REVIEW ARTICLE

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# A comprehensive review on *Nymphaea stellata*: A traditionally used bitter

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**DOI:** 10.4103/0110-5558.72424

*J. Adv. Pharm. Tech. Res.*

## ABSTRACT

*Nymphaea stellata* Willd. (Syn. *Nymphaea nouchali* Burman f.) (Nymphaeaceae) is an important and well-known medicinal plant, widely used in the Ayurveda and Siddha systems of medicines for the treatment of diabetes, inflammation, liver disorders, urinary disorders, menorrhagia, blenorrhagia, menstruation problem, as an aphrodisiac, and as a bitter tonic. There seems to be an agreement between the traditional use and experimental observations, such as, hepatoprotective, anti-inflammatory, and particularly antidiabetic activity. Nymphayol, a steroid isolated from the flowers has been scientifically proved to be responsible for the traditionally claimed antidiabetic activity; it reverses the damaged endocrine tissue and stimulates secretion of insulin in the β-cells. However, taking into account the magnitude of its traditional uses, the studies conducted are still negligible. This review is an attempt to provide the pharmaceutical prospective of *Nymphaea stellata*.

**Key words:** Bitter, indian blue water lily, *Nymphaea nouchali*, nymphayol

## INTRODUCTION

In Ayurveda, for the highest heat, fever, and pitta conditions — bitter, fire purging, and heat dispelling herbs are used, that is, bitters. Bitters are the strongest herbs for cooling pitta, for sedating, detoxifying the liver, and for reducing the deep-seated heat / fever in the interior of the body. Bitters also increase agni (Fire) by their drying action; in addition they do not aggravate pitta.[1] According to contemporary knowledge, bitters are a group of botanicals with a predominantly bitter taste, due to the presence of chemical constituents like alkaloids, monoterpenes (iridoid and secoiridoids), sesquiterpene lactones, diterpenes, triterpenes, and rarely flavanones, acyl phloroglucides, and steroids (pregnane type).[2] Bitters stimulate the gastric reflex, increase the flow of digestive juices from the pancreas and duodenum, increase the nerve tone of the entire digestive tract muscles and enhance the liver for better assimilation of the nutrients. Bitters produce a diuretic effect and also regulate the secretion of the pancreatic hormones (insulin and glucagon) that regulate blood sugar. Bitters can also be supportive in reducing stress, anxiety, and regenerating the nervous system. The intensity of all these effects is considered directly proportional to the strength of its bitterness. *Nymphaea stellata Willd.* (Nymphaeaceae) is one such traditionally recommended bitter for various ailments, in India. *N. stellata* is an ingredient of many ayurvedic formulations and its morphological parts are used by traditional healers for treating various diseases. In the last few decades there has been an increasing interest in the study of medicinal plants, as knowledge on ethnopharmacology, its holistic system approach, supported by the experiential base, can serve as an innovative and powerful discovery engine for newer, safer, and affordable medicines.[3] This review is an attempt to assess the available scattered literatures and compile them under different categories in a systematic way, to provide the pharmaceutical prospective of *Nymphaea stellata*.

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## *NYMPHEACEAE* AND *NYMPHEA*

Paleobotanical studies[4-7] support the view that the so-called ANITA clads (Amborellaceae, Nymphaeales, Illiciales, Trimeniaceae, Austrobaileyaceae) were the first line to diverge from the main branch of the angiosperm phylogenetic tree. *Nympheaceae* is classified under the order Nymphaeales, in the group of the 'basal families,' in the recent molecular-based angiosperm phylogeny.[8] *Nympheaceae* is a primitive family; the fossil record goes back to the early cretaceous period.[5] *Nympheaceae* Salisb. is cosmopolitan with about six genera and 75 species.[9] The genus *Nymphaea* includes approximately 40 species found

in tropical and temperate climates on both hemispheres. *Nymphaea* is divided into two main groups, which in turn is divided into five subgenera. Group Apocarpiae includes the subgenera *Anecphya*, *Brachyceras*, and group Syncarpiae consists of subgenera *Hydrocallis*, *lotos*, and *Nymphaea*.

## *NYMPHAEA STELLATA*

*Nymphaea stellata* Willdenow (syn. *Nymphaea nouchali* Burman f.) belongs to the family *Nympheaceae* [Figure 1]. In Greek nymphala refers to water nymph and stellata in Latin means star-shaped.[10] For a variety of reasons a lot of synonymy occurs for *N. stellata*.[11,12] The synonyms are; *Nymphaea cyanea* Roxb., *Nymphaea malabarica* Poir., *Nymphaea minima* F. M. Bailey, *Nymphaea punctata* Edgew, and *Nymphaea versicolor* Sims.[13] *N. caerula* is also considered as a synonym by some botanists, while some include as a variety, *Nymphaea nouchali* Burm.f. var. caerulea (Savigny) Verdc.[14] Other varieties recorded are, *N. nouchali* var. cyanea (Hooker F. and Thomson), Almeida (syn. *N. stellata* var. cyanea), and *N. nouchali* var. versicolor (Roxburgh) Hooker f. and Thomson (syn. *N. stellata* var. vesicolor).[15] Verdcourt has quoted that *N. nouchali* should be a synonym for *N. stellata* and not for *N. pubescens* as some have stated.[16,17] However, in some literature and books *N. stellata* and *N nouchali* have been differentiated as two species.[18] To date there exists a controversy among botanists regarding the synonymy and the varieties. Although, this review is constructed considering *N. nouchali* as a synonym of *N. stellata*.

*N. stellata* is commonly known as Indian blue water lily / Indian water lily in English and has different vernacular names in India [Table 1].[19] Sometimes this water lily is often referred as 'blue lotus of India', but it is not a lotus.[15] Many reports specify that 'blue lotus of the nile' and the 'blue lotus of India' are *N. caerulea* and *N. nouchali*, respectively, while others report 'sacred blue lily' as *Nymphaea nouchali* var. caerulea. In India the vernacular names used for *N. nouchali*, besides the correct local name 'Nilotpalam', include 'Allithamarai' and 'Vellambal' (Tamil), which are in fact applicable to *N. pubescens*.[20] Another name 'Nilotpala' refers to three plants – *N. stellata*, *N. rubra*, and *Monochoria hastate*. *N. stellata* alone has 17 names including Indivar, Nilakamala, Nilotpala, and Utpala.[21] Lotus has no blue colored flowers in India, the name 'Neelathamara' is applicable only to the water lily with bluish flowers, which is *N. stellata*. These vernacular names used for *N. stellata* in India are sometimes conclusive, but mostly diverge dramatically, making identification of the plant complicated.

**Figure 1:** *Nymphaea stellata*

Karyotype analysis on *N. stellata* showed 2n = 28.[22] Another study on the chromosome number of *N. nouchali* was seen to be euploidy in nature. Three types have been identified, *N. nouchali* (Type 1) 2n = 56, *N. nouchali* (Type 2) 2n = 84, and *N. nouchali* (Type 3) 2n= 70. *N. nouchali* (Type 1) 2n = 56 (4x) chromosomes may have evolved by the doubling of a chromosome (2n = 28) from the ancestral species. Similarly, *N. nouchali* (Type 2) 2n = 84 (6x) may have evolved from the chromosome doubling of *N. daubeniana* 2n = 42 (3x). *N. nouchali* (Type 3) 2n = 70 (5x) might have originated by the crossing of *N. pubescens* 2n = 84 (6x) and *N. nouchali* (Type 1) 2n = 56 (4x). Most of the species in *Nymphea* hybridize freely among themselves naturally, and thereby, generate uncertainty regarding their identity.[23] A lot of study remains to be done to improve the understanding of this wide-ranging and highly variable taxon and its relationship, to help the related taxa.

Genotypic studies reveal that carnivory is polyphyletic.[24] Phylogenetic trees prepared on the basis of taxonomy suggest a strong evolutionary linkage between some carnivorous families such as Nepanthaceae and Sarraceniaceae to *Nympheaceae*, which is conclusive from *N. stellata* as it indulges in a primitive form of insectivory. No insectivorous flowering plant has been reported and *N. nouchali* may be the missing link in the evolutionary history of other highly evolved carnivorous plant families.[25] *N. stellata* is also

**Table 1: Different vernacular names for *N. stellata* in India[19]**

| Languages | Vernacular names |
|---|---|
| Sanskrit | Kumuda, Indivar, Nilakamala, Nilotpala, Utpala, Padma, Kamala, Indeevararn |
| Tamil | Alli, Ambal, Allithamarai, Vellambal, Nilotpalam |
| Marathi | Kamoda, Neel Kamal |
| Hindi | Neel Kamal, Kumudinee |
| Telugu | Allitamara, Kaluvapoovu, Kaluva, Neelattamara |
| Malayalam | Ambal Poovu |
| Bengali | Kumud, Sundi |
| Gujarati | Poyanu |
| Kannada | Neeltare |
| Punjabi | Neel Kamal, Kamalini |
| Assamese | Boga bhet, Seluk |
| Urdu | Neelofar |

reported for its allelopathic potential, being more toxic to the growth of hyacinth.[26]

## GEOGRAPHICAL SOURCE

*N. stellata* is a perennial aquatic rooting herb, wild / cultivated, generally found in tanks and ponds throughout the warmer parts of India, particularly the Eastern Ghats. For centuries it has been cultivated in Southeast Asia, especially around temples.[15,27] Native to Borneo, Philippines, Srilanka, Myanmar, Afganistan, Pakistan, Bangladesh, Nepal, Cambodia, Malaysia, Laos, Thailand, Vietnam, New Guinea, Indochina to China, Taiwan and Indonesia, distribution also reported in Africa and Australia.[10,19,28-32]

## CULTIVATION

*N. stellata* is cultivated in portions of paddy fields left uncultivated during the Southwest monsoon. Seed / roots are first selected, then air dried and stored. The mud is first prepared and manured with old weeds or stubble, or special compost. Seed / roots are propagated in shallow mud and later transplanted to positions in rows three feet apart, and two-to-three feet apart in the rows. The blue water lily may be grown from seeds, but it takes three to four years to flower. The seed can be sown in spring and during summer. Finely sieved clean loam soil without any organic matter or fertilizer is used. Seeds should be sown thinly, covered lightly with soil and then plunged into shallow water, no deeper than 2.5 cm, and placed in a sunny position. Germination should take three-to-four weeks. When the first two or three floating leaves appear the seedling should be picked out and planted into individual containers and immersed back in the water. They may be submerged into deeper water and larger containers as they grow and lengthen. The easiest method of propagation is division. Plants are left in one place for two years, but pot-grown plants are best lifted, divided just before new growth commences in the spring and planted in fresh soil. The fleshy roots are pulled or cut and replanted immediately in a fresh soil mixture. Each new plant should have at least one bud at the tip of the rhizome.[33,34]

## ANATOMY, HISTOLOGY, AND MICROSCOPY

*N. stellata* is a rather weak or stout herb from a cone-like tuberous rhizome, bearing small white pithy roots; stems are often reddish violet. Rhizomes are short, erect, stout, fleshy, unbranched, pyriform, and about the size of an egg. The rhizomes are enclosed in a thin covering, which turns horny on drying. The covering is itself covered with a cottony substance, especially at the apex. The rhizome is full of starch and is very palatable when boiled or prepared with curry, being more palatable than the Yam (*Dioscorea*) and Cocoyam (*Colocasia*).[33] The fruit is about 2.5 – 3 cm in diameter, globose, 6.5 cm, glabrous, and contains round, flask-shaped seeds, less than 1 mm in diameter. It has many seeds, berries, which are ellipsoid-globose, black with a white aril, 0.5 – 1.3 mm, with longitudinal rows of hairs.[13,35,36] Table 2 shows the anatomy, histology, and powder microscopy of the flower and leaf of *N. stellata*.[15,19,32,37-44]

The Ayurvedic pharmacopeia of India has specified the proximate analytical parameters, namely, foreign matter (Not More Than 2%), total ash (NMT 8%), acid insoluble ash (NMT 0.5%), alcohol soluble extractive (Not Less Than 5%), and water soluble extractive values (NLT 22%) for identity, purity, and strength of flowers of *N. stellata*. The TLC pattern of the alcoholic flower extract in chloroform : ethylacetate : formic acid (5 : 4 : 1) showed three visible spots at $R_f$ 0.59, 0.68, and 0.81 (all bluish-gray) and on spraying with 10% aqueous ferric chloride solution two spots appeared at $R_f$ 0.68 and 0.81 (both blue color).[19]

## TRADITIONAL USES

The Indian system of medicines, particularly Ayurveda and Siddha, uses *N. stellata* as a single drug or in combination with other drugs. It is also known as *Utpala* in Sanskrit, but this name refers only to dried flowers. *N. stellata* are ingredients of many ayurvedic formulations like, Asokarista, Arvindasava, Usirasava, Candanasava, Kalyanaka Ghrta, Samangadi Curna, Kanaka Taila, Jatyadi Taila, Tungadrumadi Taila, Manjesthadi Taila, Candanadi Lauha, and Triphala Ghrta.[19] It is also an ingredient of many polyherbal formulations for anti-aging, rejuvenation, and menstrual irregularities. The traditional uses of different parts of *N. stellata* are given in Table 3. The rhizome, fruit, leaf petiole, roots, flowers, tubers, and seed are used as edible parts in different ways by people.[45-50] It has also been cultivated for food in Srilanka as the rhizomes are full of starch and reputedly quite tasty when boiled.[15] The roots and rhizomes are considered to be nutritious when eaten either raw or roasted.[51] Flowers are used in temples, rhizomes in medicine, flower and flower stalks as vegetables, green manure, and fodder. *N. stellata* is considered as one of the ten most common noxious aquatic weeds in India.[52]

## CHEMISTRY

Different solvent extracts of the entire plant have shown the presence of sterols, alkaloids, saponins, tannins, and flavonoids. Nymphayol (25,26-dinorcholest-5-en-3b-ol) [Figure 2], a new sterol has been isolated from the successive chloroform extract of the flower.[53] Protein, pentosan, mucilage, and tannins are reported in the seeds.[54,55] Astragalin, corilagin, gallic acid, gallic acid methyl ester, isokaempferide, kaempferol, quercetin-3-methyl ether, quercetin, 2,3,4,6-tetra-o-galloyl dextroglucose,

**Table 2: Anatomy, histology, and powder microscopy of different parts of *N. stellata***

| Part | Description | Diagnostic character in histology | Powder characteristics | References |
|---|---|---|---|---|
| Flower | Flowers are solitary, fragrant, open all day. Sepals usually four, green, but sometimes marked with dark purple or crimson lines or dots, and sometimes with reddish purple or crimson margins, oblong-ovate to oblong-lanceolate. Petals 12 – 27, usually blue, but sometimes pink, mauve or white, lanceolate to oblong-lanceolate, some of the outer ones occasionally sepaloid, acute to obtuse or rounded. Stamens 30 – 250, the connective appendages narrow and usually well-developed, pale to dark blue. Carpels 14 – 47; stigmatic appendages densely papillate | Sepal — unicellular hairs; large stellate air canals and vascular tissues; tanniniferous content in collenchymatous cells. Petal — stellate air canals; vascular stellate tissues; tanniniferous contents. Stamen — stellate air canals; anther shows four splitting pollen chambers attached to parenchymatous connective tissues, vascular tissues, and stellate idioblasts; endothecium consists of single-layered columnar cells; stromium in both the chambers. | Powder — Brown; shows groups of parenchymatous cells, stellate air canals, uniseriate hairs, yellowish-brown rounded pollen grains, measuring 22 – 27 $\mu$ in diameter, having thick, smooth, exine, and thin intine. | [15,19,32,37, 40-43] |
| Leaves | Leaves round to elliptic, (5-)8 – 35 (-45) cm long, 5 – 30(-40) cm wide, rounded or retuse at the apex, incised or cordate to hastate at the base; the margins entire, slightly undulating toward the base or toothed to distinctly lobulate; the upper surface green and smooth, the lower green, red, purple, or green and purple-spotted and / or with purple margins; primary lateral nerves 5 – 8 on each side and 4 – 5 additional pairs from the midrib; the nervation flat or raised beneath | Leaf is hydromorphic, lamina is 400 $\mu$m thick; stellately branched, long armed sclerenchyma cells called 'trichosclereids'; minute prismatic crystals are densely deposited on the arms of the trichosclereids; collateral vascular bundles differ in size from different zones of the lamina; ranunculaceous or anomocytic stomata. | Abundant trichosclereids of either entire or broken pieces, the surface of the sclereid is warty due to deposition of minute prismatic crystals, large masses calcium oxalate crystals. | [32,37-39,41,42,44] |

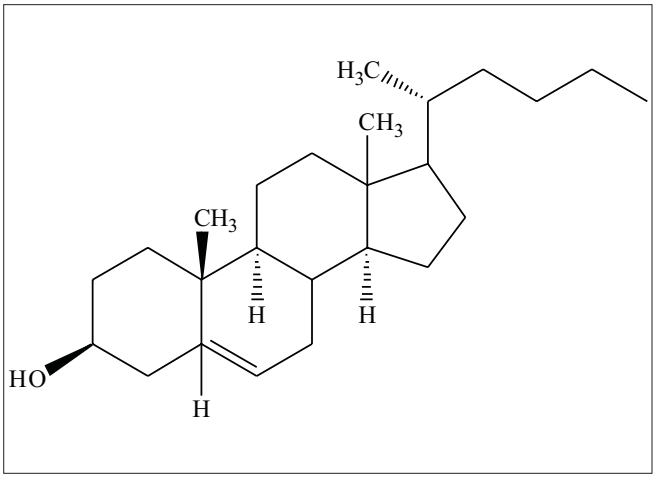


**Figure 2:** Chemical structure of Nymphayol

and 3-o-methylquercetin-3'-o-beta dextroxylopyranoside have been identified in the flowers.[56,57] The HPTLC method for quantitative determination of gallic acid from hydroalcoholic dried flower extract has been reported.[58] The leaves and shoots of *N. stellata* (Blue water lily) and *N. nouchali* (Red water lily) as different species have been studied for their chemical composition. The proximate analysis showed dry matter -8.4%, crude protein-16.8, ash-18.7, crude fat-2.8, crude fiber-26.3, and nitrogen free extract-35.4 for *N. nouchali;* and dry matter-7, crude protein-16.7, Ash-14.1, crude fat-2.6, crude fiber-24, and nitrogen free extract-42.6 for *N. stellata,* respectively. Mineral content showed sodium-1.19, potassium-2.23, calcium-0.52, phosphorus-0.32, and calcium / phosphorus ratio 1.63 for *N. nouchali;* and sodium-0.93, potassium-1.30, calcium-0.95, phosphorus-0.21, and calcium / phosphorus ratio-4.52 for *N. stellata*. Alkaloids had been detected in fraction A (extracted with chloroform from an ammonical solution) for both, while *N. nouchali* and *N. stellata* differed in their nitrate content with 2 and 0.9%, respectively. *N. nouchali* showed polyphenols total-8.7%, free-5.9%, and bound-2.8%; and *N. stellata* showed polyphenols total-10.2%; free-9.3%, and bound-0.9%.[59] On account of the nitrogen and protein content [Table 4] of *N. stellata* and *N. nouchali*, they have also been reported as two different species.[60] There is not much difference quantitatively between the two and a trivial difference in plant content is familiar. *N. stellata* (Blue water lily) and *N. nouchali* (Red water lily) may be still the same for the reason that blue, pink, mauve or white blue flower

**Table 3: Traditional uses of different parts of *N. stellata***

| Part | Traditional uses | References |
|---|---|---|
| Whole plant | Used for the treatment of liver disorders in Ayurveda. Leaves, roots and flowers are used for diabetes, blood disorders, antifertility, heart troubles, dysentery, eruptive fevers, indigestion and as a cardiotonic, emollient, diuretic, narcotic, stimulant, and aphrodisiac.<br>The flowers and roots have mild sedative properties; used for mind-altering purposes.<br>The whole plant is used as an anti-periodic and cardiac stimulant in Kashmir. | [72-77,12,78-80] |
| Flower | 3 – 6 g of the drug is used in Pipasa daha (burning thirst), Raktapitta (bile-blood), Chardi (vomiting), Murccha (fainting), Hrdraoga (heart disease), Mutra Kecchra (painful discharge of urine, a class of urinary affections), Jvaratisara (diarrhea with fever).<br>The flowers are used in the treatment of diabetes mellitus (Madhumeha) and liver disorders in the Ayurveda and siddha systems of medicine. The flower has an acrid, bitter-sweet taste, removes impurities from the blood, cools and alleviates cough, is used for biliousness, as an aphrodisiac, for vomiting, giddiness, worm infestation, and burning of the skin. The decoction of the flower is used in palpitations of the heart and as a narcotic; the syrup of the flower is used in cases of high fever, apoplexy, inflammatory diseases of the brain, and also in dysuria. The filaments of the plants are used as an astringent and a cooling agent in the burning sensation of the body, bleeding piles, and menorrhagia. | [19,29,31,75,81,82] |
| Rootstock | Powder is used to treat dyspepsia, diarrhea, and piles | [29,31] |
| Root | The roots are used as an emollient, diuretic, and to treat diabetes, blenorrhagia, infections of the urinary passages, and infertility | [16,82,83] |
| Leaf and flower | The tender leaves and flower peduncles are used as curries in Ceylon | [34] |
| Rhizome and stem | An infusion is considered to be an emollient, diuretic, and used for treatment of blennorrhagia and diseases of the urinary tract | [29,31] |
| Flower and rhizome | Flowers and rhizomes are astringent, demulcent, mild sedative, spasmolytic, antiseptic, used in infusion internally for chronic diarrhea, as a douche for leucorrhea and vaginitis, as a gargle for sore throat; also given internally for prostate problems<br>Rhizomes and flowers are used as a remedy for kidney problems | [48]<br>[46] |
| Leaf | Leaves are applied topically in erysipelas, whereas, the macerated leaves are used as a lotion in eruptive fevers | [10,29,31] |
| Seed | The seeds are said to be stomachic and restorative<br>Seeds are prescribed as a diet for diabetes mellitus, in the Aurvedic system of medicine | [29,31,82,84-86] |
| Rhizome | It is often eaten in India and Ceylon mainly as a famine food<br>The rhizomes are eaten after roasting in hot embers. Rhizome paste is used to treat menstruation problem. The rhizomes are used to treat gastrointestinal disturbances | [33,82,87,88] |
| Petiole | Petiole paste along with little common salt, seed powder of *Cuminum cyminum*, butter, and few drops of honey is taken against excessive menstrual discharge. Stripes along with roots of *Pinus longifolia* are taken against fever, dysentery, nausea, cough, vertigo, pain, and bleeding during pregnancy | [18] |

**Table 4: Nitrogen and protein content of *N. stellata* and *N. nouchali*[60]**

| Plant | Plant nitrogen % | Total protein | | Leaf protein |
|---|---|---|---|---|
| | | % of pulp nitrogen extracted | % of pulp nitrogen extracted as protein | |
| *N. stellata* | 2.70 | 26.64 | 11.53 | 5.37 |
| *N. nouchali* | 2.72 | 21.80 | 12.61 | 5.56 |

colors are also recorded in *N. stellata*. It is also possible that they may be two varieties. Apomorphine, nuciferine, and nornuciferine have been reported[61] from *N. stellata,* in fact, they have been isolated from *N. caerulea*.

## PHARMACOLOGY

### Antidiabetic Activity

The defatted ethanolic leaf extract (14.26 %w/w) at a dose of 100 and 200 mg/kg was studied for hypoglycemic activity in alloxan-induced diabetic rats (Wistar, 150 – 220 g). Oral treatment significantly and dose-dependently reduced the hyperglycemia. Moreover, it decreased the levels of cholesterol (CHL) and triglycerides (TGL) that had been increased by the alloxan treatment. On the contrary, no effect was seen in normal rats, both in the glucose and lipid plasma levels. The hypocholesterolemic effect of the ethanolic extract of the leaves of *N. stellata* could possibly be related to its amino acid and saponin composition.[62] The hydroalcoholic extract (yield: 6.8% w/w) of flowers at 200, 300, and 400 mg/kg (oral) were studied in normoglycemic and alloxan-induced diabetic rats (Male, Wistar strain, 150 – 200 g). It showed no hypoglycemic effect in normoglycemic animals, but showed statistically significant antihyperglycemic activity by improvement seen on the oral glucose tolerance test (OGTT). The flower extract caused significant reduction in the blood glucose level of diabetic rats. The dose of 300 mg/kg showed significant blood glucose level reduction

(45%), fours hours after administration of the flower extract. The hydroalcoholic extract also showed a dose-dependent response.[63]

The antidiabetic effect of hydroalcoholic extract of the *N. stellata* flower could be linked to more than one mechanism. The possible mechanism includes the stimulation of β-cells and a subsequent release of insulin and activation of the insulin receptors. The antihyperglycemic action may be due to the potentiation of pancreatic secretion of insulin, which is clearly evident from the increased level of insulin in the treated rats. *N. stellata* also acts as a hepatoprotective agent,[64] therefore, it could have improved the function of the liver and maintained glucose uptake, enhanced transport of blood glucose to the peripheral tissue, and also enhanced utilization, which may be another mechanism of action. The extract might have also have stimulated glycogenesis and / or inhibited glycogennolysis in the diabetic rat liver. Administration of the extract reduced TC, TG, LDL, VLDL, and also improved the HDL level. Serum phospholipid was elevated, whereas, the phospholipids in the liver and kidney were decreased. Treatment could have restored the normal metabolism by shifting the balance from lipid metabolism to carbohydrate metabolism.[65]

Oral administration of *N. stellata* flower extract for 30 consecutive days to diabetic rats also decreased their food consumption and improved body weight. This could be due to a better control of the hyperglycemic state in the diabetic rats. Administration of te flower extract to diabetic rats significantly increased the level of total hemoglobin, which might be due to the decreased level of blood glucose. Oral administration of the flower extract improved the total protein concentration in the serum. Administration of *N. stellata* flower extract to diabetic rats reversed the changes and improved the HDL levels. These results unmistakably indicate that the flower extract could effectively manage the diabetic complications such as body weight maintenance, hyperlipidemia, cardiovascular complications in diabetes mellitus and progression of atherosclerosis.[66] Nymphayol (25,26-dinorcholest-5-en-3b-ol), a new sterol isolated from the bioactive successive chloroform flower extract has been reported for its antidiabetic activity at 20 mg/kg bw in streptozotocin-induced diabetic rats. Oral administration of Nymphayol for 45 days significantly restored the plasma glucose levels and increased the plasma insulin levels to near normal in STZ-diabetic rats. Light microscopy and immunocytochemical staining of Nymphayol-treated diabetic pancreas revealed an increased number of insulin positive β-cells. The mode of action of Nymphayol may be due to the reversal of the damaged endocrine tissue, thereby stimulating the secretion of insulin in β-cells, as revealed by insulin assay. The active principle of Nymphayol enhances the antioxidant defense against the reactive oxygen species (ROS) produced under hyperglycemic conditions and thus protects the pancreatic β-cells against loss.[53]

### Tumor Inhibition Studies

The methanolic extract of *Nymphaea nouchali* roots at 200 μg/ml were screened for their inhibitory activity toward tumor promoter 12-*O*-hexadecanoylphorbol-13-acetate-induced Epstein-Barr virus activation in the Raji cells. The extract was inactive with zero inhibition rate.[67]

### Antihepatotoxic Effect

The alcoholic extract (yield, 9% w/w) of the *N. stellata* flowers was evaluated against carbon tetrachloride-induced hepatic damage in albino Wistar rats (8 – 10 weeks, 100 – 120 g) at 250, 500, and 750 mg/kg (orally), in the form of an aqueous suspension, once a day, for 10 days. The hepatoprotective activity exerted by the extract could be due to cell membrane stabilization, hepatic cell regeneration, and activation of antioxidative enzymes such as glutathione reductase, glutathione peroxidase, superoxide dismutase, and catalase.[64] The petroleum ether extracts of *N. stellata* seeds were tested against carbon tetrachloride ($CCl_4$)-induced hepatotoxicity in rats and mice at a dose of 300 mg/kg i.p. The extract markedly reduced the prolongation of sleeping time and significantly prevented the $CCl_4$-induced increase in weight and volume of the liver, and the mortality. The extract also prevented necrosis of the liver and promoted, to some extent, liver generation.[68]

### Cholinergic Activity

The alcohol extract of the defatted fruits of *N. stellata* produced mild sedation and ataxia, potentiated hexobarbitone-induced hypnosis in mice, and also produced a sharp and transient hypotension blocked by pretreatment with atropine. If large doses were administered after atropinization, a rise in blood pressure and also a stimulant effect was observed on guinea pig ileum, indicating the presence of some unstable cholinergic principle.[31]

### Analgesic and Anti-inflammatory Activity

The extract had a significant analgesic activity as revealed by the aconitine-induced writhing in mice and the antipyretic activity against carrageenin-induced rat paw edema. The anti-inflammatory activity exhibited was comparable to that of hydrocortisone.[69]

### Antimicrobial Activity

Flowers of *N. nouchali* were effective against *Pseudomonas aeruginosa*, *Bacillus cereus*, and *Staphylococcus aureus*.[70] *N. stellata* also demonstrated a broad spectrum of activity against phytopathogenic bacteria. The ethanolic extract of *Nymphaea stellata* leaves has shown considerable antibacterial activity against *E. coli*.[44]

### Other Activities

The $LD_{50}$ of 50% ethanol extract of *N. stellata* was found

to be 681 mg/kg in albino mice. *N. stellata* was found to be inactive as an antibacterial, antifungal, antiprotozoal, antiviral, diuretic, with no effect on the cardiovascular system and central nervous system.[71]

## CONCLUDING REMARKS AND FUTURE POTENTIAL

Regarding the copious synonymy, a lot more study remains to be done, to precisely differentiate the closely related species and varieties. The numerous vernacular names used complicate the identification of the traditionally claimed species. However, anatomical studies will provide details for establishing the identity and the degree of purity. The traditional usage will give an idea of how people treat different health problems with the aid of *N. stellata* parts. Taking into account the magnitude of its traditional uses, the studies conducted are still too scant.

To date sterols, alkaloids, saponins, tannins, and flavonoids are reported from different parts. Bitter principles are known for a variety of biological responses like blood sugar regulation, stimulating the gastric reflex, and increasing the secretion of enzymes. Although traditionally *N. stellata* is considered as bitter, no particular bitter principle has been identified. However, there is very good agreement between the traditional use and experimentally observed effect — the hepatoprotective, anti-inflammatory, and particularly antidiabetic activity. Nymphayol, an isolated steroid reverses the damaged endocrine tissue and stimulates secretion of insulin in β-cells, accentuating the fact that traditional uses of medicinal plants are frequently coherent with the pharmacological effects of the main active principles. On the other hand, experimental studies have uncovered the potential uses of *N. stellata* in hyperlipidemia, cardiovascular complications in diabetes, and also in the progression of atherosclerosis.

Some trends in *N. stellata* should be reassessed. It is evident from the reference list of the present study that extracts have been the object of relatively many investigations, while fractions of bioactive extract / pure compounds have so far been neglected by phytochemists and pharmacologists. Future phytochemical investigation may be focused on identifying bioactive moieties, such as the unstable cholinergic principle reported and the constituents responsible for the anti-inflammatory and antihepatotoxic effect. Part of the future pharmacological investigation should center their focus on exhaustive studies on unexplored claims like aphrodisia and their effectiveness in urinary disorders, menorrhagia, blenorrhagia, and menstruation problems. It is expected that many novelties will rapidly enlarge the current knowledge about *N. stellata*, their constituents, and corresponding pharmacological effects.

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**Source of Support:** Nil, **Conflict of Interest:** Nil.