• Review

A review on the pharmacological and toxicological aspects of *Datura stramonium* L.

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ABSTRACT: *Datura stramonium* L., a wild-growing plant of the Solanaceae family, is widely distributed and easily accessible. It contains a variety of toxic tropane alkaloids such as atropine, hyoscyamine, and scopolamine. In Eastern medicine, especially in Ayurvedic medicine, *D. stramonium* has been used for curing various human ailments, including ulcers, wounds, inflammation, rheumatism and gout, sciatica, bruises and swellings, fever, asthma and bronchitis, and toothache. A few previous studies have reported on the pharmacological effects of *D. stramonium*; however, complete information regarding the pharmacology, toxicity, ethnomedicine and phytochemistry remains unclear. Ethnomedicinally, the frequent recreational abuse of *D. stramonium* has resulted in toxic syndromes. *D. stramonium*, in the form of paste or solution to relieve the local pain, may not have a deleterious effect; however, oral and systemic administration may lead to severe anticholinergic symptoms. For this reason, it is very important for individuals, mainly young people, to be aware of the toxic nature and potential risks associated with the use of this plant. This comprehensive review of *D. stramonium* includes information on botany, phytochemistry, pharmacology, toxicity and ethnomedicinal uses.

KEYWORDS: *Datura stramonium*; pharmacologic actions; medicine, traditional; phytotherapy; drug toxicity; review

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1 Introduction

The genus “*Datura*” (Solanaceae) comprises all the nightshades and agricultural plants, including potato, tomato, coffee and pepper. Classification of different species within *Datura* genus relies heavily on genetic markers, which suggests that this genus has huge variation due to mutation¹². *Datura stramonium*, the most common species within this family, is native to Asia, but is also found in the United States, Canada, and the West Indies. It is widespread with higher abundance in temperate, tropical and subtropical regions.³ Traditionally, *D. stramonium* has been used for mystic and religious purposes, and as an herbal medicine with narcotic effects or to treat asthma.⁴ The seed of *D. stramonium* is smoked to achieve hallucinogenic experiences as well.⁵ *D. stramonium* is toxic when consumed improperly. Accidental poisoning of humans and animals who consumed food sources contaminated with *D. stramonium* has been reported⁶. In areas where millet, wheat, rye, corn, and bean seeds are used for human consumption, and where *D. stramonium* is a common weed, the grain sometimes has been contaminated with *Datura* seeds.⁷

In Ayurvedic medicine, *D. stramonium* is described as a useful remedy for various human ailments including ulcers, wounds, inflammation, rheumatism and gout, sciatica, bruises and swellings, fever, asthma and bronchitis, toothache, etc. Many folk medicine remedies use *D. stramonium* therapeutically. In the Hindu religion, the seed of *D. stramonium* is believed to be associated with the God Shiva, which can promote misuse of the plant on religious occasions, such as *Shivaratri* and *Swasthani Puja*. In modern medicine, the
therapeutic uses of *D. stramonium* are overshadowed by its toxic effects. The administration of large amounts of *D. stramonium* affects the central nervous system with symptoms such as confusion, bizarre behavior, hallucinations and subsequent amnesia. Though death by *D. stramonium* poisoning is rare, recovery may take several days[8]. Therefore, a thorough understanding of the possible pharmacological and toxicological effects of *D. stramonium* is needed. This review focuses on the botany, phytochemistry, pharmacology, toxicology and ethnomedicinal uses of *D. stramonium*.

2 Botany

2.1 Scientific name and classification

In Nepal, *D. stramonium* L. is commonly known as Dhaturo, Seto Dhaturo, Dhattur, and Madak. In Sanskrit language, it has several names such as Dhatturdhurtadhustura Unmatta, Kanakahwaya, Dewatakitawasturi Mahamohi Shivapiyya, and Matulo Madanashcasya phale Matulaputtrakar. Other common names of *D. stramonium* include, Estramonio (Brazil); Chan K’iue Tse (Chinese); Thorn apple, Jimson weed, Mad Apple (English); Chasse-taupe (French); and Trompetilla (Spanish). *D. inermis* Juss. ex Jacq., *D. chalybea* W. D. J. Koch and *D. tatula* (L.) Torr. are the synonyms of *D. stramonium*. It can be classified as Kingdom: Plantae – Plants; Subkingdom: Tracheobionta – Vascular plants; Superdivision: Spermatophyta – Seed plants; Division: Magnoliopsida – Dicotyledons; Subclass: Asteridae; Order: Solanales; Family: Solanaceae – Potato family; Genus: *Datura* L.; and Species: *D. stramonium* L. (Figure 1).

**Figure 1** Different parts of *Datura stramonium*  
St: stem; Lf: leaf; Fl: flower; Fr: fruit; Sd: seed.

2.2 Distribution

*D. stramonium* is native to deserts of the North American Southwest, Central and South America, Europe, Asia, and Africa. It is mainly distributed in the Himalaya region from Kashmir to Sikkim up to 2 700 m, in the hilly district of central and south India[11].

2.3 Botanical description

*D. stramonium* is a large and coarse shrub of about 3 to 4 feet in height. On rich soil, it may even reach the height of 6 feet. The root is large, whitish in color, with a taproot system giving off many fibers. The stem is green or purple, hairless, cylindrical, erect and leafy, smooth, branching repeatedly in a forked manner. Leaves and a single, erect flower arise through the forks of the branches. The alternate leaves are ovate or ovate-cordate in outline, but pinnately lobed. These lobes are somewhat shallow and point at their tips; there are usually 2 to 3 of these lobes on each side of the leaf blade. Leaves are cauleine and ramal, exstipulate, up to 8 cm long and 6 cm across, petiolate, simple, dissected, acute, glabrous, unicosted, and arranged in reticular venation. The upper surface is dark and grayish-green, generally smooth, whereas the underside is paler, and when dry, minutely wrinkled. Leaves, when bruised, exude a rank, heavy, and somewhat nauseating narcotic odor. The flowers are ebracteate, ebracteolate, pedicellate, actinomorphic, bixexual, complete, regular, pentameres, except fourth whorl and are hypogynous. They are sweet-scented, and can produce stupor if breathed for a prolonged period of time. Each flower is replaced by a hard fruit that is dry and spiny, and spheroid-ovoid in shape. Underneath, each fruit is a truncated remnant of the calyx that curves sharply down. These fruits are initially green, but become brown with maturity; they divide into four segments to release the seeds. The seeds are dull, irregular, and dark-colored; their surface may be pitted or slightly reticulated[12,13].

2.4 Propagation

*D. stramonium* is germinated via seeds. It is essentially a temperate plant but is found growing in the vicinity of cultivation, on rank soil, in all parts of the world. The seed usually germinates in 3 to 6 weeks at 15 °C. Seeds can remain viable for several years in storage[14].

2.5 Ethnomedicinal uses

In Western Nepal, leaves of *Datura* along with the leaves of *Cannabis sativa* and stem of *Neopicrorhiza scrofulariflora*, are pounded with water and applied to treat headaches. *Datura* seeds are crushed with grains of rice and taken orally to relieve indigestion. In parts of Central Nepal, fresh leaves are warmed and placed on a sprained body part repeatedly, before going to bed, for the alleged analgesic effect. Juice from the leaves is given with warm milk to expel intestinal worms, specifically tapeworm[15]. In Nigeria, the seeds are mixed with palm oil and applied to severe cases of insect bites and stings[16]. In India, the
seeds are used as a tonic and febrifuge; the leaves are roasted and applied locally to relieve pain\textsuperscript{[17]}\textsuperscript{[17]}. Women in Pakistan warm up to 8 leaves in low fire, and then tie onto sagging breasts to bust them up. Two to five seeds are added to a cup of green tea to relieve headache\textsuperscript{[18]}\textsuperscript{[18]}. Native Americans used \textit{Datura} seed for many years as a euphoric agent. Since the 1800s, it was used as a therapeutic agent in Great Britain\textsuperscript{[25]}\textsuperscript{[25]}.

### 2.6 Phytochemistry

Phytochemical studies of \textit{D. stramonium} have been conducted since the early 1930s. The major phytochemicals isolated from \textit{D. stramonium} are tropane alkaloids, atropine and scopolamine\textsuperscript{[19]}\textsuperscript{[19]}. It is reported that the whole plant contains 0.26% alkaloids. Seeds of \textit{Datura} contain the alkaloid daturine, first isolated, purified and crystallized by Geiger and Hesse, in 1833. Von Planta (1850) pronounced daturine to be identical with atropine, the principal belladonna alkaloid; later, Ladenburg differentiated daturine into atropine and hyoscyamine, the latter alkaloid predominating. Schmidt, however, contended that atropine predominates. The seeds contain fatty oil (25%), from which a new fatty acid, daturic acid (C\textsubscript{75}H\textsubscript{12}O\textsubscript{7}), was isolated. Dohme concluded that the stems contain more alkaloids (0.3% to 0.4%, volumetrically) than even the seeds (0.25% to 0.29%), and the seeds contain more alkaloid than the leaves (0.21% to 0.23%, and 0.27% for green leaves)\textsuperscript{[11]}\textsuperscript{[11]}\textsuperscript{[11]}. Berkov et al\textsuperscript{[20]}\textsuperscript{[20]} suggested hyoscyamine as the main alkaloid in both diploid and tetraploid hairy root cultures of \textit{D. stramonium}. Iranbakhsh et al\textsuperscript{[21]}\textsuperscript{[21]} reported the percentage of atropine and scopolamine in different developmental stages and the parts of the \textit{Datura}. Their study suggested that the root contained lower levels of scopolamine than that of atropine and the same goes for the stem. In stems, atropine was almost three times higher than scopolamine. However, leaves and seeds contained higher level of scopolamine than that of atropine. Recently, Li et al\textsuperscript{[22]}\textsuperscript{[22]} reported the different alkaloids from \textit{D. stramonium} seeds such as N-trans-feruloyl tryptamine, hyoscyramilactol, scopoletin, umckalin, daturaolone, daturadiol, N-trans-ferulicacetyl-tyramine, cleomicosin A, fraxetin, 1-acetyl-7-hydrox-beta-carboline, and 7-hydroxy-beta-carboline-propionic acid. The chemical structures of major phytochemicals isolated from \textit{D. stramonium} are listed in Figure 2.

### 3 Pharmacological activities

#### 3.1 Antiasthmatic activity

\textit{D. stramonium} contains a variety of alkaloids, including atropine and scopolamine, having anticholinergic and bronchodilating activity. Atropine and scopolamine act on the muscarinic receptors by blocking them (particularly the M\textsubscript{2} receptors) on airway smooth muscle and submucosal gland cells, which dilate bronchial smooth muscle and ease asthmatic attacks. Charpin et al\textsuperscript{[23]}\textsuperscript{[23]} reported that using \textit{D. stramonium} as an antiasthmatic cigarette is an effective bronchodilator in asthmatic patients with mild airway obstruction. However, the exposure of \textit{D. stramonium} to the fetus when a mother uses it for asthma will cause a continuous release of acetylcholine, resulting in the desensitizing of nicotinic receptors, which could ultimately result in permanent damage to the fetus\textsuperscript{[24]}\textsuperscript{[24]}.

#### 3.2 Epilepsy

Though the antiepileptic activity of \textit{D. stramonium} has not been reported yet, combination therapy with other herbs has the protective effect on status epilepticus. An experimental model of status epilepticus was induced in male rats by a single systemic injection of lithium (3 mmol/kg) and pilocarpine (30 g/kg). Rats were then treated with herbal mixture containing \textit{D. stramonium}. One week after the induction of status epilepticus, the rat group treated with extracts of \textit{Scutellaria lateriflora} (Skullcap), \textit{Gelsemium sempervirens} (Gelsemium) and \textit{D. stramonium} (Jimson Weed) displayed no seizure during treatment. The results of this experiment strongly suggest that the appropriate combination of herbs with \textit{D. stramonium} may be helpful as adjunctive interventions to treat epilepsy\textsuperscript{[25]}\textsuperscript{[25]}.

#### 3.3 Organophosphate poisoning

Since \textit{D. stramonium} contains atropine and other anticholinergic compounds, it is a useful remedy for the central cholinergic symptoms of organophosphate (OP) poisoning. Bania et al\textsuperscript{[26]}\textsuperscript{[26]} determined the beneficial effect of \textit{Datura} seed extracts following a severe OP poisoning. According to their experiment, \textit{D. stramonium} seeds were heated in water to make 2 mg/mL atropine solution and administered to male rats as a single intraperitoneal injection 5 min before the subcutaneous injection of 25 mg/kg of dichlorvos. Pretreatment with \textit{Datura} seed extracts significantly increased survival in a rat model of severe OP poisoning.

#### 3.4 Antimicrobial activity

The methanol extracts of aerial parts of \textit{D. stramonium} showed the bactericidal activity against Gram-positive bacteria in a dose-dependent manner. However, little or no antibacterial activity was found against \textit{Escherichia coli} and \textit{Pseudomonas aeruginosa}\textsuperscript{[29]}\textsuperscript{[29]}. Ethanol extract exhibited the highest inhibitory activity against \textit{Klebsiella pneumonia} followed by \textit{Staphylococcus aureus}, with the least activity against \textit{Salmonella typhi}. The aqueous extract showed activity on only \textit{S. aureus}, while \textit{Neisseria gonorrhea} was resistant to both extracts\textsuperscript{[28]}\textsuperscript{[28]}\textsuperscript{[28]}\textsuperscript{[28]}\textsuperscript{[28]}\textsuperscript{[28]}\textsuperscript{[28]}\textsuperscript{[28]}. \textit{D. stramonium} was very effective as vibriocidal against various strains of \textit{Vibrio cholera} and \textit{Vibrio parahaemolyticus}. The minimum inhibitory concentration (MIC) value of acetone extracts of \textit{D. stramonium} was in the range of 2.5 to 15 mg/mL serving as broad-spectrum vibriocidal agents\textsuperscript{[29]}\textsuperscript{[29]}.

#### 3.5 Antifungal activity

Acetone extracts of \textit{D. stramonium} have been reported
to have antifungal activity against several fungi including *Penicillium expansum*, *Aspergillus niger*, *Aspergillus parasiticus*, *Colletotrichum gloeosporioides*, *Fusarium oxysporum*, *Trichoderma harzianum*, *Phytophthora nicotiana*, *Pythium ultimum* and *Rhizoctonia solani*. The MIC of *D. stramonium* extracts ranges from 1.25 to 2.5 mg/mL. The fungicidal effects of the extracts indicate the potential of *D. stramonium* seeds as a natural source of antifungal agent.\(^{30}\)

3.6 Anti-inflammatory activity

The ethanolic extract of *D. stramonium* leaf showed significant anti-inflammatory activity against carrageenan-induced paw edema in rats. In one experiment\(^{31}\), 39.43% inhibition of the edema was observed after 3 h of oral administration of 200 mg/kg extracts. Maximum activity was observed when the extract was administered in doses of 3-hour intervals. Since the extract of *D. stramonium* inhibited the carrageenan-induced edema that involves the
release of histamine and serotonin in the first phase, the inhibitory effect of the extracts could be partly due to inhibition of mast cell mediator release[30].

3.7 Acaricidal, repellent and oviposition deterrent properties

*Datura* plant generates a characteristic odor that acts as repellent for various insects and pests. Kurnal et al[32] have reported that the ethanol extracts of *D. stramonium* leaf and seed showed potent acaricidal, repellent, and oviposition deterrent activity against adult two-spotted spider mites (*Tetranychus urticae*) under laboratory conditions. Leaf and seed extracts, which were applied in 167.25 and 145.75 g/L concentrations (using a Petri leaf disc-spray tower method), caused 98% and 25% mortality among spider mite adults after 48 h, respectively. These results suggest that *D. stramonium* could be used to manage the two-spotted spider mite.

3.8 Other activities

*D. stramonium* was reported to have anticancer effect against human epidermal carcinoma of the nasopharynx at a therapeutic dose of 0.05 to 0.1 g. However, precaution should be taken while using *Datura* as an anticancer agent since adverse anticholinergic effects may occur[33]. The half lethal dose (*LD₅₀*) for ethanolic extracts of *D. stramonium* leaves showed potential larvicidal and mosquito repellent activities against *Aedes aegypti* (*LD₅₀*: 86.25 mg/L), *Anopheles stephensi* (*LD₅₀*: 16.07 mg/L) and *Culex quinquefasciatus* (*LD₅₀*: 6.25 mg/L)[34].

4 Dosage

*D. stramonium* is generally administered at a dose of 60 to 185 mg powder for leaf and 60 to 120 mg powder for seed[11].

5 Toxicological assessment

*D. stramonium* is mostly studied for its toxicological properties. *Datura* poisoning is very common in India, usually involving the seeds. Many cases of unintentional poisoning by *D. stramonium* species have been reported when taken accidentally, or as decoction prepared from herbal prescription[35]. General symptoms of *D. stramonium* poisoning include delirium, agitation and seizures, mydriasis, blurred vision, photophobia, dry mouth and mucous membranes, extreme thirst, tachycardia, nausea and vomiting, decreased bowel sounds, difficulty swallowing and speaking, hyperthermia, hypertension, loss of consciousness and coma[6,36,37]. Dugan et al[38] have reported that ingestion of *D. stramonium* seed at concentrations of 0.5% or more in the diet produced adverse physiological changes in rats. Bouzidi et al[39] reviewed the acute, subacute and chronic toxicity studies of alkaloids from the seeds of *D. stramonium*. According to them, single dose acute toxicity of 100 mg/kg *D. stramonium* includes decreases in the weight of the liver, spleen and brain, and significant increases in the levels of red blood cells (RBC), hematocrit (HCT), hemoglobin (HGB), and white blood cells (WBC). Similarly, RBC, HGB, HCT and platelet levels were increased in 4-week subacute toxicity studies. However, the 120-day chronic toxicity study of *D. stramonium* alkaloids showed decreased levels of RBC, HCT, HGB and WBC, with a significant increase in liver enzymes. Fatal dosages of *D. stramonium* toxins occurred with amounts exceeding 10 mg for adults, and 4 mg for children. The amount needed to poison an adult is about 20 seeds, and the estimated LD in an adult is >10 mg atropine or >2 to 4 mg scopolamine[40].

6 Precautions and safety of usage

Almost all the parts of *D. stramonium* are reported to have toxic effects, and the toxicity of this plant is mainly due to the tropane alkaloids. Each part varies in the concentrations of alkaloids and other active substances. For this reason, it is very important for individuals, especially young people, to be aware of the toxicity and potential risks associated with the “recreational” use of this plant. *D. stramonium* in the form of a paste or solution to relieve local pain may not have a deleterious effect; however, oral and systemic administration of the *D. stramonium* may lead to severe anticholinergic symptoms. Various cases of toxic delirium and psychiatric symptoms have been reported after ingestion of *D. stramonium*[36,37,40,41], indicating the necessity of extreme precaution while using this plant.

7 Conclusion

In Ayurveda, different parts of *D. stramonium* are used for various human ailments when applied both locally and through oral administration, but classic Ayurveda lacks specific knowledge on the toxicity of *D. stramonium*. The pharmacological effect of *D. stramonium* described above can be applied through modern or alternative herbal medicine approaches. *D. stramonium* should only be used therapeutically while under the care of knowledgeable health care professionals. The adverse effects of *D. stramonium* can be extremely severe and detrimental. Therefore, even in light of its many beneficial effects, the risk-benefit ratio should be always taken into consideration before using *D. stramonium*.

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9 Competing interests

The authors declare that they have no competing interests.

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