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Review

Taxonomic and phytomedicinal properties of *Oroxylum indicum* (L.) Vent: A wonderful gift of nature

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This paper is a review on pharmacological studies, phytochemical analysis and problems associated with natural seed germination of *Oroxylum indicum* (L.) Vent. The different parts of this plant like leaves, fruits, stem bark, seeds and roots are used in indigenous medicine preparation against various diseases. Chemical investigation of various parts of this plant resulted in characterization of various bioactive principles. It shows antioxidative, antitumour, antiinflammatory, analgesic, antimicrobial and hepatoprotective activity. Due to significant medicinal properties and continuous increasing demand, this plant has been put in endangered category (IUCN).

Key words: *Oroxylum indicum* (L.) Vent, endangered, propagation, medicinal plant, phytomedicinal action.

INTRODUCTION

Over the last thirty years, medicinal plants are 'important' natural resources used by indigenous medicinal system for treatment of diseases. A list of 243 commonly used medicinal plants is drawn having great demand for manufacture of mixtures, compound formation and potent medicine by the Central Council of Research on Ayurveda and Sidha (Thatoi, 2008). The Indian Himalayan Region (IHR) recognized amongst 34 biodiversity hotspots in the world. It contains about 1,748 different species of medicinal plants (Samant et al., 1998).

Among different medicinal plants of IHR, *Oroxylum* (Family: Bignoniaceae) possess high economical, ecological and medicinal importance and has about 112 genera and more than 725 species of trees, shrubs and vines spreading all over the world.

Oroxylum indicum is a small to medium sized deciduous tree widely distributed in tropical and subtropical regions. This plant is native to the Indian subcontinent, in the Himalayan foothills with a part extending to Bhutan, South China and Malaysia ecozone (Lawania et al., 2010). In India, it is distributed in Eastern and Western Ghats and North East India (Jayaram and Prasad, 2008). North East India comprising the states of Arunanchal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura lying between 21°34´N to 29°50´N latitude and 87°32´E to 97°52´E longitude (Mao et al., 2009).

The English name of this plant is "Indian trumpet flower" and commonly known as "Shyonaka". It grows upto 10 to 12 m with light grayish brown, soft and spongy bark, in its natural habitat. Leaves are compound, 60 to 120 cm in length, pinnate and stipules are absent. The flowers are bisexual and zygomorphic. Androecium consists most commonly of didynamous stamens that are attached to the corolla tube. The gynoecium consists of a

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single compound pistil of two carples, a single style and a superior ovary with typically two locules, each bearing numerous axile ovules. An annular or cupular nectary disk is usually found around the base of ovary. The fruit is capsular with winged seeds or sometimes indehiscent with wingless seeds (Angiosperm phylogeny website, Wikipedia). *O. indicum* is chiropterophilous in nature, and while studying its pollination ecology it has been reported that dawn bat *Eonycteris spelaea* is the pollinator of *O. indicum* in Western Malaysia and *Leschenault's Rousette* (*Rousettus leschenaultii*) as a pollinator in India (Fujita, 1991).

O. indicum lives in relationship with an actinomycete *Pseudonocardia oroxyli*, a high-G+C-content, Gram-positive bacterium, strain D10T present in the soil surrounding the roots. Based on 16S rRNA gene sequence analysis, strain D10T was a member of the genus *Pseudonocardia* and was most closely related, albeit loosely, to *Pseudonocardia halophobica*. (Gu et al., 2006). Numerous studies have indicated that these prolific actinobacteria appear to have a capacity to produce an impressive array of secondary metabolites exhibiting a wide variety of biological activity, such as antibiotics, antitumor and anti-infection agents, plant growth promoters and enzymes, and may contribute to their host plants by promoting growth and enhancing their ability of withstanding the environmental stresses (Qin et al., 2011). In nature, different developmental stages of *O. indicum* are shown in Figure 1.

Therefore, this study was done to evaluate the different medicinal properties of *O. indicum* and to explore the need of conserving this plant.

CHEMICAL CONSTITUENTS OF *O. INDICUM*

The plant *O. indicum* contains flavonoids like chrysin, oroxylene, and baicalein as active principal component (Choudhury et al., 2011). From the seeds of *O. indicum*, amounts of bioactive flavonoids such as baicalein-7-o-diglucoside, baicalein-7-o-glucoside, baicalein, chrysin, and apiagenin have been identified (Chen et al., 2003). Flavonoids such as chrysin, oroxylin-a, scutellarin, baicalein, biochanin-a and ellagic acid shows anti-arthritic, diuretic, antifungal, anti-inflammatory and anti-bacterial activities (Zaveri et al., 2008). Chemical investigations of acetone and hexane extracts of stembark resulted in isolation and characterization of two new flavonoids which are found to possess gastro-protective activity (Babu et al., 2010). The root extracts of *O. indicum* inhibited the activity of both enzymes-5-lipooxygenase and cyclocoygenase (Ali et al., 1998). Seeds of this plant are also reported to contain ellagic acid, which is an important polyphenolic compound (Sastry et al., 2011). Flavones, sterols and prunetin have been reported in different parts of *O. indicum* (Chen et al., 2003). Different phytochemical and their quantitative values are as shown in Table 1.

TRADITIONAL/FOLK USES

“Shyonaka” is a wonderful plant because almost every part such as leaves, stem bark, root bark, and fruits possess medicinal properties. It has been used in several traditional Ayurvedic and Folk medicines. The root bark of this plant is reported to be administered as astringent, bitter tonic, stomachic and anodyne. The root bark is an important ingredient in famous tonic formulations such as Chyawanprash, Dashmularisht, Narayan taila, Bhrama Rasayna, Dhanwatara, etc., (Sastry et al., 2011).

The decoction of the bark is taken for curing gastric ulcer and a paste made of the bark powder is applied for mouth cancer, scabies and other skin diseases. The seed is ground with fire-soot and the paste applied to the neck for quick relief of tonsil pain. Also, a paste made of the bark is applied to the wounds of animals to kill maggots. Decoction of the bark is given to animals for de-worming. The sword-like fruit or a branch of the plant is used by the farmers to kill crabs in wet paddy fields (National Innovation foundation-India). Mature fruits are acrid, sweet, anthelmintic, and stomachic. They are useful in pharyngodynia, cardiac disorders, gastropathy, bronchitis, haemarrhoids, cough, piles, jaundice, dyspepsia, smallpox, leucoderma and cholera (Warrier et al., 1995). Seeds are used as purgative. Dried seed powder is used by women to induce conception. Seeds yield non-drying oil used in perfume industry. The seeds are ground with fire soot and the paste is applied to the neck for quick relief of tonsil pain. The medicated oil of *O. indicum* in sesame oil base instilled into ears mitigates the pain in otitis (Chauhan, 1999). Roots are sweet, astringent, acrid, refrigerant (Yoganarasimhan, 1996), aphrodisiac, expectorant, carminative, digestive, anthelmintic, constipating, diaphoretic, diuretic, antiarthritic, anti-diabetic and febrifuges. Tonic is useful in dropsy, cough, sprains neuralgia, hiccough, asthma, bronchitis, anorexia, dyspepsia, flatulence, colic, diarrhea, strangury, gout, vomiting, leucoderma, wounds, rheumatoid arthritis and fever. Root bark is used in stomatitis, nasopharyngeal cancer and tuberculosis (Khare, 2004; Bhattacharje, 2005).

It is believed to have been prescribed by Malayasians to treat toothache, wound, splenomegaly, gastralia, dysentry, cholera, loss of appetite and fever. Any part of the plant may be used for making a decoction for external uses in childbirth. In Philippine Islands, the bark of the root is claimed as a diaphoretic. An alocoholic maceration of fresh bark is applied externally as a lacquer to relieve allergic dermatitis (Herbal Medicine Research Institute, 2002). In Vietnamese folk medicine, a decoction of the seeds is used for cough, bronchitis and gastritis.

In China, the seeds of *O. indicum* are used to cure liver and stomach problems and to heal ulcers and boils. In

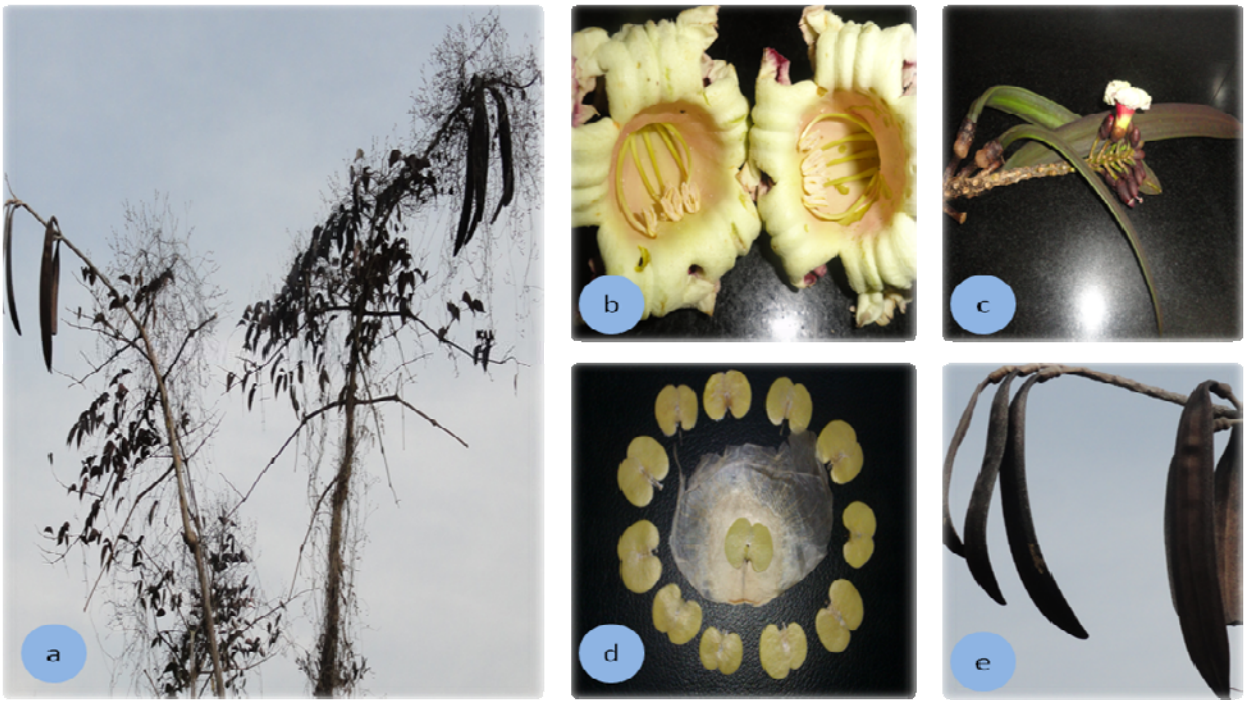

Figure 1. Different developmental stages of *O. indicum*: (a) Tree growing in its natural habitat (photograph taken from village Fatehpur, Haldwani (Uttarakhand) in the month of March, (b) Flowering during the month of August, (c) Flower and fruits, photograph taken in month of August, (d) Winged and naked seeds, and (e) Capsular fruits.

Table 1. Quantitative phytochemical values (D'Mello et al., 2012).

Total tannins	Total glycosides	Total phenolics dry weight	Total phenolic acids mg/g dry weight
10.63% w/v	12.95% w/v	1.436	1.275 ± 0.062

Burma, Vietnam and Philippines, the bark is used to treat dysentery and rheumatism (Choudhury et al., 2011).

PHARMACOLOGICAL USES

O. indicum seeds, leaves, stem bark and root bark are used in treatment of remittent fever, otorrhoea, bronchitis, leucoderma, diarrhea, inflammation and acute rheumatism (Bisht et al., 2011; Sastry et al., 2011). Various medicinal properties are shown Table 2. The different chemical extracts from stem bark, fruits and roots have different pharmacological activities.

Antitumor activity

Root bark of *O. indicum* shows antiproliferative activity on HL-60 cell line and anticancerous on CEM, B-16 and HCT-8 cell lines (Thatoi et al., 2008). Baicalein, the most abundant flavonoid present in the leaves of *O. indicum* has been isolated and tested on the viability and induction of apoptosis in the HL-60 cell line. Pretreatment with baicalein for 24 h caused a 50% inhibition of HL-60 cells at concentrations of 25 to 30 µM exposure of HL-60 cells to 10 to 20 µM baicalein for 36 to 48 h caused the cells to accumulate at S or G2M phases. The result of the study indicated that the baicalein has anti-tumor effect on human cancer cells (Roy et al., 2007). Non-polar extracts of *O. indicum* (especially PHO, petroleum ether hot extract) can effectively target Estrogen Receptor (ER)-negative breast cancer cells to induce apoptosis, without harming normal cells by cancer-specific cytotoxicity. Hence, it could be considered as an extract with candidate precursors to possibly harness or alleviate ER-negative breast cancer progression even in advanced stages of malignancy (Kumar et al., 2012).

The antitumor property of *O. indicum* has been evaluated in the experimental animals induced by different types of carcinogens, and in human cell lines by a number of experiments. Ethanolic extract of *O. indicum* was found to have antiproliferative effect on Hep 2 cell lines. Ethanolic extract exhibited cytotoxic activity against the Hep 2 cell lines at a concentration of 0.05% (Narisa et al., 2006).

Table 2. Major constituents of *O. indicum* and their activity (Zaveri et al., 2008; Choudhry et al., 2011).

Flavonoid	Concentration (µg/ml)	Activity
Baicalein	8.0	Antioxidant, antimutagenic, anticancerous, and antiinflammatory
Chrysin	8.0	Antioxidant, nephroproprotective, and immunomodulatory
Biochanin A	26.0	Antidiuretic, antimicrobial, antiarthritic, and antioxidant
Ellagic acid	8.0	Antioxidant, hepatoprotective, and antifungal

Antioxidant activity

The production of different oxidative species and free radicals due to stress leads to adverse effects on various vital organs and tissues of body. Antioxidants are now standing on the mainstay of the treatment and prevention of several diseases (Uttara et al., 2009). Current research is directed towards finding naturally occurring antioxidants particularly of plant origin. *In vitro* antioxidant activity of n-butanol extract of stem and root bark of *O. indicum* was determined by 2, 2′-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) radical cation decolorization assay and reveals the presence of very high significant antioxidant activity (Zaveri and Dhru, 2011). *In vitro* antioxidant activity (IC_{50} 22.7 µg/ml) was the highest in methanolic extract of stem bark of *O. indicum* (Moirangthem et al., 2013). The ethanol extract of stem bark exhibited maximum antioxidant potential due to its free radical scavenging activities in b-carotene bleaching assays, whereas chloroform extract showed maximum reducing power in total antioxidant activity may be due to its reducing potential (Kalaivani and Mathew, 2009). The ethyl acetate extract (EAE) of stem bark showed the lowest IC_{50} value (0.76 mg/ml) with the highest inhibition of 2, 2-diphenyl-1-picrylhydrazyl (DPPH). In the ferric reducing antioxidant power (FRAP) assay, the hexane extract (HE) showed the highest ferric reducing ability whereas the EAE showed better antioxidant ability with the lowest IC_{50} value (0.80 mg/ml) (Kumar et al., 2011). Methanolic and aqueous extracts of stem bark of *O. indicum* have also been found to have diverse therapeutic potentials. Various properties including antioxidant property, cytotoxicity, and protection against oxidative DNA damage, FRAP, free radical (DPPH and OH-) scavenging activities as well as inhibitory effect on lipid peroxidation have also been confirmed. In the cytotoxicity test, cytotoxicity of the extracts has been characterized by XTT assay in MDA-MB-435 S and Hep 3D cell lines. Protection of DNA by the extracts against oxidative damage by UV-photolysis of H_2O_2 was studied. Both extracts inhibited lipid peroxidation in a dosage dependent manner. Both extracts exhibited considerable free radical scavenging and ferric reducing abilities. The extracts demonstrated extensive cytotoxicity in both tested cell lines. Both extracts exhibited moderate levels of DNA protection against oxidative stress (Ahad et al., 2012).

Antiinflammatory activity

O. indicum is found to possess an efficient anti-inflammatory activity. Dichloromethane extract of the stem bark and root of *O. indicum* were found to have anti-inflammatory properties (Ali et al., 1998). Different extracts of *O. indicum* against experimental acute and chronic inflammatory model has proven the occurrence of anti-inflammatory activity in the plant extracts. *O. indicum* showed most promising NF-kappa B inhibitory effect with the lowest IC (50) value and is identified as Thai anti-inflammatory remedy (Siriwatanametanon et al., 2010). Arya and Arya (2011) reported that *O. indicum* have flavones and glycosides such as baicalein and scutelarcin which imparts anti-inflammatory effect to its bark.

The antiinflammatory activity was evaluated by carageenan induced rat paw edema model in rats using diclofenac sodium as standard drug. Two doses 150 and 300 mg/kg of aqueous extract of *O. indicum* were used. Result showed that paw volume was significantly reduced in dose dependent manner as compared to control. Extract at a dose of 300 mg/kg showed maximum antiinflammatory activity. However, the activity produced by both the doses was less than the reference standard. Extract at both doses showed significant ($P<0.05$) anti-inflammatory activity at 5 h suggesting that the extract predominantly inhibit the release of prostaglandin like substances (Upaganlawar et al., 2009).

Antimicrobial activity

The anti-microbial activity of various extracts of *O. indicum* has been screened against various pathogens and reveals the use of plant extract and phytochemicals for therapeutic treatment (Das and Chaudhry, 2010). The antimicrobial activity of crude extract of *O. indicum* (petroleum ether, ethyl acetate and methanol), compound 1 (2,5-dihydroxy-6,7-dimethoxy flavone) and compound 2 (3, 7, 3′,5′-tetramethoxy-2-hydroxy flavone) was tested against fourteen pathogenic bacteria (5 Gram-positive and 9 Gram-negative) and seven pathogenic fungi. Nutrient agar and nutrient broth were used as bacteriological media and potato dextrose agar (PDA) was used for fungal growth. In antibacterial screening, each sample was dissolved in methanol at a concentration of 200 µg/10 µl. The activity of these

samples was compared with standard kanamycin disc (K-30 µg/disc) using the standard disc diffusion method. Similarly, antifungal screening was done at a concentration of 300 µg/disc for each sample and the activity was compared with the standard clotrimazole disc (K-30 µg/disc). From the antibacterial and antifungal experimental results, it was evident that the crude extracts (petroleum ether, ethyl acetate) and compounds 1 and 2 showed significant antibacterial and antifungal activity, but were less potent than that of standard kanamycin and clotrimazole, whereas methanol extract showed little activity. The findings support the use of *O. indicum* in traditional medicine for the treatment of bacterial and fungal infection (Chopade et al., 2008). The antimicrobial activity of 40 medicinal plants has been examined from Similipal Biosphere Reserve, Orissa, India. *O. indicum* was one of those plants with prominent antimicrobial activity in root bark against various pathogenic bacteria e.g., *Staphylococcus aureus, Bacillus licheniformis, Bacillus subtilis, Pseudomonas aeruginosa, Vibrio cholerae*, etc., (Thatoi et al., 2008). Dichloromethane extracts of stem bark and root of *O. indicum* were found to have antimicrobial activities against Gram-positive (*B. subtilis* and *S. aureus*), Gram-negative (*Escherichia coli* and *P. aeruginosa*) and a Yeast (*Candida albicans*) (Ali et al., 1998). Uddin et al. (2003) isolated two flavonoid from *O. indicum*- 2,5-dihydroxy-6, 7-dimethoxy flavones (1) and 3,7,3´,5´-tetramethoxy-4´-hydroxy flavones (2). The MIC of compounds 1 and 2 were measured against *B. subtilis, S. aureus, E. coli* and *Shigella dysenteriae* and values were found between 64 and 128 µg/ml.

Immunomodulatory activity

The root bark of *O. indicum* was found to have immunostimulant/immunomodulatory activity (Zaveri et al., 2006). Research showed that treatment with n-butanol fraction of the root bark of *O. indicum* resulted in significant rise in circulating hemagglutinating antibody titers during secondary antibody responses, represents the potentiation of certain aspects of the humoral response. The treatment also resulted in a significant rise in paw edema formation, indicating increased host delayed type hypersensitivity (DTH) response. Additionally, the antioxidant potential of the drug was exhibited by significant reductions in whole blood malondialdehyde (MDA) content along with a rise in the activities/levels of superoxide dismutase (SOD), catalase (CAT) and reduced glutathione (GSH). In addition, histopathologic analysis of lymphoid tissues showed an increase in cellularity, e.g., T-lymphocytes and sinusoids, in the treatment group. The reported immunomodulatory activity of an active fraction of *O. indicum* might be attributed to its ability to enhance specific immune responses (both humoral and cell-mediated) as well as antioxidant potential.

The immunomodulatory properties of *O. indicum* have also been evaluated through estimation of humoral and cell mediated immune response in broiler chicks. Day old broiler chicks were grown up to 7 days and divided into different groups. All the groups were vaccinated against Ranikhet disease (RD) virus on days 7 and 28 except one group which served as unvaccinated control. All the groups of chicks were vaccinated against infectious bursal disease (IBD) on day 14. Two groups of chicks were fed *O. indicum* stem bark and root bark powder, respectively each at 250 mg/kg body weight. One group was fed levamisole at 10 mg/kg body weight, which acts as standard drug.Humoral immune response was measured by hemagglutination (HA) test and hemagglutination inhibition (HI) test against ND virus. Cell mediated immune response was studied on the basis of delayed hypersensitivity reaction or measured by contact sensitivity test with 2, 4-dinitrofluorobenzene (DFNB). The highest MHI antibody titter was found in levamisole treated group, followed by groups treated with root powder and stem powder of *O. indicum*, respectively. Similarly, six hours post DNFB challenge, a significant rise in mean skin thickness (MST) was observed in all the treated groups. The highest was observed in levamisole treated group, followed by groups treated with root powder and stem powder of *O. indicum*, respectively. These findings suggested that the root bark of *O. indicum* possessed the significant immunomodulatory activity, that ism stem bark counterpart. Thus, *O. indicum* root bark powder may be recommended as safe and commercially beneficial immumomodulator (Kumari et al., 2011).

Hepatoprotective activity

Hepatoprotective activities of petroleum ether, chloroform, methanolic and aqueous extracts of *O. indicum* were examined against carbon tetrachloride induced liver damage in mice using silymarin as control. These studies indicate that alcoholic stem bark extracts of *O .indicum* had activity over carbon tetrachloride treatment as compared to control. Results of the present investigation confirmed the traditional use of this plant as a potential hepatoprotective agent (Tripathy et al., 2011). *O. indicum* has been found to offer liver protection against various experimentally induced damages. Different extracts of leaves of *O. indicum* showed significant hepatoprotective activity against CCl_4 induced hepatotoxicity in Wistar albino rats. Carbon tetrachloride injection leads to the significant increase in the level of serum enzymes. Ethanolic extract was found to be more effective than all other extracts (Siddiqui et al., 2012). The aqueous root extract of *O. indicum* has potent hepatoprotective activity against paracetamol induced liver damage in rats, it also showed that, it has great influence on liver blood parameters. Thus, it is proved

that *O. indicum* aqueous extract has potent hepatoprotective activity and was found to be dose dependant and this could be attributed to the new flavonoid Oroxylin-B (Sastry et al., 2011). The hepato-protective activity of *O. indicum* was studied against carbon tetrachloride (CCl_4)-induced hepatotoxicity in mice and rats. Biochemical study indicated that alcoholic (300 mg/kg), petroleum ether (300 mg/kg) and *n*-butanol (100 and 300 mg/kg) extracts significantly (P<0.05) lowered the elevated serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvate transaminase (SGPT), alkaline phosphatase (ALP) and total bilirubin (TB) levels as compared to the control group. The increased lipid peroxide (LPO) formation, reduced glutathione (GSH) and decreased antioxidant enzyme activities of superoxide dismutase (SOD), catalase (CAT) in the tissues of CCl_4-treated animlas were significantly normalized by *O. indicum* treatment. Histopathological study also revealed that pretreatment with *O. indicum* restored CCl_4-induced alteration in anti-oxidant status of the tissues. It is suggested that root bark showed significant antioxidant activity, which might be in turn responsible for its hepatoprotective activity (Zaveri and Jain, 2009). The hepatoprotective activity of stem bark of *O. indicum* against CCl_4 induced liver damage in mice has also been confirmed. Pet ether, chloroform, methanolic and aqueous extracts of stem bark of *O. indicum* were examined against carbon tetrachloride induced liver damage in mice using silymarin as control. Enzyme activities of SGPT, ALP and SGOT were analyzed. All the extracts were shown to have significant hepatoprotective activity, with the methanolic extract being more efficient (Bichitra et al., 2011).

Antimutagenic activity

Methanolic extract of *O. indicum* strongly inhibited the mutagenicity of Trp-P-1 in Ames test. The major antimutagenic constituent was identified as baicalein with an IC_{50} value of 2.78±0.15 µM. The potent anti-mutagenicity of the extract was correlated with the high content (3.95±0.43%, dry weight) of baicalein. Baicalein acted as a desmutagen since it inhibited the N-hydroxylation of Trp-P-2 (Nakahara et al., 2001). Methanolic extract of the fruits of *O. indicum*, inhibited *in vitro* proliferation of HL-60 cells and flavonoid baicalein was found as an active component in the extract (Roy et al., 2007). *In vitro* anti-mutagenic activity of selected plants including *O. indicum*, was done by Ames *Salmonella* mutagenicity test using histidine mutants of *Salmonella typhimurium* tester strains, MTCC 98, MTCC 1251 and MTCC 1252. The hydroalcoholic extract of *O. indicum* significantly inhibited ($P < 0.001$) the *in vitro* by direct mutagens-sodium azide (NaN_3), 4-nitro-o-phenylenediamine (NPD), and indirect mutagens benzo[a]pyrene (B[a]P) 2-aminoflourene(2-AF) induced his revertants in a dose dependent manner (Zaveri et al., 2011). Ethanol soluble fraction prepared from twigs and leaves of this plant have reported for their antimutagenic activity (Wall et al., 1988). Methanolic extracts have antimutagenic activity against hetrocyclic amines (ayurvedainstitute.org/shop/MNOMedicines.htm).

Gastroprotective activity

The n-butanol fraction of the root bark of *O. indicum* showed significant gastroprotective activity against both ethanol and Water Immersion Plus Restraint Stress (WIRS)-induced gastric ulcers in rats, that could be attributed to its antioxidant activity, vasodilatation, and gastric cytoprotection (Zaveri and Jain, 2007). Chemical investigation of the stem bark of *O. indicum* resulted in the isolation and characterization of two new flavonoid glycosides. Their structures were established on the basis of extensive spectroscopic (IR, MS, 2D NMR) data analysis, and all the compounds were tested for their ulcer protective effects against various gastric ulceritis inducing models in rats (Babu et al., 2010). Various polyphenolic compounds have been reported for their anti-ulcerogenic activity with a good level of gastric protection. Besides their action as gastroprotective, these phenolic compounds can be an alternative for the treatment of gastric ulcers. Therefore, considering the important role of polyphenolic compounds in the prevention or reduction of gastric lesions induced by different ulcerogenic agents, in this review, we have summarized the literature on some potent antiulcer plants, such as, *O. indicum, Zingiber officinale, Olea europaea* L., Foeniculum *vulgare, Alchornea glandulosa, Tephrosia purpurea*, etc., containing phenolic compounds, namely, baicalein, cinnamic acid, oleuropein, rutin, quercetin, and tephrosin, respectively, as active constituents (Sumbul et al., 2011).

The 50% alcohol extract of the root bark of *O. indicum* and its petroleum ether, chloroform, ethyl acetate and *n*-butanol fractions were studied against ethanol-induced gastric mucosal damage. The alcohol extract (300 mg/kg, p.o.) and its different fractions (100 and 300 mg/kg, p.o.) showed reduction in gastric ulceration. The petroleum ether and *n*-butanol fractions showed maximum inhibition of gastric lesions against ethanol-induced gastric mucosal damage. The results were comparable with omeprazole (reference standard). In the ethanol-induced gastric ulcer model, treatment with both the active fractions and omeprazole showed significant antioxidant activity as evident from the reduction in the extent of lipid peroxidation. The effect of active fraction of root bark on the ulcer index, total acidity, total acid output, pepsin activity, pepsin output and total carbohydrate to protein ratio in pyloric-ligated rat was studied. The active fraction of root bark at a dose level of 100 mg/kg p.o. showed significant reduction (P<0.05) in

the ulcer index, total acidity, total acid output, pepsin activity and pepsin output along with a significant rise in total carbohydrate to protein ratio. The mechanism of antiulcer activity could be attributed to a decrease in gastric acid secretory and antioxidant activities leading to gastric cytoprotection. This activity could be linked to the presence of baicalein in the root bark of the plant (Khandhar et al., 2006).

Commercial value

O. indicum has a number of medicinal properties and various parts of this plant have been used in Ayurvedic preparations. The large pods of this plant sold at a market downtown, Bangkok, Thailand. The tree is often grown as an ornamental for its strange appearance. Materials used include the wood, tannins and dyestuffs (Wikipaedia, 2013). Extracts of this plant are also used in herbal tea formulations like vata and kapha (BF1.biz, 2009). *O. indicum* is also used in mentat (mindcare) and mentat syrup preparation (La Medica, 2007).

PROBLEMS ASSOCIATED WITH THE PLANT

According to the Red list of threatened species, 44 plant species are critically endangered, 113 are endangered, and 87 vulnerable (IUCN, 2000). Many medicinal plants are also in trouble due to over harvesting and destruction of habitat. *O. indicum* has become 'vulnerable' in some states of India due to reduction of its population (Sharma et al., 2010). It has also been listed to 'endangered' category in some other states (Gokhale and Bansal, 2005; Tewari et al., 2007). This plant naturally germinate by seeds, in the beginning of rainy season; however, the seed set is poor and seed viability is low, are the problems for its natural propagation along with its indiscriminate exploitation for medicinal purpose have pushed it to this state.

CONCLUSION

Enormous uses of *O. indicum* in medicine and Ayurvedic preparations revealed its properties as antimicrobial, antimutagenic, antiinflammatory, gastroprotective, etc. Therefore, the plant has effective pharmacological action and has proven its potential for future researchers but still the antitumor property of this plant needed to be investigated and further studies may be carried out to prove its promising uses. Due to high medicinal value of this plant, there has been increasing pressure on the collection of this species. So, altitudinal characterization of genetic diversity for this plant shall be helpful for conservation strategies. *In vitro* propagation method offers highly efficient tool for mass multiplication of many threatened plants. Hence, there is an urgent need to develop efficient and rapid conservation strategy for this plant.

Conflict of Interest

Authors have not declared any conflict of interest.

REFERENCES

Ahad A, Ganai AA, Sareer O, Najm MZ, Kausar MA, Mohd M, Siddiqui WA (2012). Therapeutic Potential of *Oroxylum Indicum*: A Review. J. Pharm. Res. Opin. 2:163-172.

Ali MR, Houghton PJ, Raman A, Hoult JRS (1998). Antimicrobial and anti inflammatory activities of extracts and constituents of *Oroxylum indicum* (L.) Vent. Phytomedicine 5:375-381.

Arya V, Arya ML (2011). A review on antiinflmmatory plant barks. Int. J. Pharm. Technol. Res. 3:899-908.

Babu TH, Manjulatha K, Kumar GS, Hymayathi A, Tiwari KA, Purohit M, Rao MJ, Babu SK (2010). Gastroprotective flavonoid constituent from *Oroxylum indicum* Vent. Bioorg. Med. Chem. Lett. 20:117-20.

BF1.biz (2009). Oroxylum indicum Herbal Tea - 13g. http://bf1.biz/oroxylum-indicum-herbal-tea-%E7%8E%89%E8%9D%B4%E8%9D%B6-13g

Bhattacharje SK (2005). Use of flavours and fragrances. In: Bhattacharje SK, editor. Handbook of aromatic plants. 2nd ed. Jaipur: Pointer Publishers.

Bichitra NT, Panda SK, Sahoo S, Mishra SK, Nayak L (2011). Phytochemical analysis and hepatoprotective effect of stem bark of *Oroxylum indicum* (L) Vent. on carbon tetrachloride induced hepatotoxicity in rat. Int. J. Pharm. Biol. Arch. 2:1714-1717.

Bisht A, Zaman K, Singh M, Gupta R, Singh V (2011). Pharmacognostical studies on *Oroxylum indicum* (Linn.) Vent. stem bark. Indian J. Nat. Prod. Resour. 2:472-478.

Chauhan NS (1999). Medicinal and Aromatic plants of Himachal Pradesh. 1st ed. New Delhi: Indus Publishing; *Oroxylum indicum*. pp. 96-298.

Chen LJ, Games ED, Jones J (2003). Isolation and identification of four flavonoid constituents from the seeds of *Oroxylum indicum* by high-speed counter-current chromatography. J. Chromatogr. 988:95-105.

Chopade VV, Upaganlawar AB, Yeole PG (2008). Antimicrobial activity of *Oroxylum indicum*. Antiseptic 105:146-7.

Choudhury S, Datta S, Talukdar AD, Choudhury MD (2011). Phytochemistry of the Family Bignoniaceae- A review. Assam Univ. J. Sci. Technol. 7(1):145-150.

D'mello P, Shetgiri P, Darji K (2012). Investigation and quantitation of phytoconstituents from *Oroxylum indicum* bark by GC-mass and HPLC techniques. Int. J. Pharm. Biol. Sci. 3:237-242.

Das S, Choudhury MD (2010). Antimicrobial Activity of Stem Bark extracts from the Plant *Oroxylum indicum* Vent., Assam Univ. J. Sci. Technol. 5:95-99.

Fujita MS (1991). Flying Fox (Chiroptera:Pteropodidae) Pollination, Seed Dispersal, and Economic Importance: A Tabular Summary of Current Knowledge. Bat Conservation International, Incorporated. P 124.

Gokhale M, Bansal YK (2005). An avowal of importance of endangered tree *Oroxylum indicum* (Linn.) Vent. Nat. Prod. Radiance 5:112-114.

Gu Q, Luo H, Zheng W, Liu Z, Huang Y (2006), *Pseudonocardia oroxyli* species, a novel actinomycete isolated from surface sterilized *O. indicum* root. Int. J. Syst. Evol. Microbiol. 56:2193-2197.

Herbal Medicine Research Centre (HMRC) (2002). Institute of medical research. Kuala Lumpur. Compendium of medicinal plants used in Malaysia.

La-Medicca (India) Private Limited (2007). Raw Herbs: *Oroxylum indicum*. http://www.la-medicca.com/raw-herbs-oroxylum indicum.html

Jayaram K, Prasad MNV (2008), Genetic diversity in *Oroxylum indicum* (L.) Vent. (Bignoniaceae), a vulnerable medicinal plant by random amplified polymorphic DNA marker. Afr. J. Biotechnol. 7:254-262.

Kalaivani T, Mathew L (2009). Phytochemistry and Free radical scavenging activities of *Oroxylum indicum.* Int. J. Sci. Technol. 4:45-52.

Khandhar M, Shah M, Santani D, Jain S (2006). Antiulcer activity of the root bark of *Oroxylum indicum* against experimental gastric ulcers. Pharm. Biol. 44:363-70.

Khare CP (2004). *Oroxylum indicum* In: Khare CP, editor. Indian Herbal Remedies: Rational Western Therapy, Ayurvedic and other traditional usage, Botany. 4th ed. New York: Springer-Verlag Berlin Heidelberg. pp. 340-1.

Kumar DRN, George CV, Suresh PK, Kumar AR (2012). Cytotoxicity, Apoptosis Induction and Anti-Metastatic Potential of *Oroxylum indicum* in Human Breast Cancer Cells. Asian Pac. J. Cancer Prev. 13(6):2729-2734

Kumar V, Chaurasia AK, Naglot A, Gopalakrishnan R, Gogoi BJ, Singh L, Srivastava RB, Deka DC (2011). Antioxidant and antimicrobial activities of stem bark extracts of *Oroxylum indicum* Vent. (Bignoniaceae): A medicinal plant of northeastern India. South Asian J. Exp. Biol. 1:3.

Kumar V, Gogoi BJ, Meghvansi MK, Singh L, Srivastava RB, Deka DC (2009). Determining the antioxidant activity of certain medicinal plants of Sonitpur, (Assam), India using DPPH assay. J. Phytol. 1:49-56.

Kumari R, Prasad A, Tiwary B, Ganguly S (2011). *Oroxylum indicum* possess a potential effect on humoral and cell mediated immune response in broiler chicks. Indian J. Anim. Sci. 81:1212–1214.

Lawania RD, Ranjeeta P, Mishra A, Gupta R (2010). Pharmacognostic and Phytochemical Studies of Bark of *Oroxylum indicum.* Pharmacogn. J. 2:297-303.

Mao AA, Hynniewta TM, Sanjappa M (2009). Plant wealth of Northeast India with reference to ethnobotany. Indian J. Tradit. Knowl. 8:96-103.

Moirangthem DS, Talukdar NC, Bora U, Kasoju N, Das RK (2013). Differential effects of *O. indicum* bark extracts: antioxidant, antimicrobial, cytotoxic and apoptotic study. Cytotechnology 65:83-95.

Nakahara K, Onishi-Kameyama M, Ono H, Yoshida M, Trakoontivakorn G (2001). Antimutagenic activity against trp-P-1 of the edible Thai plant, *Oroxylum indicum* Vent. Biosc. Biotechnol. Biochem. 65:2358-2360.

Narisa K, Jenny MW, Heather MAC (2006). Cytotoxic Effect of Four Thai Edible Plants on Mammalian Cell Proliferation. Thai Pharm. Health Sci. J. 1:189-95.

National Innovation foundation-India. Department of Science and Technology. Ministry of India. www.nif.org.in/?q=medicinalproperties .

Qin S, Xing K, Jiang JH, Xu LH, Li WJ (2011). Biodiversity, bioactive natural products and biotechnological potential of plant-associated endophytic actinobacteria. Appl. Microbiol. Biotechnol. 89(3):457-73.

Roy MK, Nakahara K, Thalang NV, Trakoontivakorn V, Takenaka M, Isobe S, Tsushida T (2007). Baicalein, a flavonoid extracted from a methanolic extract of *Oroxylum indicum* inhibits proliferation of a cancer cell line in vitro via induction of apoptosis. Pharmazie 62:149-153.

Samant SS, Dhar U, Palni LMS (1998). Medicinal plants of Himalaya: diversity distribution and potential values. Himavikas, Gyanodaya Prakashan. pp. 163-172.

Sastry AVS, Sastry VG, Mallikarjun P, Srinivas K (2011). Chemical and pharmacological evaluation of aqueous extract of root bark of "*Oroxylum indicum"* Vent. Int. J. Pharm. Technol. 3:1796-1806.

Sharma S, Rathi N , Kamal B, Pundir D, Kaur B, Arya S (2010). Conservation of biodiversity of highly important medicinal plants of India through tissue culture technology- a review. Agric. Biol. J. North Am. 1:827-833.

Siddiqui WA, Ahad A, Ganai AA, Sareer O, Najm MZ, Kausar MA, Mohd M (2012). Therapeutic potential of *Oroxylum indicum*: a review. J. Pharm. Res. Opin. 2:163-172.

Siriwatanametanon N, Fiebich LB, Efferth T, Prieto MJ, Heinrich M (2010). Traditinally used Thai medicinal plants*: In vitro* anti-inflammatory, anticancer and antioxidant activities. J. Ethanopharmacol. 130:196-207.

Sumbul S, Ahmad MA, Mohd A, Mohd A (2011). Role of phenolic compounds in peptic ulcer: An overview. J. Pharm. Biol. Allied Sci. 3:361-367.

Tewari S, Singh K, Sah P (2007). *In vitro* propagation of *Oroxylum indicum*-An endangered medicinal tree. Biotechnology 6:299-301.

Thatoi HN, Panda SK, Rath SK, Dutta SK (2008). Antimicrobial activity and ethanomedicinal uses of some medicinal plants from Similipal Biosphere Reserve, Orrissa. Asian J. Plant Sci. 7:260-267.

Tripathy NB, Panda SK, Sahoo S, Mishra SK, Nayak L (2011). Phytochemical Analysis and Hepatoprotective Effect of Stem Bark of *Oroxylum indicum* (L) Vent. on Carbon Tetrachloride Induced Hepatotoxicity in Rat. Int. J. Pharm. Biol. Arch. 2(6):1714-1717.

Uddin K, Sayeed A, Islam A, Rahman AA, Ali A, Khan MAGRM, Sadik MG (2003). Biological Activities of extracts and two flavonoids from *Oroxylum indicum* Vent. (Bignoniaceae). Online J. Biol. Sci. 3:371-375.

Upaganlawar AB, Tende CR, Yeole PG (2009). Antiinflammatory activity of aqueous extract of *Oroxylum indicum* Vent. leaves extract-preliminary study. Pharmacol. online. 1:22-6.

Uttara B, Singh AV, Zamboni P, Mahajan RT (2009). Oxidative stress and neurodegenerative diseases: a review of upstream and downstream antioxidant therapeutic options. Curr. Neuropharmacol. 7:65-74.

Wall ME, Wani MC, Hughes JJ, Taylor H (1988). Plant antimutagenic agents 1. General bioassay and isolation procedure. J. Nat. Prod. 51:866-873.

Warrier PK, Nambiar VP, Ramankutty C, Vasudevan R (1995). editors. Indian Medicinal Plants: A compendium of 500 species. 1st ed. Chennai: Orient Longmam Private Ltd; *Oroxylum indicum*. pp. 186-90.

Wikipaedia (2013). Oroxylum indicum. (http://en.wikipedia.org/wiki/oroxylum_indicum

Yoganarasimhan SN (1996). Bangalore: Interline Publishing;. Medicinal plants of India: Karnataka. pp. 366-7.

Zaveri M, Dhru B (2011). *In-vitro* antioxidant potential of stem and root bark of *Oroxylum indicum.* J. Global Pharm. Technol. 3:42-48.

Zaveri M, Jain S (2007). Gastroprotective Effects of Root Bark of *Oroxylum indicum*, Vent. J. Nat. Remedies 7:269-277.

Zaveri M, Jain S (2009). Hepatoprotective effect of root bark of *Oroxylum indicum* on carbon tetrachloride (CCl_4)-induced hepatotoxicity in experimental animals. http://www.biology-online.org/articles/hepatoprotective-effect-rootbark-oroxylum.html.

Zaveri M, Khandhar A, Jain S (2008). Quantification of Baicalein, Chrysin, Biochanin-A and Ellagic Acid in Root Bark of *Oroxylum indicum* by RP-HPLC with UV Detection. Eurasian J. Anal. Chem. 3:245-257.

Zaveri M, Patel P, Dhru B, Patel S (2011). Screening of in-vitro anti-mutagenic activity of selected plants. Am. J. Pharm. Res. 1:232-243.

Zaveri M, Gohil P, Jain S (2006). Immunostimulant activity of n-butanol fraction of root bark of *Oroxylum indicum*, Vent. J. Immunotoxicol. 3:83-99.