxyproline content and decreased epithelization period.	[32]
Hepatoprotective	Aerial parts	Methanol	400 mg/kg	Wistar albino rats with hepatotoxicity induced by CCl_4	Silymarin (50 mg/kg)	Significant reduction in serum enzymes AST (aspartate aminotransferase), ALT (alanine aminotransferase), ALP (alkaline phosphatase), ALB (albumin), ALP (total protein), DBIL (direct bilirubin) and TBIL (total bilirubin).	[23]
	Leaves	Alcoholic	50, 100 and 200 mg/kg	Sixty male adult albino rats (180-200 g)	Carbon tetrachloride (CCl_4) in sunflower oil, 1 ml/kg	Dose dependent reduction in serum aspartate aminotransferase, alanine aminotransferase and alkaline phosphatase as well as total and direct bilirubin.	[24]
Anticancer	Leaves	Alcoholic	1 mg/ml	HepG2 cell line (SRB assay)	Doxorubicin (Dox)	IC_{50} values for cells treated with extract and Dox were 20.4 and 4.15 lg/ml, respectively following 48 h.	[24]
Anti-diarrhoeal	Flowers	Ethanolic	100, 250, 500 mg/kg	*In-vivo* anti-diarrhoeal activity in experimental induced diarrhea in Wistar albino rats	Loperamide (1 mg/kg)	Dose dependent anti-diarrhoeal effect.	[25]
Anti-inflammatory	Leaves	Ethanol	100, 200 and 400 mg/kg	Carrageenan-induced rat paw edema	Indomethacin (10 mg/kg)	48.1% reduction in carrageenan-induced rat paw edema at 400 mg/kg after 3 h.	[33]
Anthelmintic	Flowers and leaves	Methanol and water	25, 50, 100 mg/ml	*Pheritima posthuma* (Indian earthworm	Piperazine citrate (10 mg/ml)	Time of paralysis and death was found to be 11 and 17 minutes; 12 and 18 minutes by methanol and aqueous extracts, respectively. Crude aqueous extract of the leaves exhibited paralysis of 12 minutes and time of death of 18 minutes.	[27]
Antimalarial	Leaf, fruit peel, bark, seeds and	Hexane, chloroform, methanol, ethanol and water	72.8 mg/kg	*In-vivo* test on mice infected by *Plasmodium berghei*.	DMSO (negative control)	Bark and fruit peel extract was found to be highly effective producing inhibition of 122% and 117%	[34]

	flowers					respectively. 87.45%, 75.99% and 78.43% inhibition was seen in case of extracts of seeds, flowers and leaves.	
	Seeds	Ethanolic and aqueous extracts	0.02, 0.05, 0.1 0.2, 0.5, 1, 2, 5, 10, 15, 20 mg/ml	2nd instar larvae of *Anopheles gambiae* (L.).	50 ml of distilled water+2% ethanol	LC_{50} for ethanolic and aqueous extracts was found to be 1.40 mg/ml and 11.50 mg/ml, respectively.	[35]
Antiarthritic	Flowers	Alcoholic	200 mg/kg and 400 mg/kg	Adult female Wistar rats	Diclofenac (5 mg/kg)	Significant reduction in the paw edema volume	[28]
Antiulcer	Flowers	Ethanolic	100, 200 and 400 mg/kg	ethanol induced ulcer model in experimental rats	8 mg/kg of lansoprazole	% of protection was found to be 34.73%, 63.90% and 76.40% at 100, 200 and 400 mg/kg.	[29]
Biotermicidal	Bark extract	Chloroform, methanol, ethyl acetate, n-hexane and water	0.5,1 and 5%	Termite workers (*Anacanthotermes* sp. F. Hodotermitidae)	The solvents for extraction of the extracts served as controls	80% mortality rate by chloroform extract at 5%, followed by 65% at 1% concentration after 48 h.	[30]
Formulation and evaluation of sunscreen cream	Flowers	Hexane, ethyl acetate and ethanol	200 µg/ml	Presence/absence of microbes and rabbit skin test		Spectrophotometry and UV 2000S ultraviolet Transmittance Analyzer showed SPF of 3.99 and 3.92, respectively.	[41]
Insecticidal	Leaves	Methanol	2.5, 5, 7.5 and 10 mg/ml for larvae of *Artemia salina;* 2, 4, 6, 8 and 10 mg/ml for adult of *Sitophilus oryzae*	Larvae of *Artemia salina*, adult of *Sitophilus oryzae*	Streptomycin	70%, 80%, 90% and 100% mortality against the larvae of *Artemia salina* after 24 h; whereas 20%, 35%, 30%, 35% and 100% mortality against the adult of *Sitophilus oryzae*.	[51]
	Leaves	Acetone	25%, 50%, 75% and 100% dose	Eggs of pulse beetle, *Callosobruchus chinensis*		19.64%, 31.58%, 53.84% and 65.79% egg mortality. .	[53]

Table 2: Antioxidant activities of different parts of *Delonix regia* (Boj.) Raf

Plant part	Extract type	Assay	Result	Reference
Leaves, flowers and bark	80% methanol, 80% Ethanol, deionized water, absolute methanol, absolute ethanol, 80% acetone, absolute acetone.	Total phenol and total flavonoid content	80% methanol extract of leaves showed 3.63 g GAE/100 g DW of total phenolic content and 1.19 g CE/100 g DW of total flavonoid content	[42]
		DPPH assay	IC_{50} of 8.89 µg/ml in DPPH scavenging activity.	
		Antioxidant Activity of Extracts in Linoleic Acid Peroxidation System	Inhibition of peroxidation in leaves (85.54%) and flowers (79.69%) extracts (80% methanol) was higher than that of bark extract (52.3%),	
Flowers	Alcoholic extract (AE)	Total phenol and total flavonoid content	34.44 mg/g and 30.45 mg/g of total phenolic and flavonoid content respectively	[54]
Flowers	Methanol crude extract	Total phenol content	Total phenolic content was found to be 169.67 mg GAE/g dw.	[55]
Leaves	95% ethanol	Total phenol, total flavonoid content and DPPH assay	Total flavonoid and total phenolic content was found to be 0.20 mg/100g GE, and 16.00 mg/100 g of GAE. In DPPH assay, the leaves were found to show 10.73 mg/100g of ascorbic acid equivalent antioxidant capacity (AEAC).	[56]
Leaf, fruit and stem	Condensed tannins	DPPH and FRAP assay	In DPPH and FRAP assay, the IC_{50} was found to be 90±2, 115±3, 161±9 µg/ml and 5.42±0.09, 3.39±0.08, 3.80±0.15	[57]

bark			mM AAE/g, by stem bark, fruit and leaf extract, respectively	
Floral Petal	Hexane, EtOAc, Acetone, methanol, Water and crude pigment extracts	Anthocyanin, total phenolics and total carotenoid content NO assay	The anthocyanin, total phenolics and total carotenoid content was found to be 5.8 µg/g, 33.5 mg/g and 694 µg/g respectively. At 50 ppm, the hexane extract and the crude pigment extract showed 93.9% and 93.1% NO scavenging activity respectively.	[58]
Stem bark	Methanol extract	DPPH activity	% antioxidant activity was 78.35% which was close to gallic acid (80%)	[48]
Leaves and flowers	Methanol extract	DPPH and ABTS assay	Leaves and flower extract showed IC_{50} of 35.97 and 41.19 µg/ml in DPPH assay and 22.50, 24.88 µg/ml ABTS assay, respectively	[49]

Antioxidant potential

The different parts of *Delonix regia* possess diverse antioxidant capacity. The antioxidant potential of the plant has been explored by various workers as shown in table 2.

Phytochemicals in *Delonix regia*

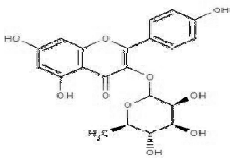
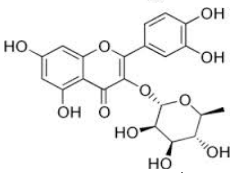
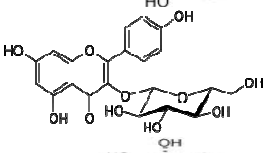
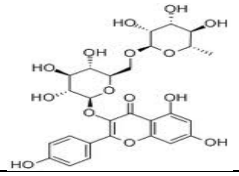
The wide pharmacological and antioxidant potential of *Delonix regia* might be due to the presence of immense phytochemicals (table 3). Bark contains β-sitosterol, saponins, alkaloids, carotene, hydrocarbons, phytotoxins and flavonoids [59], whereas flowers contain tannins, saponins, flavonoids, steroids, alkaloids, carotenoids; seeds contain saponins, and leaves have lupeol and β-sitosterol [54]. Tannins, terpenoids, alkaloids, glycosides, carbohydrates and sterols were reported to be present in the root bark of *Delonix regia* [60]. The preliminary phytochemical analysis of alcoholic extract (AE) of flowers was found to contain proteins, amino acids, cardioglycoside, alkaloids, flavonoids, tannins and phenolic compounds [54]. Carbohydrates and saponins were found in the water, chloroform and methanol extracts of seeds of *Delonix regia*, whereas in the chloroform and methanol extracts, flavonoids were also detected [61].

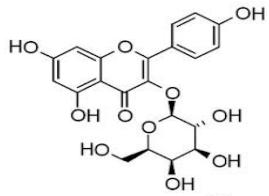
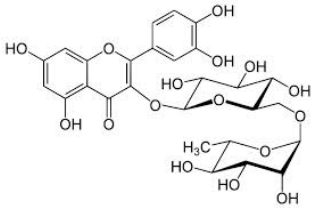
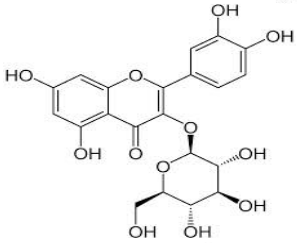
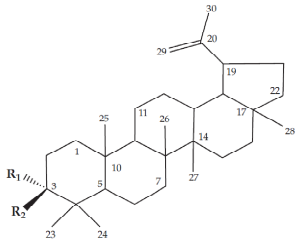
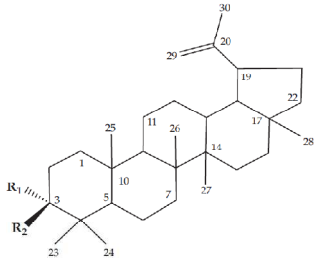
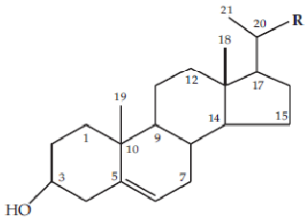
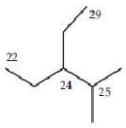
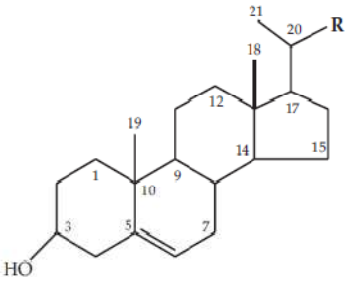
The chemical components and fatty acid content in the seeds and seed oils of *Delonix regia* was studied. *Delonix regia* was reported to contain 7% of crude fat, 45.2% of crude protein and 39.5% of carbohydrate content. Neutral, glycolipids and phospholipids with values of 80.2±0.5, 13.6±0.1, and 6.2±0.5 respectively were found. Hydrocarbons, ergost-5-en-3-ol, sitosterol and ergost-4-en-3-one were also detected [62]. The qualitative and quantitative distribution of carotenoids was studied in different parts of flowers of *Delonix regia*. Petals were found to contain 29 carotenoids *viz.* phytoene, phytofluene, β-carotene, γ-carotene, lycopene, rubixanthin, zeaxanthin, lutein etc. Sepals were found to contain 18 (phytoene, phytofluene, β-carotene, γ-carotene, lycopene, etc), whereas filaments contain 20 (phytoene, β-carotene, γ-carotene, lutein, zeaxanthin, antheraxanthin, flavoxanthin and other epoxy carotenoids) carotenoids. Anthers were reported to contain the highest concentration of carotenoids, from which 90% was zeaxanthin [63].

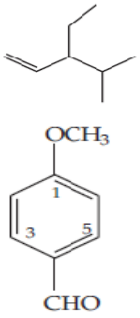
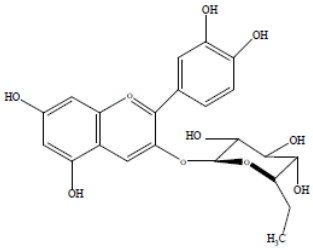
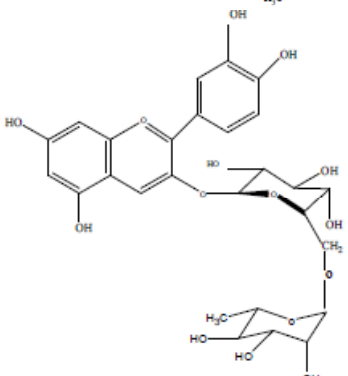
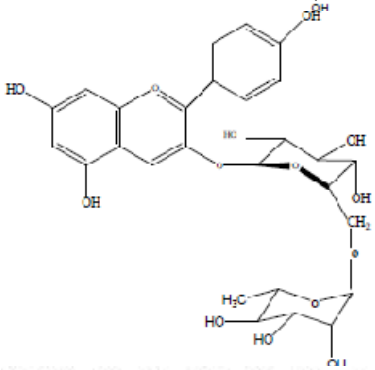
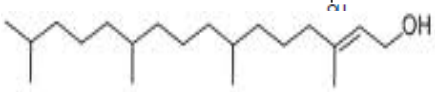
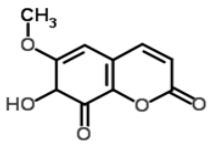
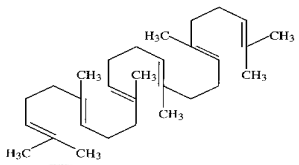
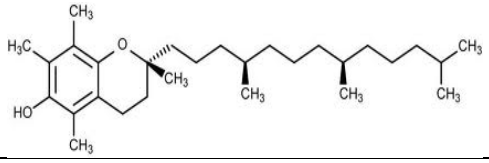
Alkaloids, flavonoids, proteins, tannins, carbohydrates, phenols, triterpenes and steroids were found to be present in *Delonix regia* flowers [45, 25, 31, 55]. Three major anthocyanins in the water extract of *Delonix regia* flowers were characterized. LC-MS was used to confirm the molecular structure. Cyanidin 3-O-rutinoside and pelargonidin 3-O-rutinoside were identified in the concentration of 10.7 and 0.9 mg/l respectively [64]. The GC-MS analysis of the leaves extract revealed the presence of benzenetriol, butyl-8-methylnonyl ester, lupeol and vitamin E as the major compounds [56].

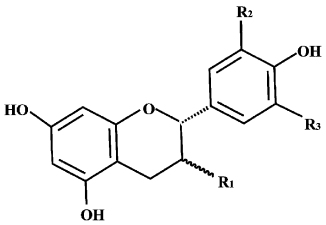
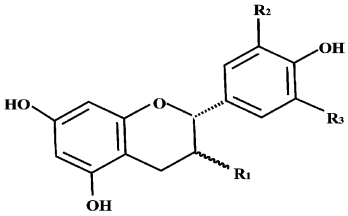
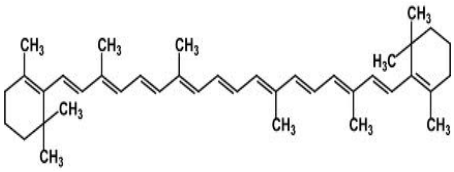
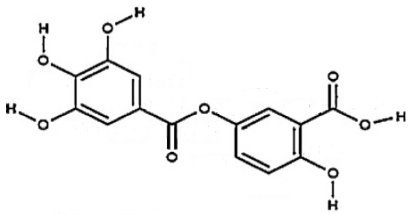
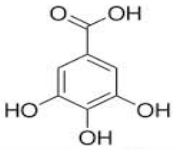
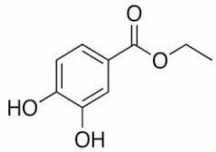
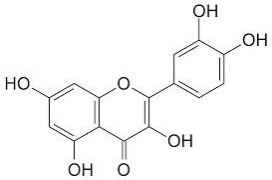
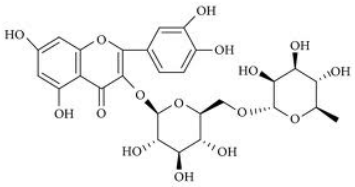
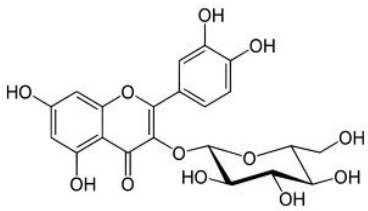
The structure of the condensed tannins isolated from leaf, fruit and stem bark of *Delonix regia* was investigated by using [13]C Nuclear Magnetic Resonance (^{13}C NMR), high performance liquid chromatography electrospray ionization mass spectrometry (HPLC-ESI-MS) coupled with thiolysis and matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-ToF MS) analysis. The condensed tannins of leaf, fruit and stem bark were reported to be tyrosinase inhibitors with IC_{50} values of 38±1, 73±2, and 54±1.5 µg/ml, respectively [65].

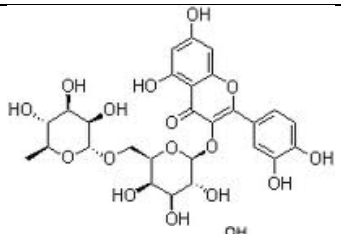
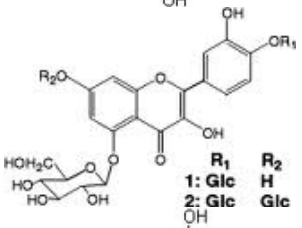
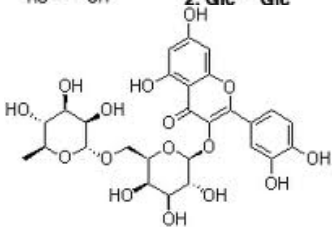
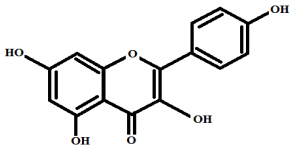
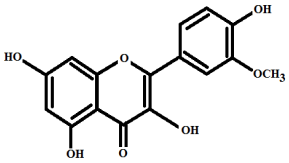
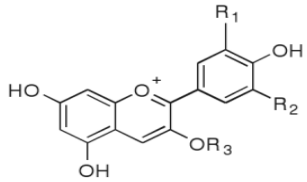
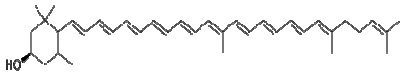
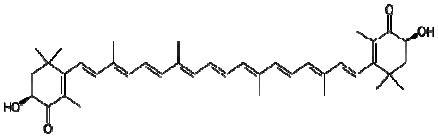
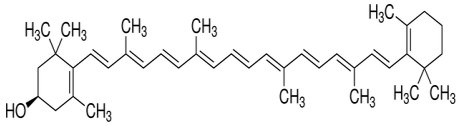
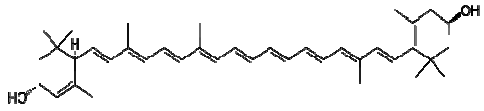
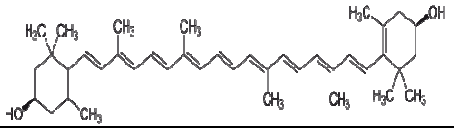
Table 3: Phytochemicals present in different parts of the plant *Delonix regia* (Boj.) Raf

S. No.	Phytochemicals	Structure	Plant part	Reference
1.	Kaempferol 3-rhamnoside		Leaves	[24]
2.	Quercetin 3-rhamnoside			
3.	Kaempferol 3-glucoside			
4.	Kaempferol 3-rutinoside			

5.	Kaempferol 3-neohesperidoside			
6.	Quercetin 3-rutinoside			
7.	Quercetin 3-glucoside			
8.	Lupeol	 R_1 = H; R_2 =OH	Stem bark	[47,59]
9.	Epilupeol	 R_1 = OH; R_2 =H		
10.	β-sitosterol	 **R=** 		
11.	Stigmasterol	**R=** 		

12.	*p*-methoxybenzaldehyde			
13.	Cyanidin 3-O-glucoside		Flowers	[64,65]
14.	Cyanidin 3-O-rutinoside			
15.	Pelargonidin 3-O-rutinoside			
16.	Phytol		Leaves	[56]
17.	Coumarin 7, 8-dihydro-7-hydroxy-6-methoxy-8-oxo			
18.	Squalene			
19.	Vitamin E			

20.	Propelargonidin (PP)	 R_1 = OH; R_2 = H; R_3 = H	Leaves, fruit and stem bark	[57]
21.	Prodelphinidin (PD)	 R_1 = OH, R_2 = OH, R_3 = OH	Leaves	
22.	Carotene		Bark	[59]
23.	2-hydroxy-5-[(3,4,5 trihydrioxrphenyl)carbonyl oxy] benzoic acid		Flowers	[17]
24.	3,4,5-trihydroxybenzoic acid (gallic acid)			
25.	3,4-dihydroxybenzoic acid (protocatechuic acid)			
26.	Quercetin			
27.	Rutin			
28.	Quercetin 3-O-glucoside			

29.	Quercetin 3-O-galactoside			
30.	Quercetin trihexoside			
31.	3-O-robinobioside			
32.	Kaempferol rhamnosylhexoside			
33.	Isorhamnetol rhamnosyl-hexoside			
34.	Petunidin-3-O-glucoside		Flowers	[65]
35.	Peonidin-3-O-glucoside			
36.	Petunidin-3-O-acetyl glucoside			
37.	Rubixanthin			
38.	Astaxanthin			
39.	β-Cryptoxanthin			
40.	Lutein			
41.	Zeaxanthin			

Miscellaneous

The plant hasalso been reported to show other properties apart from pharmaceutical and antioxidant potential. The pharmacognostical parameters of the gum isolated from the seeds of *Delonix regia* linn was evaluated [61]. The gum sample was characterized using scanning electron microscopy (SEM), particle size analysis, X-ray powdered diffraction (XPRD), Differential scanning colorimetry (DSC) and Fourier transmittance infra red (FTIR). The gum was found to contain galactomannons and was found to be used as a matrix forming polymer because of its excellent swelling property in water. The flowers of *Delonix regia* Raf. were used for natural dyeing of silk. The silk fabric was dyed using the aqueous extract of dried red flowers. When 30% of extract was used, a bright reddish-brown hue colour was observed [66]. The dyed fabric was found to be resistant to fading. *Delonix regia* seed gum (DRSG) can be used as a paracetamol tablet binder [67]. The tensile strength (TS) was found to increase whereas the brittle fracture index (BFI) was found to reduce with the increase in the concentration of the gum binder. The official gum standards used were acacia BP (ACG) and tragacanth BP (TRG). The crushing strength-friability/disintegration time ratio was found in the order-tablets containing DRSG>tablets containing ACG>tablets containing TRG at 1% concentration of bonder.

The nano silica from the pods of *Delonix regia* was synthesized and characterized. After the heat treatment at 600 °C for 4 h, the silica with 99% silica content was produced from the pods of *Delonix regia* ash (PDRA). The precipitation method was used to produce nano silica from PDRA. The silica from PDRA was refluxed in boiling 2.5 N and 3 N NaOH, respectively for precipitation. 2.5 N NaOH treatment was found to result in the highest SiO_2 content nano silica particle in the agglomerate of the particle with dimension of 5-10 nm and surface area of 600 m^2g^{-1}[68]. The single step chemical activation process was used to produce activated carbon from *Delonix regia* fruit pod (DRFP) by pyrolsis at 400 °C [69]. DRFP treated with H_3PO_4 showed the highest yield of 41.09%. The maximum bulk density of 0.46 g/ml was recorded for KOH treated DRFP, followed by H_3PO_4 treated DRFP. Higher surface area was shown by H_3PO_4 treated DRFP. The flower extract of *Delonix regia* Raf. can be used as acid-base indicator [70]. Polyphenolic, flavonoids and anthocyanins were found in the flower extracts. It was found that there was sharp colour change at the end point of titration due to the presence of flavonoids which indicated that these can be used as natural indicators in all types of acid-base titrations.

A lectin from *Delonix regia* (DRL) seeds was purified by gel filtration on Sephadex G-100 followed by ion-exchange chromatography on diethylaminoethyl-Sepharose and reverse-phase high-performance liquid chromatography on a C18 column. Rat erythrocytes were used to monitor the hem agglutinating activity. DRL was found to show no specificity for human erythrocytes of ABO blood groups. A single protein in the presence of 0.1 M of dithiothreitol (DTT) was revealed by Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) [71]. A serine proteinase inhibitor (DrTI) from *Delonix regia* seeds was purified. DrTI was found to inactivate trypsin and human plasma kallikrein with K (i) values 2.19x10 (-8) M and 5.25 nM, respectively. The inhibitor was found to be a protein with a single polypeptide chain of M (r) 22 h Da by SDS-PAGE analysis [72].

CONCLUSION

Delonix regia (Boj.) Raf. shows diverse therapeutic prospective such as antifungal, antibacterial, antioxidant, antiemetic, larvicidal, hepatoprotective, anti-diarrhoeal, anti-inflammatory, antimalarial, anthelmintic, antiarthritic, wound healing and anticarcinogenic potential. However, there are still many areas that need further research to avail the health benefits of phyto-constituents of *Delonix regia* (Boj.) Raf. Studies need to be conducted to explore the potential phyto-constituents of this plant for the prevention of various other diseases and to further unravel, characterize, patent and commercialize the protective components from different parts of this plant for the benefit of humans. Biochemical mechanisms and pathways responsible for different activities of *Delonix regia* (Boj.) Raf. are still not well understood and deserve further exploration. *In vivo* clinical studies with *Delonix regia* (Boj.) Raf. are necessary to alacrity its authenticate use, as this plant deserves appropriate position in therapeutics.

CONFLICT OF INTERESTS

Declared None

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