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An Invasive Yet Potentially Diverse and Unexplored Genus: *Typha* L.

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Authors' contributions

This work was carried out in collaboration among all authors. Authors VM, AK, NK, KL, SG contributed in collection of data through extensive literature survey of online and college library resources and drafted the article. Author PV co-supervised the work and contributed to drafting and reviewing the manuscript. Author MS was responsible for the concept, design and supervision of the article preparation process and contributed to critical reading of the manuscript. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Aim: *Typha* genus belongs to the family Typhaceae and is comprising of about 13 known species distributed in the subtropical and tropical regions of North America, South America, Asia, Africa, Australia and Europe. Several species are considered as invasive weeds that colonize wetlands and marshes because they are highly productive by clonal growth, forming very large, persistent and often monospecific stands. This review offers detailed information on the aquatic species of the cosmopolitan genus *Typha* L. with specific focus on their distribution, identification, importance in bioremediation, usability and traditional uses along with chemical and biological diversity.
Methodology: An extensive browsing in three electronic databases (Unbound Medline, PubMed and ScienceDirect) and internet search engines (Scifinder and Google Scholar) enabled us to connote the studies on *Typha* genus available till date.
Results: Literature survey corroborated that some species of *Typha* are valuable as sources of traditional medicine in human health, while some are still widely used for non-pharmacological

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purposes. Numerous phytochemical investigations of plants of this genus confirmed the presence of alkaloids, glycosides, tannins, steroids, phenols, saponins, flavanoids, carbohydrates, proteins, oils and fats. Besides, various studies cited in this review article have demonstrated that the extracts or active substances that have been isolated from the species of *Typha* genus have multiple pharmacological activities.
Conclusion: The review draws the attention of scientists towards the utility and important issues associated with the probable approaches that should be investigated to encourage people to take maximal benefit of the potentially useful species of *Typha* genus.

Keywords: Typha genus; unexplored; aquatic species; phytochemistry.

1. INTRODUCTION

Globally, there is a resurgence of traditional medicines due to a common belief, that unlike modern medicines, they are free from the intrinsic side effects. Over the past three decades, the scientific community worldwide is inclined towards the long-standing traditional systems of medicine to explore the opportunities to formulate novel phytotherapeutic agents. Bioactive compounds are valuable as precursor for the natural, green pharmaceuticals, nutraceuticals, aromatics, cosmetics and pesticides. The genus *Typha* L., the sole member of the family Typhaceae, is one of the most common plants of marshes and shallow waters throughout the world [1,2]. It is almost cosmopolitan in distribution, including 13 species of globally distributed aquatic plants that possibly originated from eastern Eurasia. The plants in this genus are universally known as 'Cattails', 'Reedmace' or 'Bulrush' in British English and 'Corn dog grass', 'Bulrush' or 'Cumbungi' in Australia. These plants grow in various aquatic habitats on all the continents except Antarctica [3]. In India, the genus Typha is represented by four species namely *T. angustata* Bory & Chaub., *T. elephantina* Roxb., *T. latifolia* L. and *T. laxmannii* Lepech. The first two species, *T. angustata* and *T. elephantina* are widespread, while the other two are restricted in their distribution to Kashmir, Punjab, Deccan and Kutch [1,4].

Typha grows wildly in wet soil, roadside ditches, wet meadows, reservoirs, lake shores, marshes and bogs. The basic form for all *Typha* members is clonal with ramets, comprising of leaf systems and their associated rhizomes, roots and inflorescences [5]. People have utilized the plants of *Typha* genus for hundreds of years as almost all parts of the plant are edible. *Typha* genus is also valued for its antimicrobial, astringent, diuretic, emmenagogue, haemostatic, antipyretic, antitumor and anti-inflammatory potential [2,6]. This article is an effort to compile information on all the species of *Typha* genus in a systematic manner so as to provide a single document that would offer several unexplored areas that need to be studied effectively for the utilization of these plants in traditional as well as modern medicine.

2. METHODOLOGY

To collate research data for this investigation, a detailed search on Scifinder, Scopus, Medline, Google Scholar, ScienceDirect and Academic Search Premier Databases was carried out. A Boolean search strategy was adopted where the keywords entered for search were *Typha*, genus, species, distribution, traditional, chemistry, pharmacology and therapeutic uses in differing orders to pool the information for this narrative review.

3. TAXONOMICAL ASPECTS

3.1 Taxonomical Classification [7]

Kingdom	:	Plantae
Subkingdom	:	Tracheobionta
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Typhales
Family	:	Typhaceae
Genus	:	*Typha* L.

3.2 Taxonomical Divergence

Due to the high morphological variability and frequent inter-specific hybridization of plants of *Typha* genus, its taxonomy has been a long-standing debate. Traditionally, the genus was classified into two sections, Ebracteolatae and Bracteolatae, based on the presence or absence of bracteoles in the pistillate flowers, respectively [8,9]. In 1987, a taxonomic revision of *Typha* was done and 8 to 13 species in six groups were recognized (without sections or subsections) on the same basis, in addition to morphological characteristics of the stigma and pollen grains. However, fifteen new species were published after 1987. Some studies showed that the morphological characters of certain new species overlapped with those of existing species [9,10]. Furthermore, botanists questioned the validity of the two new species, *T. tzvelevii* sp. *nova* and *T. joannis* sp. *nova*, based on their similarities to *T. laxmannii* and *T. orientalis*, respectively [6]. Similarly, the validity of three endemic Chinese species (*T. przewalskii*, *T. davidiana* and *T. changbaiensis*) is placed in doubt by two morphological studies, which are supported by a molecular study with extensive sampling throughout China [7,8]. Based on a study, the genus is divided into two clades. The first clade (clade I) consisted of *T. minima* and *T. elephantina* and each species is determined to be monophyletic. The second clade (clade II) included all remaining species and represented a polytomy of four robustly supported subclades. Subclade I included *T. angustifolia* only, while subclade II included *T. angustifolia*, *T. domingensis* and *T. capensis*. Within this subclade, *T. domingensis* and *T. capensis* formed a supported group that is polyatomic with three accessions of *T. angustifolia*. Within subclade III, *T. latifolia* is found to be similar to *T. shuttleworthii* and it is further divided into two supported groups. Subclade IV consisted of *T. orientalis* and *T. laxmannii*, both of which formed their own monophyletic groups [6,8,9].

4. DESCRIPTION

Typha species grow perennially in light (sandy), medium (loamy) and heavy (clay) soils. They can flourish in acidic, neutral and alkaline soils, but do not grow in the shade. These plants prefer moist soils and can grow in water [11].

The main meristem within the ramet is basal and gives rise to both leaves and inflorescences. Flowering generally consumes the meristem and terminates the further production of leaves. These plants are 4-9 feet tall and unbranched with green, glabrous, stiff and round stalk having air cavities. Leaf is ascending, blade plano-convex, flat distally with internal air cavities, sheath-tip lobes may or may not be present [6]. *Typha* species are monoecious and unisexual plants having wind-pollinated flowers, which develop in dense spikes. Inflorescence is terminal bearing sometimes more than 1000 flowers; staminate flowers are distal mixed with many papery scales; pistillate flowers are proximal, clustered on peg-like compound pedicels; bractlets are numerous, thread-like with enlarged tips, generally visible at spike surface, or may be absent based on the types of species. In staminate flowers, stamens are 2-7 on a slender stalk; filaments are also slender, generally deciduous in fruit. In pistillate flowers, the stalk is long-hairy and persistent with a single ovary chamber, single style, and single persistent stigma; many modified pistils show enlarged sterile ovary with deciduous style. Fruits are fusiform, thin-walled, yellow-brown and wind-dispersed. Several species are considered invasive that colonize wetland and marshes because they are highly productive by clonal growth, forming large, persistent and often monospecific stands [6,8,11,12]. The macroscopical characteristics of some popular species are mentioned below:

Typha angustifolia L. (Narrow leaf cattail) occurs from South Nova Scotia (Canadian province) through parts of New England along the coast to southern Florida (USA), in brackish or sub-saline water or moist soil, growing from sea level to elevations of 1900 m [12]. The plants are 1.5 to 3 m tall with perennial and branched stem that is 70 cm long and 2-4 cm in diameter; creeping rhizomes bear dense fibrous roots [9]. The spike-like, terminal, cylindrical inflorescence has staminate flowers above and pistillate flowers below. Sheath-tip lobes are membranous; leaves are strongly plano-convex with parallel venation disintegrating with age; widest fresh blades are 4-15 mm wide and dry ones 3-8 mm wide (Fig. 1). Flowering occurs from June to July and staminate flowers bear a single yellow-coloured pollen grain and an infertile pistillate flower [12].

Fig. 1. Plants of *Typha angustifolia* [13]

T. domingenesis (Per.) Steud. (Southern cattail) mainly occurs in brackish to fresh marshes in North America at elevations from sea level to 2000 m [14]. It is also widespread in tropical, subtropical and warm temperate regions of

America. The plants are 1-6 m in height and 3-4 mm in width with cylindrical and erect shoots; rhizomes with stolons, producing abundant adventitious roots; linear alternatively arranged leaves with glabrous surface, the widest fresh blades being 6-18 mm wide, dry blades 5-15 mm wide. Flowers occurring in June to July are monoecious and straw coloured. The male spike is above the female spike on the stem with a single pollen grain [14].

T. latifolia L. (broadleaf cattail) grows throughout the world from the Arctic till latitude regions, including Britain, India, Australia, Russia and Canada and excluding Africa and South Asia [15]. Plants have 3-7 mm thick stems; 70 cm long, 0.5-3 cm in diameter creeping rhizomes with fibrous roots; linear flat and pale-greyish green coloured leaves with parallel venation. Staminate and pistillate are contiguous. Flowers appear from June to August with pollen grains in tetrads. It grows in shallow water up to 15 cm deep in ponds, lakes ditches and slow-flowing streams, under acidic or alkaline conditions [15].

T. capensis (Rohrb.) N.E. Br. (Bulrush) is a common robust aquatic perennial herb which grows abundantly throughout wetlands (dams, marshes and shallow or stagnant water courses), often forming large colonies in South Africa. It is also distributed in in tropical regions including Northern Africa and the Okavango Delta. The plant is up to 2.5 m in height with branched rhizome and a 2-4 m tall erect stem. Leaves are linear and 2 m long. Flowering stems of both sexes, with characteristic terminal inflorescences, are separate. Male spikes are 8-15 cm long, while female spikes are 12-32 cm long below the male inflorescence [16].

T. elephantina Roxb. (Elephant grass) is a 2-3 m tall plant growing in a salty and arid environment. It occurs in India (Gujarat, Kashmir, Maharashtra, Assam and Punjab), China (Yunnan), North Africa- Algeria to Egypt, Pakistan and Iran [17, 18]. The rhizome is seated 0.8-2 m below the soil surface and bears robust, long roots that are rich in fibres. It is composed of more aerenchymatous spongy tissues, compared to the main species, *T. angustifolia.* The plant produces unisexual flowers from March to August; female and male spikes are larger and more robust and nearly 3-4 times more pollen grains are produced as compared to *T. angustifolia* [19].

T. laxmannii Lepech. (Graceful cattail) is rarely more than 130 cm tall. The plant occurs in Europe (Bulgaria, France, Germany, Italy, Poland, Ukraine, Poland and Romania), South-western Russia, Northern China and India. It has a 60-90 cm long stem; 2-4 mm creeping rhizomes; long narrow sword-like linear green coloured leaves; male spikes are 10-32 cm and female spikes are 4-11 cm in length; flowers are monoecious blooming from July to November; staminate and pistillate flowers are separated by a distance of up to 0.7 cm [20].

T. minima (Dwarf Bulrush) is the smallest of the *Typha* genus. It reaches an average height of 30-80 cm, rarely up to 140 cm. This plant is widespread in temperate Europe and Asia. It also grows in shallow water, ponds and rivers in Northern China. It can grow in alkaline as well as in an acidic environment [21]. The plants have rhizomes growing up to 20 cm deep with 16-65 cm tall slender stalks; shoots are erect and 45-65 cm in length; leaves are basal sheath-like, with or without blades [20]. Flowers are blue-green, linear and narrow. Male flowers are yellow, while female ones are green and both are separate from each other [22].

T. orientalis C. Presi (Raupo or Bulrush cumbungi) is found near ponds and riversides in lowland areas in East-Asian countries like China and Japan as well as Russia, Myanmar, Australia and India (Kashmir and Himalaya) [23]. The plant grows up to 270 cm tall, with robust cream to white coloured rhizomes; 1.3-2 cm tall stems with nodes and internodes; 40-70 cm x 4-9 mm, convex, dark green coloured leaves and elliptic fruits. Flowering occurs in full bloom during May to July. The male flower contains 3 stamens and female flower has 2-2.5 mm long gynophore with hairs on the stalk [23].

T. shuttleworthii Koch & Sond. (Reedmace) is 1.5 m tall and similar to *T. latifolia*. It is a semi-aquatic plant growing in rivers valleys, ditches and streams. It mainly occurs in Eastern France to Ukraine, Western Russia, Poland, Iran and Turkey [24]. Its flowering period is during June to September. The leaves are light green in colour, 1.5 cm wide and 1.5 m long [24]. The plant has dark brown, monoecious cylindrical flowers without a gap between them. Male inflorescence is 4-5 cm (sometimes up to 12 cm) long but 1.5-4 times shorter than female inflorescence [25,26].

T. changbaiensis M. Jiang Wu & Y. T. Zhao. is a plant species native to the Changbai Mountains in the Jilin province of North-eastern China, where it grows in freshwater marshes [22].

T. martini var. davidiana Kronf. is also native to China, growing in freshwater marshes and on the banks of lakes and streams [27].

T. joannis Mavrodiev is found in freshwater marshes and river banks of Mongolia and Amur [28]. This is a rare plant and detailed information of this species is not yet available.

5. USABILITY

5.1 Nutritional Value

All parts of the plant species belonging to *Typha* genus are edible to humans, especially the rhizomes. Evidence of preserved starch grains on grinding stones indicate that they were eaten 30,000 years ago in Europe [29]. In Spring, the root stocks and rhizomes are used as nutritious food as they are more starchy than potatoes and their protein content is similar to maize and rice [30,31]. The roots contain about 80% carbohydrates (including 30-46% starch) and 6-8% protein. The roots are sun-dried and pounded to make nutritious flour [30]. Young shoots are used as substitute for asparagus and tastes like cucumber, but requires a long cooking. They are eaten raw or boiled. The lower parts of the leaves are used in salads, while the young flowers are roasted before eating. Yellow pollens (appearing in mid-summer) are added to pancakes for added nutrition. Pollens are also used as thickener in soups and stews or mixed with flour for enhancing the taste of bread [30]. The seeds are small and have a pleasant nutty taste when roasted. They are ground into flour and used in making cakes. The fixed oil obtained from the seeds is well utilized as edible oil [32].

5.2 Traditional Uses

Typha plants have been reported to have a medicinal potential. Numerous ethnic groups and traditional practitioners use them to treat intestinal disorders. Pounded roots, seeds and dried flowers are used as a poultice for burns and sores. Seed and flower fuzz are also useful in preventing chafing in babies. Young flowers are ingested for the treatment of diarrhoea, while the paste of flowers is applied over wounds due to good healing property. The rhizomes are used in treatment of dysentery, gonorrhoea and measles. The pollen is used as astringent, desiccant, haemostatic and to control uterine bleeding.The plants of this genus are mainly used in folk remedies for the treatment of tumours, as anticoagulant, astringent, sedative and tonics. In Traditional Chinese Medicine (TCM) also, the pollen of *T. angustifolia* is used for improving the microcirculation and also to promote wound healing [33]. The soft and woolly floss of male spikes and ripe fruits are also used in wounds and ulcers as medicated absorbent. The thick fleshy rhizomes are harvested to make decoctions that can be utilized for treatment of diarrhoea, dysentery and other stomach ailments, to treat venereal diseases, to promote fertility in women and libido in men, to improve circulation and also during pregnancy to ensure an easy delivery [34].

In India, *T. angustifolia*, *T. elephantina* and *T. latifolia* are used as an antimycobacterial agent [35]. The pollen of these species is used as diuretic, emmenagogue and haemostatic. The dried pollen is said to be an anticoagulant, but when roasted with charcoal, it becomes haemostatic. The plants are eaten for the treatment of kidney stones, haemorrhage, painful menstruation, abnormal uterine bleeding, post-partum pains, abscesses and cancer of the lymphatic system. These species are also used in the treatment of tapeworms, diarrhoea and injuries [36].

5.3 Other Uses

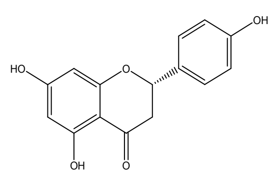
The dried aerial parts of this genus are frequently woven under furniture for mats, in India. Furthermore, their mash and fibres are used to make paper, strings, baskets and as packing material. They are utilized as torches by dipping the head in oil or fat [37]. The fluffy wool of the head is used as diapers because of its softness and absorbency. It is also used as insulation in clothing, pillows, mattresses, quilts and life jackets [37,38]. The whole plant of *T. latifolia* is especially used in flavour, beverage and colour protection industries [39, 40].

6. PHYTOCHEMISTRY

Phyto-constituents such as flavanoids, sterols and triterpenoids are reported as major constituents in the different species of *Typha* [41-51].

The phytochemical screening of crude extracts of aerial parts of *T. latifolia, T. angustifolia* and *T. orientalis* showed the presence of alkaloids, tannins, steroids, phenolics, saponins and flavonoids in the aqueous and methanolic extracts [41]. *T. angustifolia* is documented to contain nonacosanol and lupeol acetate that are responsible for its anti-microbial activity [41,42]. In recent studies, 14 chemical constituents have been isolated and identified from this species, namely *β*-sitosterol, pentacosanoic acid, nonadecanol, naringenin, vanillic acid, nicotinic acid, succinic acid, thymine, daucosterol, uracil, typhaneoside, stearic acid propanetriol ester and isorhamnetin-3-*O*-neohespeidoside [43]. Besides, isorhamnetin-3-*O*-rutinoside, quercetin-3-*O*-neohesperidoside, quercetin-3-*O*-(2^{G}-α-L-rhamnosyl)-rutinoside, isorhamnetin-3-*O*-neohesperidoside, typhaneoside, kaempferol-3-*O*-(2^{G}-α-L-rhamnosyl)-rutinoside, kaempferol-3-*O*-neohesperidoside, 5α,8α-epidioxyergosta-6,22-dien-3*β*-ol, stigmastan-3,6-dione, *β*-sitosteryl-3-*O*-glucopyrano-side-6'-palmitate, *β*-sitosteryl-3-*O*- glucopyranoside-6'-eicosanoic acid, allantoin, 6-aminopurine, hypoxanthine, stearic acid, lauric acid, nonacosanediol-6,8, nonacosanediol-6,10, nonacosanediol-6,21, hexacosanol-1, hexadecanol-1, pentacosane and monopalmitin were also isolated and identified from ethyl acetate and *n*-butanol extracts of pollen obtained from *T. angustifolia* [43-45]. The chemical structures of important constituents are shown in Fig. 2.

Another bioassay-guided study targeting isolation and detection of the active ingredients in pollen of *Typha* having analgesic activity led to identification of naringenin, 4-hydroxy cinnamic acid, 3-methoxy-4-hydroxy cinnamic acid, vanillic acid, isorhamnetin-3-*O*-α-L-rhamnose-based (1→2)-β-D-glucoside, typhaneoside and *β*-sitosterol. Further, an experimental study aiming at evaluation of analgesic activity of pollen of *T. angustifolia* reported seven compounds were isolated and identified, namely zarzissine, choline, pyrimidine-2,4-(1H,3H)-dione(III), 6-methyl-pyrimidine-2,4-(1H,3H)-dione, (S)-N-(2S,3S,4R,Z)-3,4-dihydroxy-1-[(2R,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)tetrahydro-2H-pyran-2-yloxy]nonadec]-8-en-2-yl)-2-hydroxytricosanamide, (S)-2-hydroxy-N[(2S,3R,4E,3Z)-3-hydroxy-1-((2R,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)tetrahydro-2H-pyran-2-yloxy) nonadeca]-4,3-dien-2-yl)nonadecanamide, *β*-sitosterol and stigmasterol [43,46-48].



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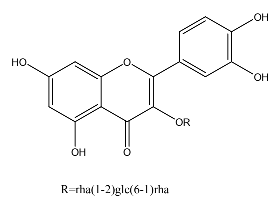

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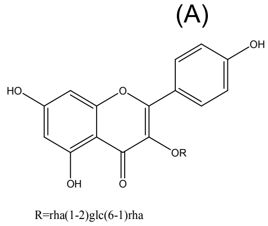

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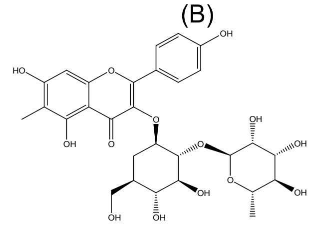

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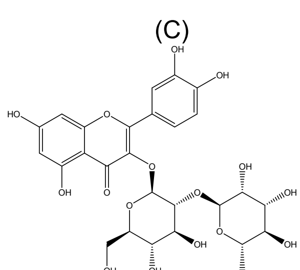

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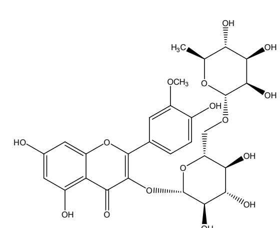

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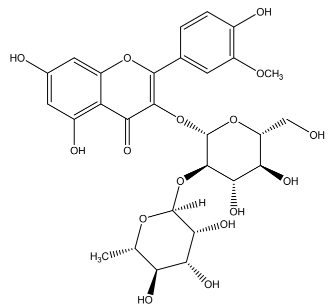

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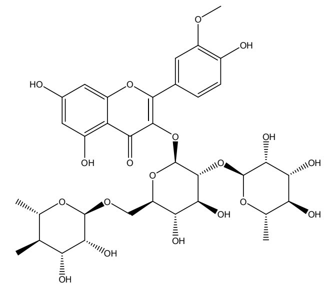

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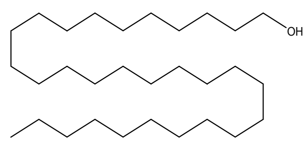

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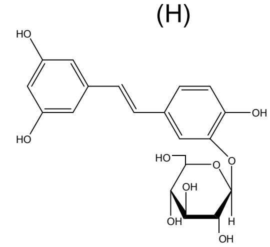

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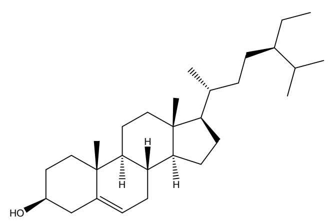

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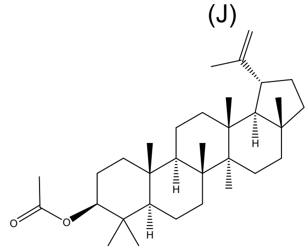

(L)

(M)

Fig. 2. Chemical structures of phytoconstituents found in species of *Typha* genus

(A) Naringenin, (B) Quercetin-3-O-(2G-α-L-rhamnosyl)-rutinoside, (C) Kaempferol-3-O-(2G-α -L-rhamnosyl)-rutinoside, (D) Kaempferol-3-O- neohesperidoside, (E) Quercetin-3-O-neohesperidoside, (F) Isorhamnetin-3-O-rutinoside, (G) Isorhamnetin-3-O-neohesperidoside, (H) Typhaneoside, (I) 1-triacontanol, (J) 3-O-β-D-glucopyranoside, (K) β-sitosterol, (L) lupeol acetate and (M) Nonacosanol.

Phytochemical studies on *T. elephentina* revealed the presence of four constituents, namely pentacosane, *β*-sitosterol, 1-triacontanol and 3-*O*-*β*-D-glucopyranoside [49]. A number of phenolic compounds such as flavanol glucoside, typhaneoside and isorhamnetin-3-*O*-neohesperidoside were found to be present in *T. latifolia* [50]. Sporopolleninm, a biopolymer consisting mainly of unbranched aliphatic compounds with a variable number of aromatics, is the main component of the outer walls of spores and pollen. Sporopollenin from the pollen of *T. angustifolia* is found to be soluble in 2-aminoethanol [51].

7. PHARMACOLOGICAL ACTION

Various plants of the genus *Typha* have pharmacological actions on living organisms.

Several studies have been listed to support this statement [47-68].

7.1 Analgesic Activity

In a study aimed at investigation of analgesic activity of the different fractions of *T. elephantina* using acetic acid-induced writhing test in Swiss albino mice, it was found that all fractions at the doses of 200 and 400 mg/kg b.w. produced significant ($p<0.05$) analgesic action in a dose-dependent manner [52]. Further, it was also noted that petroleum ether, carbon tetrachloride and ethyl acetate fractions of roots (400 mg/kg) produced a maximum of 62.59%, 66.14% and 69.29% inhibition of the writhing, respectively [52]. The pollen of *T. angustifolia* is also reported to produce analgesic activity [47,48].

7.2 Actions on Central Nervous System

T. latifolia is reported to have sedative activity [53], while *T. domingensis* is shown to exert anxiolytic effects [54].

7.3 Actions on Cardiovascular System

Typha angustifolia increase the cyclic adenosine monophosphate (AMP) level and thus possibly prevent and cure coronary heart disease, hyperlipidaemia and myocardial infarction [55,56]. *T. domingensis* and *T. orientalis* have been shown to possess cholesterol and lipid lowering effects [57].

7.4 Antifertility Activity

T. capensis is reported to affects human sperm motility [58,59]. It is found to enhance testosterone production and is suggested to be useful in the treatment of male infertility, libido and ageing problems [58,59]. *T. angustifolia*, *T. orientalis* and *T. latifolia* are reported to contain active constituents that can be used in treatment of dysmenorrhea [57].

7.5 Anti-inflammatory Activity

In an experimental study, pollen of plants of *Typha* genus showed anti-inflammatory action by inhibiting histamine-prompted rodent paw oedema [60]. *T. elephantina*, *T. capensis* and *T. domingensis* are mainly reported to show anti-inflammatory, analgesic and antipyretic activities [61].

7.6 Antioxidant Activity

In a few studies, it was suggested that flavanoids of *Typha* genus play a major role as an antioxidant [33,40,62]. Studies have also shown the relationship between inflammation and antioxidants. The two main flavanoids, typhaneoside and isorhamnetin-3-*O*-neohesperidoside of *T. latifolia* pollen showed antioxidant action in a lipopolysaccharide-induced inflammatory model. Ethanolic and aqueous extracts of *Typha* pollen are reported to exhibit radical-scavenging activity and protect the endothelium from damage caused by lipopolysaccharides. The two flavanoids studied from different species of the *Typha* genus caused an increase in cell survival rate and hence could reduce inflammatory responses. *T. angustifolia* is also shown to have an antioxidant action due to presence of these flavanoids [33]. The female flower and fruit extracts of *T. domingensis* exhibited antioxidant effects when administered internally [62]. A topical preparation of *T. latifolia* is used to reduce skin aging due to its antioxidant potential [40].

7.7 Anti-microbial Activity

The screening of anti-microbial activity of different extracts against various organisms has revealed the anti-microbial potency of *Typha* pollen [36,41,54,63,64]. Methanolic extract is reported to have the highest zone of inhibition against *E. coli,* followed by *P. aeruginosa, S. typhimurium, E.* aerogenes and *K. pneumoniae*. However, the aqueous extract showed greater activity than the methanolic extract in order of highest to lowest against *E. coli, E. aerogenes, P. aeruginosa, K. pneumoniae*and *S. typhimurium*. Chloroform extracts showed moderate inhibitory effect on these organisms. This activity is attributed to the presence of secondary plant metabolites like alkaloids, tannins, steroids, phenols, saponin and flavanoids, which have been reported to exhibit anti-microbial activity [41]. In another study, the leaves of *T. angustifolia* showed antimicrobial potential against Gram positive and Gram negative bacterial strains i.e. *E. coli*, *Staphylococcus aureus*, *P. aeruginosa* and some fungal strains like *Aspergillus niger* and *Aspergillus flavus* [36,63]. *T. capensis* has also shown inhibition of bacterial growth in an antimicrobial assay [54]. *T. orientalis* is also reported to cause inhibition of *E. coli* [64].

7.8 Antitumour and Anthelmintic Activity

T. angustifolia, *T. latifolia*, *T. Elephantine* and *T. orientalis* are documented to exhibit anti-cancer activity against certain types of tumours as well as anthelmintic activity [65].

7.9 ImmunomodulatorActivity

Ethanolic extract of *Typha* pollen has been recorded to suppress conconavalin A and lipopolysaccharide-stimulated spleenocyte proliferation *in vitro* in a concentration-dependant manner [54]. Further, the mechanism of suppressing the formation of antibodies is attributed to its immunosuppressive action. *T. capensis* and *T. domingenesis* are also shown to exert immunosuppressant activity [54,66].

7.10 Miscellaneous Activities

T. angustifolia, *T. orientalis* and *T. latifolia* are reported to contain active constituents that can be used in treatment of stranguria, haematuria, dysmenorrhea, metrorrhagia and general injuries [57]. Species of genus *Typha* are also reported to have astringent properties, thus providing scientific evidence for its traditional uses as anticoagulant, haemostatic and in treatment of diarrhoeal. The inflorescence of *T. elephantina* has been reported to possess membrane stabilizing potential along with thrombolytic and wound healing activities [67,68].

8. VITAL EFFECTS AND MODERN DISCOVERIES

8.1 Carbon Nanotubes

*T. orientalis*is used as precursor to synthesize carbon nanotubes (CNTs) by the combination of hydrothermal and calcination techniques [69]. Supercapacitors as green energy storage devices have gained notable attention due to its high power density, fast charge discharge rate and low cost, when compared with commercial CNTs. It was found that the electrochemical performance of the CNTs from the biomass of *T. orientalis*was 2.7 times higher than that of CNTs obtained commercially. It offers a new way of synthesizing CNTs and may provide unique characteristics to the CNTs. Currently, nitrogen-doped nano-porous carbon nanosheets are prepared from *T. orientalis*. Compared to the preparation of commercial CNTs, biomass-derived CNTs have advantages such as low-cost, environmental-friendly and a scalable approach [69].

8.2 Phytoremediation and Bioenergy Source

The heavy metals pollution of soils and waters has become one of the most serious problems worldwide because these elements are toxic, non-biodegradable and can be incorporated into the food chain. Mercury, cadmium and lead are considered as chief pollutants due to their toxicities and impact on the environment [70]. The removal of these elements from soil and their accumulation by the plants are necessary. Various species of *Typha* genus are capable of removing various pollutants including heavy metals, organic matters and micropollutants [71]. According to few studies, young plants of *T. latifolia*, collected from a non-contaminated site, were studied and results showed that it effectively removed cadmium and lead from waterlogged soil and was able to accumulate these metals in the roots and to a lesser extent in the leaves. *T. latifolia* potentially removed phosphorous from wetlands [70]. The roots of *T. latifolia* are predominantly coated with ferric ions and are shown to form complexes with arsenic, thus decreasing the mobility of this toxic element in wetland sediments [72]. As lead, zinc and copper are found to be least mobile, they have been shown the following accumulation scheme: roots > rhizomes > lower leaves part > top leaves part. In contrast to this, Manganese can be easily transported in the plants as well as accumulated in green plant organs, showing the following order of the accumulation in different parts of the plant: roots > top leaves part > lower leaves part > rhizomes. The concentration of nickel, cadmium and iron, shown to get accumulated by *T. latifolia*, is in the following order: roots > rhizomes > top leaves part > lower leaves part [71]. *T. latifolia* is also recorded to remove the anilines and nitrates from wetlands [73].

Very few records of other species are also available regarding phytoremediation properties. *T. domingensis* is reported to treat waste water because of its adaptability at high pH and salinity. The female flowers and fruit extracts have shown iron chelating effects when consumed [74]. *T. orientalis* is also proven to contribute towards reduction of heavy metals and pesticides level in water bodies [75]. *T. angustifolia* cause phytoremediation of chromium and enzymatic degradation of azo dye [76,77]. In the Ashi River Basin (India), its pollutant removal property has been studied [78]. Moreover, biogas emission by *T. latifolia* at AntiyaTaal Lake (Jhansi) has become an area of interest for scientists in India during the last few years [40].

8.3 Allelopathic Effect

Allelopathy is the production of specific chemicals by plants that are inhibitory or stimulatory for the growth of other plants. A greater cause of extinction of plant species is the competitive effect of exotic plants on the native ones. Studies suggest that among the species of *Typha* genus, *T. latifolia* and *T. domingensis* are notably allelopathic as they produce some phytotoxins [43,79]. A study on the allelochemicals produced by two species of this genus indicated that *T. angustifolia* is invasive, while *T. latifolia* is not invasive in North America [10]. *T. angustifolia* is also shown to exert allelopathic effects on phytoplanktons [76].

9. CONCLUSION

This review is compiled by citing articles published over the period from 1894 till 2020, resulting in approximately 6500 records. The literature survey was aimed at annotating important information to delineate the genus *Typha*.

Typha, the only genus of the family Typhaceae, is one of the most common aquatic plants found in marshes and shallow waters throughout the world. It is taxonomically diverse and its different species can be used to solve many environmental problems, health-related problems and also bioenergy related issues. All parts of plants are edible and therefore may serve as a rich source of fibre and nutrients. This genus also has multiple applications. Records indicate the use of *Typha* as one of the ingredients in traditional remedies, especially Chinese polyherbal formulations used for the treatment of atherosclerosis, cardiovascular diseases, uterus contraction and wounds. It has been used to treat myocardial infarction, anxiety and many more life-threatening diseases. Furthermore, many studies indicate *Typha* as phytoextractor, bioaccumulator and an important element for phytoremediation. Interestingly, no part of the *Typha* species goes waste and are used commercially in making paper, string, biofuel, water, fabric, dye remover and building material.
This review article provides general information about the genus *Typha* L. From the literature survey, it can be concluded that individual species exhibit varying pharmacological actions, yet the collaborative efforts of ethnobotanists, anthropologists, pharmacists and physicians could be a workable strategy to evaluate and validate the usage of this wide spread genus with modern scientific methods and innovative techniques.

CONSENT

It's not applicable.

ETHICAL APPROVAL

It's not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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