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A Comprehensive Review Study on Ecological Landscape of *Oroxylum indicum*

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Abstract

Oroxylum indicum, commonly called the Indian trumpet tree, is a tropical species that grows in India, Malaysia, Indonesia, China, Sri Lanka, and Japan. Numerous chemical compounds, including biochanin-A, tetuin, anthraquinone, ellagic acid, baicalein—including its 6- and 7-glucuronides—scutellarein and aloe-emodin—can be extracted from the various portions of this plant. Components of plant are extremely useful for the traditional medicine and Ayurveda to recover from range of diseases, including diarrhoea, cancer, ulcers, fever, and jaundice. According to current research, this plant has anticancer, antioxidant, antibacterial, antimutagenic, hepatoprotective, photocytotoxic, antiproliferative, antiarthritic, and anti-inflammatory properties. It also functions as an immune stimulant. The *Oroxylum indicum* may face threats such as habitat loss due to deforestation, land conversion for agriculture, and urbanization. Therefore, it required serious efforts to conserve this important plant species. *Oroxylum indicum* is a significant plant species with various ecological, cultural, and medicinal importance. Therefore, this review majorly explains medicinal properties and conservation strategies of *Oroxylum indicum*.

Key Words: *Oroxylum indicum,* trumpet tree, distribution, conservation, and sustainability.

Introduction

Nowadays, there is a worldwide increase in curiosity about plants and herbal remedies, which is being matched by a rise in laboratory investigations into the pharmacological characteristics of the bioactive components and their potential to treat different ailments (Mohanta et al., 2018; Sonbol et al., 2021; Deepa et al., 2022; Ameen et al., 2023). The research on these bioactive components, their characteristics, and several medicinal properties have made their way onto

the global market (Saravanan et al., 2018; Ameen et al., 2019; Ameen et al., 2023). Even though a large number of plants including fungi and lichens are studied scientifically (Singh et al., (2018); Singh et al., (2019); Singh and Arya, (2019); Arya et al., (2020); Srivastava and Arya, (2021); Shivani et al., 2021; Singh and Arya, (2023); Sethi et al., (2023); Srivastava et al., 2023; Bee et al., 2024) and from them only a tiny number of commercially viable medications or botanical compound elements have made their way into evidence-based treatments (Nakahara et al., 2002; Patil et al., 2019; Arya et al., 2021; Panwar et al., 2024; Singh et al., 2024). For thousands of years, the indigenous medical system and Ayurvedic medicine have used *Oroxylum indicum*, often known as "Sonapatha," as a significant herb. In the Indian medical system or Ayurveda, *Oroxylum indicum* has been employed either as a stand-alone medication or as a component of specific polyherbal therapeutic compositions. It is an effective constituent of popular Ayurvedic remedies like Dashmularistha and Chyavanprash. Due to their antiallergic qualities, the root and stem bark is used to cure a variety of conditions, including jaundice, asthma, sore throats, measles, laryngitis, infantile erythema, urticaria, hoarseness, gastralgia, diarrhea, and dysentery (Dev et al., 2010).

Oroxylum indicum belongs to the kingdom *Plantae,* Class *Magnoliophyta*, Order *Lamiales*, Family *Bignoniaceae*, Genus *Oroxylum*, and Species–*Indicum*. *Oroxylum indicum* is a deciduous tree growing throughout India, Myanmar, Bangladesh, South East Asia, South Asia, Sri Lanka, Philippines, Bhutan, Indonesia, China, Mallaca and Malaysia. It usually grows in subtropical and tropical climates, with a preference for damp deciduous forest regions. It is typically found in ravines, wet areas of forests, and damp regions up to an altitude of 1200 meters (Chauhan, 1999). It is found in North East India, the Eastern and Western Ghats, and the slopes of the Himalayas (Jayaram and Prasad, 2008). It is primarily seen on hillside or riverbank slopes. The actinomycete *Pseudonocardia oroxyli*, which grows in the soil around the roots, has an association with *Oroxylum indicum* (Qiang et al., 2006; Singh and Chaudhary, 2011).

Researchers are continuously interested in the chemical components of *Oroxylum indicum*. The availability of many secondary metabolites in different areas of the plant includes flavonoids, glycosides, alkaloids, tannins, terpenoids, etc. (Samatha and Swamy, 2020). *Oroxylum indicum* plays a role in the ecosystem by providing habitat and food for various wildlife species. Its large, showy flowers attract pollinators, contributing to ecosystem diversity. *Oroxylum indicum* contains bioactive compounds with potential medicinal properties. Several previous studies have shown that it possesses antioxidant, anti-inflammatory, antimicrobial, and anticancer activities, among others. Extracts from different parts of the plant are being studied for their pharmacological potential. The plant also has economic importance, as its various parts can be used in industries such as pharmaceuticals, cosmetics, and food. Sustainable harvesting and cultivation of *Oroxylum indicum* could provide livelihood opportunities for local communities. Overall, *Oroxylum indicum* is a valuable plant species with diverse ecological, cultural, medicinal, and economic significance. Ensuring its conservation and sustainable management is essential for maintaining biodiversity and harnessing its potential benefits for future generations (Singh and Chaudhary, 2011).

The conservation status of *Oroxylum indicum* varies across its range. In some areas, it may face threats due to habitat loss, deforestation, and over-exploitation. However, it is not currently listed as endangered globally. Local conservation efforts and awareness programs may be necessary to protect its populations, especially in areas where it faces threats. Therefore, sustainable management practices can help to ensure the future sustainability of *Oroxylum indicum*. This may include measures such as promoting its cultivation in agroforestry systems, establishing protected areas where it occurs naturally, and regulating its harvest to prevent over-exploitation. Additionally, research into its propagation methods, ecological requirements, and potential cultivation in different regions could contribute to its long-term sustainability. This review may help to enhance the knowledge and understanding of the properties, distribution, and significance of *Oroxylum indicum*.

Description of *Oroxylum indicum*

The Indian trumpet tree, or *Oroxylum indicum,* is a member of the *Bignoniaceae* family. This deciduous tree, which is small to medium in size, can reach a height of 12 meters. It has enormous, flat, sword-shaped capsules that are filled with numerous flat, papery thin seeds that are spherical and have broad, papery silvery wings. It also has large, ovate or elliptic leaves that are pinnate, bipinnate, or tripinnate (Samatha and Swamy, 2020). The tree also has

lurid purple, fleshy, foetid flowers. According to Samatha and Swamy, (2020), the tree blooms at night, and its flowers are suited for bat pollination. The leaves have a broad length of 2 to 4 inches, while the leaflets have sharp edges and are 5 inches long but 3 to 4 inches broad. The flower stalk measures one foot in length. Fruits vary in length from one to three feet and width from two to four inches. The seeds are flat, measure two inches in width and three inches in length. Fruit appears from December to March, while flowers bloom throughout the rainy season (Fig 1) (Dev et al., 2010; Thokchom et al., 2014; Mamun-Or-Rashid et al., 2017).

Fig. 1: ***Oroxylum indicum:*** **(A) Plant; (B) Fruit; (C) Seed; (D) Flower**

Distribution of *Oroxylum indicum*

Oroxylum indicum is indigenous to the Indian subcontinent, namely the Indo-China ecozone, the Himalayan foothills, Bhutan, and southern China. According to reports from Sri Lanka, it is widely available in the Assam National Park's Forest. *Oroxylum indicum* is a deciduous tree that grows in the Philippines, Mallaca, Southeast Asia, and South Asia. It is typically found in ravines, moist areas of woods, and damp regions up to an altitude of 1200 meters. It is available in the North East India, the foothills of the Himalayas, and as well as in the Eastern and Western Ghats. It is primarily observed on the hills or along the banks of rivers. *Pseudonocardia oroxyli*, an actinomycete found in the soil around the roots, coexists with *Oroxylum indicum* (Dev et al., 2010; Singh and Chaudhary, (2011)**;** Samatha and Swamy, 2020).

Chemical constituent of *Oroxylum indicum*

Flavones and their glycosides, chrysin (5,7-dihydroxy flavone), chrysin-7-O-glucuronide, chrysin-diglucoside, scutellarein and its 7-glucuronides, 6 and 7-glucuronides of baicalein, anthraquinone and aloe-emodin, baicalein (5, 67-trihydroxy flavone), and irridoids are all known to be present in the leaves of *Oroxylum indicum*. Baicalein 7-O-glucoside, chrysin, baicalein, and baicalein-7-O-diglucoside were separated from extract of *Oroxylum indicum* leaves prepared in ethyl acetate. Chrysin-7-O-glucuronide, Chrysin-diglucoside, and baicalein were isolated from the methanolic extract prepared by leaves of *Oroxylum indicum* (Singh and Chaudhary, (2011)). A gummy substance obtained from the chloroform extraction of defatted leaves yields aloe-emodine and anthraquinone (Kapoor, (2001); Chen et al., 2005; Jayaram et al., 2008; Yuan et al., 2008). Stosterol and prunetin are found in heartwood. Fruit pod methanol extract is said to include triterpene carboxylic acid, ursolic acid, chrysin, and baicalein. A variety of oils and flavonoids, including saponins, 6-glucoside of baicalein,chrysin, baicalein, tetuin, baicalein, benzoic acid, terpenes, alkaloids, baicalein-7-O-diglucoside (Oroxylin B), and fatty acids, are found in seeds. Oleic, linoleic, palmitic, palmotoleic, stearic, lauric, and caprylic acids are all present in the seed oil. Twenty percent glossy oil is also present in seeds. Scitularéin was obtained from the ether extract of *Oroxylum indicum* (Kapoor, (2001); Chen et al., 2005; Jayaram et al., 2008; Yuan et al., 2008; Singh and Chaudhary, (2011)). Flavones such as oroxylin A (5,7-dihydroxy-6-methoxy flavone), chrysin, baicalein along with its 6 and 7-glucuronide, scutellarin-7-rutinoside, ellagic acid, galactose, sitosterol, alkaloids, biochanin-A, and baicalein are found in stem bark. Two flavonoids have been identified in the ethyl acetate extract of *Oroxylum indicum*

roots first is 3,7,3',5', -tetramethoxy-2-hydroxy flavone, and another second is 2,5-dihydroxy-6,7-dimethoxy flavone. The contents of root bark include sitosterol, ellagic acid, oroxylin-A, galactose, baicalein, scutellarin-7-rutinoside, biochanin-A, chrysin, weak acids, and traces of alkaloids. 6-methoxy-5,7-dihydroxy flavone Singh and Chaudhary, (2011). Scillaréin and Baicalein were produced using aqueous mother liquor. The main flavonoid identified in petroleum ether extract is baicalein (Table 1) (Kapoor, (2001); Chen et al., 2005; Jayaram et al., 2008; Yuan et al., 2008; Vineeta et al., 2019; Salleh et al., 2020).

Table 1: Chemical Constituents of *Oroxylum indicum* parts

Plant Part	**Chemical Constituent**	**Biological Activities**
Root Bark	Bhrysin, dihydro baicalein, iso-flavone, â-sitosterol, baicalein, oroxylin A, and prunetin	Neurogenesis, Cardioprotective, Wound healing, antimicrobial
Root and Stem	Oroxylin A, p-hydroxy phenylethanols, pterocarpan, rhodioside, baicalein, chrysin, and cyclohexanols	Anti-cancer
Stem Bark	Tannic acid, Alkaloids, sitosterol and galactose	Anti-cancer, Anti-hyperglycemia, antioxidant, Neurogenesis, Anti-inflammatory, Wound healing
Leaves	Scutellarein anthraquinone, flavones, glycosides, baicalein, and aloe-emodin	Anti-cancer
Seeds	Chrysin, baicalein-7-O-diglucoside or Oroxylin B, baicalein, baicalein-7-O-glucoside,	Anti-hyperglycemia
Fruits	Chrysin, oroxylin A, ursolic acid and aloe-emodin	Antibacterial, antioxidant, Anti-adipogenesis

Importance of *Oroxylum indicum*

Oroxylum indicum has a great significance for the pharmacology and medicinal purposes (Fig 2). The plant's root bark is sharp, bitter, and astringent to the bowels. It also has cooling, aphrodisiac, tonic, and appetite-boosting properties. It is beneficial for treating "vata," vomiting, bronchitis, intestinal worms, dysentery, biliousness, leucoderma, asthma, fevers,

inflammation, and anal problems. Diaphoretic, dysentery, diarrhea, and rheumatism are among some medical conditions it treats. A paste composed of sesame oil (*Sesamum indicum*) and powdered root bark of *Oroxylum indicum* is used as an aid for digestion. Oral use of the purgative seeds is recommended for the treatment of hypertension and throat infections (Singh et al., 2002; Dev et al., 2010).

The fruits are sweet and bitter, stomachic and anthelmintic, useful in treating heart and throat conditions, piles, bronchitis, and acting as an anticipatory. They also enhance appetite and are beneficial for leucoderma. However, various parts of plants are prescribed as a medicine for snake bites. Leaves are applied externally to relieve headaches, ulcers, and enlarged spleen. They are also known to have analgesic and antibacterial properties. In Nepal, a root decoction is used to treat dysentery and diarrhea. Seeds of *Oroxylum indicum* also consisting digestive properties. Wounds and boils are treated with a paste made from seeds (Dev et al., 2010). Astringent, aphrodisiac, anthelmintic, expectorant, anti-inflammatory, and tonic properties are all associated with the root of *Oroxylum indicum*. The bark of *Oroxylum indicum* helps with diarrhea and dysentery and is stomachic and diuretic condition. The seeds and bark of the root have astringent, diaphoretic, stomachic, tonic, and carminative properties. Furthermore, cough, diarrhoea, dysentery, and bile problems can also be treated with root bark of *Oroxylum indicum* (Dev et al., 2010).

The most popular Ayurvedic medicines, including Brhatpancamulyadi kvatha, Amartarista, Dantyadyarista, Dasamularistha, Syonaka putapaka, Syonaka side ghrta, Dhanawantara Ghrita, Brahma Rasayana, Narayana Taila, and Chyavanaprasa, utilize *Oroxylum indicum* as one of their key ingredients (Zaveri et al., 2008). The biological effects of flavonoids include inducing antiangiogenesis, apoptosis, antiproliferation, cell cycle arrest, and antioxidation, or a combination of these. The anti-inflammatory and anti-allergic properties of flavonoids are well-established (Kao et al., 1998). One flavone that exhibits a wide range of biological properties is chrysin that include antibacterial, antioxidant, anti-inflammatory, anti-allergic, anti-cancer, anti-estrogenic, and anxiolytic properties. In order to enhance the antibacterial activity of chrysin, a series of chrysin derivatives with 3, 4, and 6-carbon spacers between the chrysin and the heterocyclic ring were synthesized and their antibacterial activity assessed (Singh and Chaudhary, 2011). A naturally occurring monoflavonoid called oroxylin-A has a variety of biological properties, including the inhibition of, cytotoxicity, and anti-microbial properties. Additionally, it showed anti-HIV and prevention of lipid peroxidation properties.

Oroxylin-A exhibits antibacterial activity, and the addition of an acyl group at its C-7 position has significantly increased its inhibitory potential against various bacterial infections (Nakahara et al., 2001; Dev et al., 2010).

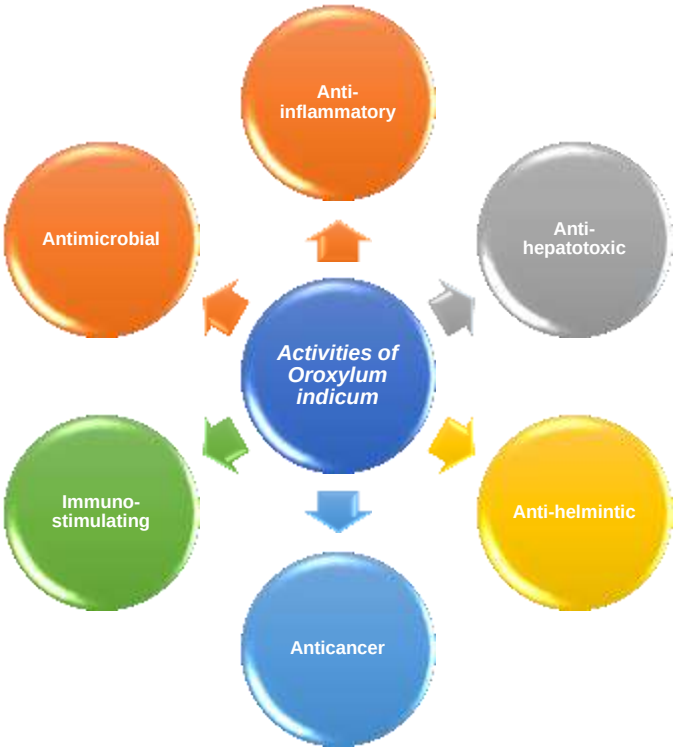

Fig. 2: Medicinal properties of *Oroxylum indicum*

Conservation techniques for *Oroxylum indicum*

Oroxylum indicum is a medicinal plant that is at risk of extinction because the herbal industry overuses its roots. *Oroxylum indicum* is reportedly vulnerable in Andhra Pradesh, Assam, Karnataka, Meghalaya, and Sikkim, and endangered in Kerala, Maharashtra, Madhya Pradesh, and Chhattisgarh (Rajasekharan et al., 2017; Sharma et al., 2023). Through the help of this study, we have attempted to conserve and mass-produce this therapeutic plant by utilizing several biotechnological techniques.

1. In Vitro Seed Germination

Different media types, including MS, B5, and WPM, with variable sucrose concentrations can be utilized for in vitro seed germination to improve seedling formation and increase the percentage of germination (Samatha et al., 2016a, b). To do this, *Oroxylum indicum* decoated seeds were administered to a variety of media (MS, B5, and WPM) with varying sucrose concentrations (Samatha and Swamy, 2020). Regardless of the sucrose concentration, the

absolute percentage of germination was noted on all varieties of MS media. According to prior studies, seed germination on ½ strength MS and MS medium with varying sucrose concentrations was 100% successful. Additionally, germination took 6-7 days shorter time compared to growth on other types of media (Samatha and Swamy, 2020). In B5 and WPM media, the percentage of seed germination was observed to be slightly lower across all applied sucrose concentrations (Samatha et al., 2016a, b).

2. In Vitro Regeneration

In *Oroxylum indicum*, callus-mediated and direct regeneration are the two methods available for plant regeneration or organogenesis. Leaf and cotyledonary leaf explants must be cultivated on MS medium containing 30 g/L sucrose supplemented with varying concentrations of 2,4-D/IAA/IBA/NAA in order to facilitate callus-mediated regeneration. It is important to note that the Callusing response can vary from auxin to auxin and also from explant to explant in *Oroxylum indicum*. According to Samantha et al., (2016a, b), the callusing response was higher in cotyledonary leaf explants cultivated in all auxin concentrations. Leaf and cotyledonary leaf explants can yield newly isolated, green, nodular, and friable calli that can be employed for callus-mediated regeneration following subculturing. The improvement in shoot bud induction can be attributed to the higher concentration of PGRs. Healthy shoot buds were continuously produced by repeatedly subculturing explants with shoot buds on fresh shoot proliferation medium (Gokhale and Bansal (2009); Samatha et al., 2016a, b).

3. In Vitro Zygotic Embryo Culture

An important factor in the quick multiplication of this threatened tree species is in vitro zygotic embryo culture. In vitro, zygotic embryo culture is a viable option for the conservation of the species, as it can shorten the period needed to generate a plantlet and prevent the issue of seed dormancy. For the development of numerous shoots, *Oroxylum indicum* zygotic embryos required MS media fortified with varying concentrations of BAP/Kn/TDZ (Samatha et al., 2013a).

4. Somatic Embryogenesis

Cotyledonary leaf explants must be cultivated on MS media with sucrose supplemented with varying doses of BAP along with IAA/2,4-D in order to execute this procedure. The PGRs can be used in any combination or concentration to generate somatic embryogenesis. According to Samatha and Swamy (2015), after two weeks of culture in all concentrations of

BAP + IAA/2,4-D evaluated, the cut ends of explants may result in the culturing of callus. Immediately after the third week of incubation, a gradual onset of somatic embryogenesis can be noticed. According to Samatha and Swamy's (2015) study, the identical mix of PGRs was associated with the highest frequency of somatic embryo conversion. In order for somatic embryoids to mature from globular to other shapes dependent on the PGRs present in the medium, the explants containing somatic embryoids must later be subculture on a fresh medium containing the same combination of PGRs (Samatha and Rama Swamy, 2015). In an effort to conserve the species, in vitro, micropropagation using nodal, shoot tip, and cotyledonary node culture has been performed with *Oroxylum indicum*.

5. Nodal Culture

In order to propagate clones, *Oroxylum indicum* nodal explants must be cultivated on MS media supplemented with varying amounts of BAP/Kn and TDZ as the sole PGR. According to Samantha et al., (2016a, b), there may be a correlation between the concentration of BAP and the percentage of response.

6. Shoot Tip Culture

It is also possible to culture the shoot tip explants for meristem culture on MS medium with 30 g/L sucrose that has been separately supplemented with varying amounts of BAP/Kn and TDZ. In addition, the single shoot could also trigger the shoot tips grown on MS media without growth regulators (MSO) to elongate. The highest number of numerous shoots/explants can be obtained at the same BAP concentration in this particular case. It is important to remember that BAP has a stronger influence on the induction of more multiple shoots from shoot tip culture in *Oroxylum indicum* than do Kn and TDZ (Samatha et al., 2016a, b).

7. Cotyledonary Node Culture

It is possible to cultivate *Oroxylum indicum* cotyledonary nodal explants on MS media that have been supplemented with various PGR concentrations, such as BAP/Kn/TDZ. All PGR concentrations can be cultivated in the cotyledonary nodal explants, which can help with the induction and growth of axillary bud development in *Oroxylum indicum*. The percentage of response increased along with the BAP concentration. It takes at least four weeks for nodal explants to grow during the culturing process. GA3 has a significant effect on the growth and elongation of explants. Moreover, in vitro, rooting can be achieved using these elongated shoots (Samatha et al., 2016a, b).

In addition, ex vitro rooting from *Oroxylum indicum* regenerated shoots was reported. When the in vitro-derived micro-shoots were inserted immediately into pots filled with garden soil, they took 20 to 25 days to develop their roots. Ex vitro rooting in *Oroxylum indicum* is an important milestone because it lowers the cost of micropropagation and can be easily adapted to field conditions. Ex vitro rooting is a promising technique since it reduces costs by not requiring auxins for in vitro rooting, labor costs, and the amount of time required for plants to grow in soil (Samatha et al., 2013a; Sharma et al., 2023). According to Harsha and Rajasekharan, (2023), it has been revealed that Oroxylum pollen may be efficiently preserved by using cryogenic techniques. This is necessary for the preservation of the tropical plant species' nuclear genetic diversity and the prolonged use of male gametophytes in breeding. In tissue culture technology, hardening/acclimatization is crucial for the establishment of in vitro-developed plantlets for the Lab-to-Land program. These methods are essential for the rapid growth of plantlets in the conservation and propagation of forest tree species, particularly those that are medicinal, endangered, and commercially significant.

Conclusion

In addition to being utilized in folk medicine, *Oroxylum indicum* is an important plant that is used in Indian medicine to treat a variety of conditions, including cancer, enlarged spleens, dysentery, wound inflammation, ulcers, diarrhea, healing, coughs, jaundice, scabies, and other skin disorders. The majority of these findings are supported by research employing various in vivo and in vitro biological evaluation techniques. According to a review of the literature, a tremendous amount of research done on this plant, still some of its pharmacological properties remain unproven scientifically. The main areas of recent research include this endangered plant's therapeutic qualities and methods of regeneration. An attempt was made to create an updated and thorough assessment of *Oroxylum indicum*, covering its phytochemistry, medicinal applications, distribution, description, and conservation methods.

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Data Availability

The authors affirm that the article and its supplemental materials have the sufficient data needed to support the findings of this study.

Declaration

Ethics Approval and Consent to Participate

Not Applicable

Consent to Publication

All authors give their consent to publish this paper.

Competing Interest

All the authors declare that there are no competing interests.

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