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Phog: A nutraceutical shrub of Thar desert

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Abstract
Plant species give essential food, vegetables, and pharmaceutical compounds that help people stay healthy. Since ancient times, many ailments have been treated by plant extracts. Plant-derived compounds play a critical biological function in our body and considered as major source of modern medications. India is noted for having a large number of medicinal and aromatic plants, which are mostly harvested as raw materials for medicine production. Ancient Indian literature has long documented the use of plants for therapeutic purposes. During the previous years of chronic drought in Western Rajasthan, a plant *Calligonum polygonoides* locally known as Phog has become one of the most economically beneficial species. *C. polygonoides* contains a complex variety of phytochemicals including flavonoids, alkaloids, proteins, tannins, steroids, phenols, carbohydrates, and terpenoids etc. This review brief about the morphology and geographical distribution, phytoconstituents, antioxidant potential, medicinal importance, and biological activities of plant *C. polygonoides.*

Keywords: India, Antioxidant, *Calligonum polygonoides*, nutraceutical shrub, phytoconstituents, Thar desert

Introduction
India is blessed with a profound cultural heritage deeply rooted in the utilization of wild plants for herbal remedies. Over its extensive history, the nation has woven customs around the medicinal properties found in the barks, seeds, fruit bodies, and various plant parts. This enduring relationship between humans and nature reflects a continuous quest for healing, showcasing the intricate knowledge passed down through generations. The utilization of wild plants as herbal medicines not only signifies India's cultural richness but also underscores the symbiotic connection between traditional practices and the natural world in addressing human health challenges.

The dry climate of the Thar Desert is characterized by low humidity, sandstorms, minimal precipitation, and variations in daily and annual temperature. Multiple types of the flora that evolved to survive in this severe climate, including bryophytes, pteridophytes, lone gymnosperms, and angiosperms are often classified as hydrophytes, xerophytes, and halophytes based on their unusual morphology (Arora *et al.*, 2010) [4]. *Calligonum polygonoides* L. commonly known as 'Phog' or 'Phogla' in western Rajasthan is a shrub found mainly in the Thar Desert. It is the most suitable species in terms of sand dune stabilization, fuel and fodder production with minimum use of water in arid regions. *C. polygonoides* is incredibly resistant to frost and drought in its natural habitat in the Rajasthan desert (Kumar *et al.*, 2015) [11]. The extracts of *C. polygonoides* demonstrate the potential of tissue culture to serve as a sustainable and alternative source of secondary metabolites from a valuable medicinal plant, and also presents a good opportunity to increase such secondary metabolite yield. With the use of biotechnological methods, field crops could no longer be the primary source of this essential pharmaceutical raw material (Owis *et al.*, 2019) [13]. The present review gives a detail insight to nutraceutical potential of *C. polygonoides.*

Classification
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Caryophyllales
Family: Polygonaceae
Genus: *Calligonum*
Species: *polygonoides*

Geographical distribution

The genus *Calligonum*, initially established by Linnaeus, comprises over 150 species, as documented in The Plant List of 2013, curated by the Royal Botanical Garden Kew. Linnaeus's taxonomy laid the foundation for recognizing and categorizing this diverse genus. The comprehensive list compiled by the Royal Botanical Garden Kew serves as a valuable reference, encompassing the extensive diversity within the *Calligonum* genus. This compilation aids researchers, botanists, and enthusiasts in understanding and studying the various species of *Calligonum*, contributing to our knowledge of plant biodiversity and facilitating further exploration of their ecological roles and potential applications. More than 80 species are well distributed in different countries, including northern Africa, southern Europe, and western Asia (Samejo *et al*., 2013) [18]. There are two species known to be found in India: *C. polygonoides* L and *C. comosu*m L'Her.

Calligonum polygonoides, a notable species within the *Calligonum* genus, thrives in the arid landscapes of the Western Asian Thar Desert. Its habitat encompasses diverse regions, extending from Northeast Afghanistan, Persia, Armenia, and Syria to Southern Punjab and Western Rajasthan in India, and the Boogtee Hill in Pakistan. This resilient plant has adapted to harsh conditions, showcasing its ability to survive in arid climates. The distribution of *C. polygonoides* across these geographically distinct areas underscores its ecological versatility and highlights its significance in the arid ecosystems of the mentioned regions, contributing to the unique biodiversity of the Western Asian Thar Desert. (Talbot *et al.* 1976) [24]. *C. polygonoides* thrives as psammophytic flora in the arid regions of Rajasthan, specifically in the districts of Barmer, Bikaner, Churu, Jaisalmer, Jhunjhunu, Jodhpur, Nagaur, Sikar, and Shri Ganganagar. This resilient species has adapted to the challenging environment of sand dunes in these districts. The plant's ability to flourish in such sandy terrains showcases its remarkable adaptation to arid conditions, playing a vital role in stabilizing the dunes and contributing to the overall ecological resilience of these regions. Its presence in these specific districts highlights its significance in the local ecosystems and its integral role in sustaining biodiversity in the desert landscape (Shankarnarayan, 1988) [21].

Plant profile

C. polygonoides, a mid-size shrub, typically reaches a height of 1.38m, exhibiting a Y-shaped crown. (Rathore *et al*. 2015) [17]. *C. polygonoides*, a remarkable shrub, with a diameter ranging from 1.66 to 1.82 meter, where the stem forms the predominant structure. The stem exhibits prominent nodes and internodes, establishing robust connections with branches. Its leaves are simple, needle-like, stipulate, and characterized by reduced scales, adapting effectively to arid conditions. The regular, tiny, white, bisexual flowers add a delicate charm to the plant (Fig.1). Notably, the rectangular fruit structures resemble nuts, encapsulating tiny spherical seeds. The shrub's roots are massively branching and tap rooted, enhancing stability in the sandy terrain. This prostrate shrub, with its unique morphology and adaptive features, symbolizes resilience, thriving in arid landscapes with its extensive, outward-shooting roots. (Swarnkar *et al.* 2019) [23]. The flower buds, also known as "Phogla" in the western Rajasthan, are only available for one to two weeks. Depending on the climatic conditions, the fruits mature in the first week of April and the majority of them fall in the last week of April (Purohit and Kumar, 2020) [16].

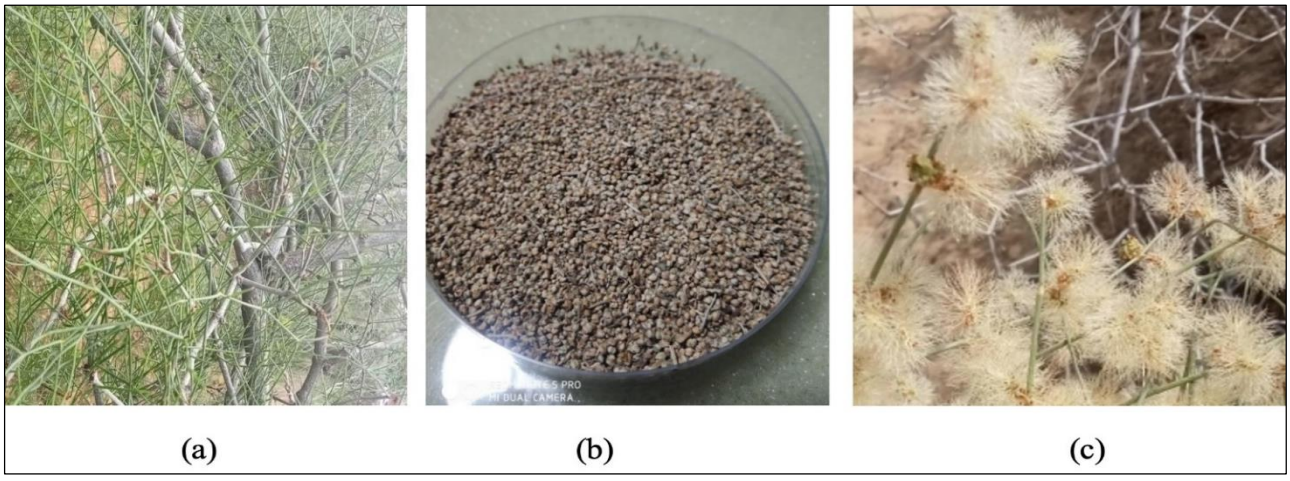

Fig 1: Parts of *Calligonum polygonoides* (a) Stem (b) Flower bud (c) Fruit

Phytoconstituents

The phytochemical content, antioxidant capacity, and enzyme inhibitory qualities of several extracts with different solvents derived from the *C. polygonoides* plant were examined (Table 1). β-glucogallin, 3, 4-dihydroxybenzoic acid, 2, 4, 6-trihydroxybenzoic acid, 4-O-methyl-gallate, ethylvanillin glucoside, dihydroferulic acid, 4-O-glucuronide, 2-hydroxy-3, 4-dimethoxybenzoic acid, gallic acid, and rhododendrin were among the major phenolic constituents found in this plant. Likewise, the flavonoid derivatives listed were dihydrorobinetin, 6-hydroxyluteolin 5-rhamnoside, 8-hydroxyluteolin 8-glucoside, robinetin 3-rutinoside, isoetin 4′-glucuronide, and tricetin 3′-methyl ether. Flavones such as Scutellarein 4′-methyl ether with 7-glucuronide Melanoxetin, 7-glucuronide, 6,8-di-C-beta-D-arabinopyranosylapigenin, 5,7-tetrahydroxyflavone, 2′, 3′ 5,6,7,3′,4′-tetrahydroxyflavone 7-glucuronide, tricetin 3′-methyl ether, 6-hydroxyluteolin 5-rhamnoside, isoetin 4′-glucuronide, and 5,6,7,2′-pentahydroxy-8-methoxyflavone 7-apioside also reported in the plant. *C. polygonoides* also contains 7-glucuronide, medicarpin 3-O-(6′-malonylgluclside), terpenes such as emmotin, salannin, and alkaloids such as ecgonine in various extracts. (Pervaiz *et al.* 2020) [15]. The study on *C. polygonoides* revealed varying antioxidant activities, total phenolic, and flavonoid contents in different plant parts. Notably, the bark and leaves emerged as rich sources of these

phytoconstituents. Chromatographic analysis highlighted distinct distributions of phenolic constituents within various plant organs. Flowers and fruits exhibited the highest concentrations of flavonols, while leaves, stems, and bark displayed richness in taxifolin and catechin. This nuanced distribution underscores the plant's organ-specific synthesis of bioactive compounds, offering insights into potential medicinal or nutritional applications, emphasizing the significance of diverse plant parts in harnessing specific phytochemical benefits. (Ahmed *et al*. 2020) [3].

C. polygonoides extracts from the flower buds, leaf, bark, and roots demonstrated potential antioxidant activity and were one of the greatest sources of phenolic compounds. The beauty of this plant is its ability to create a lot of biomass and bioactive substances despite having very limited resources. Fifteen phenolic components were identified and measured in extract of this plant; gallic acid content was the most common, followed by catechin. Other important phenolic compounds present in different plant components included vanillic acid, epicatechin, coumaric acid, epicatechin, catechol, and syringic acid. Total phenolics, flavonoids, and antioxidant capacity all showed extremely high values (Berwal *et al.* 2021a) [5]. The antioxidant potential assay and gas chromatography mass spectrometry (GCMS) study of a methanolic extract of a *C. polygonoides* flower bud were performed and around 93 substances identified in the results including hexanoic acid, decanal dimethyl acetal, pantolactone, benzoic acid trimethylsilyl ester, 1,2-Benzenediol catechol, dehydromevalonic lactone, deoxyspergualin, benzoic acid, 1,3-diethylimidazolidine, tetradecanoic acid, nonanoic acid, eicosanoic acid, octadecanamide, tetratriacontane, squalene, 1-triacontanol, 2-nonadecanol, trichloroacetic acid hexadecyl ester, pentafluoropropionic etc (Berwal *et al.* 2021b) [6].

Table 1: Phyto-chemical constituents present in different parts of *Calligonum polygonoides*:

S.No.	Plant Part	Compound	Reference
1.	Stem	*p*-Coumaric acid, Quercetin, Kaempferol, Taxifolin, Astragalin, Isoquercitrin, Rutin, Naringenin, Epicatechin gallate, Vanillin, Gallic acid, Protocatechuic acid, Catechin hydrate, Chlorogenic acid, Caffeic acid,2-Methoxy-4-vinylphenol, 3-O-glucuronide, isoterpinolene, 5-Pentyl-2(5H)-furanone, Decanoic acid, and Drimenol.	Samejo *et al.* 2017 [20] & Ahmed *et al*. 2020 [3]
2.	Flower buds	Protocatechuic acid, Gallic acid, Rutin, Rutin hydrate, deoxyspergualin, Tetradecanoic acid, 1-Triacontanol, Pantolactone, 2-Hexenoic acid, Decanal dimethyl acetal, Pantolactone, 2-Pyrrolidinone, Benzoic acid trimethylsilyl ester, Cyclopentanethiol, Tetradecanoic acid, Nonanoic acid, 1-Triacontanol, Pentafluoropropionic and Catechin hydrate.	Samejo *et al.* 2017 [20] & Berwal *et al*. 2021(a, b) [5-6]
3.	Flower	Gallic acid, Astragalin, Isoquercitrin, Quercetin, Taxifolin, Catechin, Kaempferol, Quercetin-3-O-glucuronide and Kaempferol-3-O-glucuronide	Ahmed *et al*. 2020 [3]
4	Fruit	Gallic acid, Astragalin, Isoquercitrin, Quercetin, Taxifolin, Catechin, Kaempferol, Methyl jasmonate, 9,12-octadecadienoic acid methyl ester, kaempferol-3-O-glucuronide, quercetin-3-O-glucuronide, and etracosanoic acid methyl ester	Ahmed *et al*. 2020 [3]
5	Root	Quercetin, Kaempferol, Campesterol, Epicatechin, Gallic acid, Catechin, Chlorogenic acid, Caffeic acid, Coumaric acid, and Stigmast-4-en-3-one and Stigmasterol-stigmastan-3-ol.	Samejo *et al.* 2013 [18]

Biological activities

Biological activity refers to a molecular entity's capacity to induce a specific biological effect on a target, quantified by the required amount of the molecule to elicit the activity, assessed through biological assays. In the plant kingdom, diverse biologically active substances act as defensive mechanisms against pathogens, insects, and microbes. *C. polygonoides*, a plant of particular interest, exhibits notable biological activities (Figure 2). These include antimicrobial properties that help combat pathogens, anti-insect capabilities as a defence against insects, and potentially other yet-to-be-discovered bioactive traits (Table 2). Studying the biological activities of plants like *C. polygonoides* not only contributes to understanding their ecological roles but also unveils opportunities for harnessing these natural compounds for medicinal or agricultural purposes, showcasing the multifaceted significance of plant biology in various fields. *C. polygonoides* showed following biological activities in various studies.

1. Antibacterial activity

Extract prepare from stem of *C. polygonoides* showed antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* bacteria (Mukhtar *et al.* 2018) [12]. A crude extract from *C. polygonoides* had strong inhibitory effects on *Escherichia coli* and *Pseudomonas aeruginosa*. *C. polygonoides* methanol and ethyl acetate fractions show exceptional efficacy against both bacteria. Chloroform fraction of *C. polygonoides* showed second highest inhibitory zone (Shinwari *et al*. 2019) [22].

2. Antifungal activity

Aspergillus niger and *Aspergillus flavus* fungus are most inhibited by the methanolic extracts of *C. polygonoides* and *Rosa brunonii*, but *Sueda fruticosa* has the least inhibitory impact on both fungal species. *C. polygonoides* methanolic extract has antifungal activity against two fungus strains (*Aspergillus niger* and *Aspergillus flavus*) (Khan *et al*. 2017) [9]. The methanolic extract, hexane extract, ethyl acetate extract, and aqueous extract of *C. polygonoides* were used to evaluate *Aspergillus niger* and *Candida albicans*. The reported minimal inhibitory concentration (MIC) of *C. polygonoides* for the methanolic extract was 6.5 g/mL, and the MIC for the ethyl acetate extract was 9.8 g/ml. aqueous and hexane extracts did not exhibit any significant activity (Ahmad and Akram, 2019) [1].

3. Anti-urease activity

High urease-inhibitory activity can be seen in the *C. polygonoides* plant's n-hexane fractions. In order to treat pathological diseases and infections linked to urease, innovative antibacterial medicines with improved efficacy and decreased antibiotic resistance may one day be developed using this plant-based anti-urease fraction as a starting point (Pervaiz *et al.* 2019) [14].

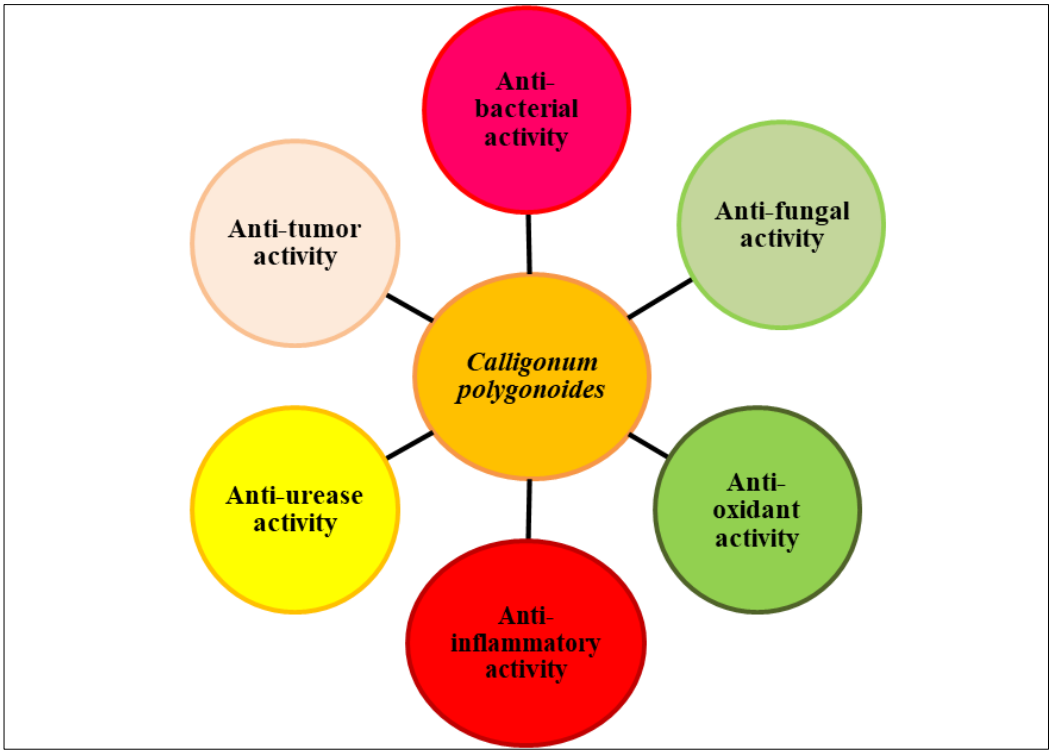

Fig 2: Different biological activities found in *C. polygonoides.*

4. Anti-tumour activity

Methanolic extract was used for *in vitro* biological experiments against brine shrimps. Primary cytotoxicity screening of the plant gives useful information about the plant's extract's anti-tumour and anti-cancer properties for future usage. Testing and documentation were done on the cytotoxic impact of *C. polygonoides* methanolic crude extract (CPME) on brine shrimp growth. The findings of this study suggest that *C. polygonoides* contains noteworthy bioactive chemicals that are anti-oxidant, antifungal, and cytotoxic (Khan *et al.* 2015) [8]. The hydro ethanol extract of *C. polygonoides* was used to isolate flavonoids, which were then tested for cytotoxicity against the HepG2 liver cancer cell line and the MCF-7 breast cancer cell line. From the aerial portions of *C. polygonoides*, a novel flavonoid called kaempferol-3-O-D-(6″-n-butyl glucuronide) and 13 other recognized flavonoids were extracted. HepG2 and MCF-7 cell lines were significantly cytotoxic to quercetin when exposed to them (Ahmed *et al.* 2016) [2].

5. Anti-inflammatory activity

In HEK293 cells, the methanol extract and ethyl acetate fraction of *C. polygonoides* L. shown anti-inflammatory effectiveness against the NF-κB translocation pathway. When compared to other flavonoids such as taxifolin, catechin, and mequilianin, the flavonoid glycoside kaempferol-3-O-D-glucuronide exhibited the greatest reduction of NF-β. Consequently, an extensive level of anti-inflammatory activity against NF-β-translocation was observed in a methanic extract of the aerial parts of *C. polygonoides* (Zaher *et al.* 2020) [26].

6. Antioxidant activity

DPPH and ABTS radical scavenging assay were performed for evaluating antioxidant potential. *C. polygonoides* extract possess significant antioxidant potential (Khan *et al.* 2017b) [10] Antioxidant potential and total phenolic compound of *C. polygonoides* stem and buds extract were demonstrated using DPPH radical scavenging assay. Stem extract provide better protective effect compare to bud's extract against free radical oxidative damage (Samejo *et al.* 2017) [20].

Since phenolic compounds and antioxidant activity exhibit a high positive correlation, phenolic compounds are likely the main antioxidants in *C. polygonoides* leaf. The only factor influencing the phenolic content and antioxidant activity throughout harvest season is the ambient temperature, with the highest values recorded during harsh winter and summer months. To obtain the highest output of phenolic bioactive components, two harvests of *C. polygonoides* foliage are recommended, one in June and second one in December (Berwal *et al.* 2021c) [7].

Table 2: Various biological activities exhibited by different parts of *Calligonum polygonoides*

Activity	Plant Part	Model	Reference
Antibacterial	Stem	*Escherichia coli* and *Staphylococcus aureus*	Mukhtar *et al.* 2018 [12]
	Whole plant	*Escherichia coli* and *Pseudomonas aeruginosa*.	Shinwari *et al.* 2019 [22]
Antifungal	Whole plant	*Aspergillus niger* and *Aspergillus flavus*	Khan *et al.* 2017 [9]
	Root	*Aspergillus niger* and *Candida albicans*	Ahmad & Akram, 2019 [1]
Anti-tumour activity	Whole plant	Brine shrimps	Khan *et al.* 2015 [8]
	Aerial	HepG2 liver cancer cell line and the MCF-7 breast cancer cell line	Ahmed *et al.* 2016 [2]
Anti-inflammatory	Aerial	HEK293 Cell line	Zaher *et al.* 2020 [26]
Anti-oxidant	Stem and Flower bud	*In-vitro* Spectro-photometrical Analysis	Samejo *et al.* 2017 [20]
	Flower bud, Foliage, Root, Bark	*In-vitro* Spectro-photometrical Analysis	Berwal *et al.* 2020 [5]
	Foliage	*In-vitro* Spectro-photometrical Analysis	Berwal *et al.* 2021(c) [7]

Conclusion

For centuries, plant-derived phytoconstituents have served as vital sources for medicinal compounds, forming the foundation for numerous drugs. *C. polygonoides* has been identified as a repository of diverse phytochemicals, holding significant potential for medicinal applications. The rich history of utilizing plant extracts for therapeutic purposes underscores the importance of exploring the medicinal potential of phyto-compounds from *C. polygonoides*. Rigorous verification and in-depth studies are imperative to understand the precise therapeutic properties, dosage, and safety profiles of these compounds.

The exploration of *C. polygonoides* in pharmaceutical research unveils promising prospects. Comprehensive investigations can unravel novel bioactive compounds with therapeutic effects, potentially addressing various health challenges. Given the global demand for sustainable and effective medicinal resources, the pharmaceutical investigation of *C. polygonoides* presents an opportunity for the development of new drugs or supplements. The undergoing research in our laboratory on plant's untapped potential underscores the importance of continued research, offering a pathway for harnessing nature's bounty to advance healthcare and pharmaceutical innovation.

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