MEDWIN PUBLISHERS
Committed to create value for Researchers

Advances in Pharmacology and Clinical Trials
ISSN: 2474-9214

Zanthoxylum Armatum: A Systemic Review of its Ethno-Medicinal Properties, Phytochemistry, Pharmacology and Toxicology

Bhattacharjee A*, Biplab Kumar D, Das B, Dkhar D and Kachari D

Faculty of Pharmaceutical Science, Assam down Town University, Guwahati-781026, Assam, India

***Corresponding author:** Atanu Bhattacharjee, Associate Professor, Faculty of Pharmaceutical Science, Assam Down Town University, Guwahati, Assam, India, Tel: +91-8073612051; Email: atanu1983@gmail.com

Mini Review

Volume 4 Issue 3

Received Date: July 02, 2019

Published Date: July 29, 2019

DOI: 10.23880/apct-16000162

Abstract

Background: *Zanthoxylum armatum* DC., a popular spice and traditional medicine is widely distributed throughout North Eastern region of India. The plant has been used in different indigenous medicinal practices to cure several diseases associated with digestive and nervous system.

Aim: The aim of this paper is to provide a systematic review on taxonomy, ethnomedicinal properties, phytochemistry, pharmacology, and toxicology of this plant. Furthermore, the possible development and perspectives for future research on this plant are also discussed.

Materials and methods: Upto date information was gathered through a search of different books, journals, articles, annual reports, proceedings and web-based materials.

Result: The different plant parts like leaves, fruits, stem, bark, seeds and roots are enriched with various secondary metabolites viz. alkaloids, sterols, phenolics, lignins, coumarins, terpenoids and flavonoids. It is considered as one of the most valued commercial trade medicinal plant due to its multidirectional therapeutic applications in Ayurveda and other traditional system of medicine. Pharmacological findings revealed its potential as nootropic, antioxidant, anti-inflammatory, cytotoxic, insecticidal/larvicidal drug.

Conclusion: *Zanthoxylum armatum* is one of the important folklore medicinal plants cultivated in North Eastern region of India. Its diverse therapeutic applications can be associated with the presence of various secondary metabolites. The various ethno-pharmacological applications of Zanthoxylum armatum have been verified by several related researches. More extensive study on the individual specific phyto-component can lead to novel innovations for the well-being of mankind.

Keywords: *Zanthoxylum armatum*; Ethnomedicine; Phytochemistry; Pharmacology

Introduction

Medicinal plants represent a great deal of untapped reservoir of natural medicines. The structural diversity of their phytoconstituents makes them a valuable source of novel lead compounds for the quest of drugs to treat acute and chronic diseases. Indian subcontinent has richest plant based medicinal traditional system because of its rich biodiversity [1]. These herbal medicines are mainly used for health care due to their better economy and lesser side effects on human body. The Indian Himalayan region contains about 1,748 different species of medicinal plants [2].

Among them *Zanthoxylum armatum* DC (*Z armatum*) (Family: Rutaceace) is regarded as an important medicinal plant due to its immense therapeutic efficacy. It is commonly known as Indian Prickly Ash, Nepal Pepper or Toothache tree. It is widely distributed in India, from Kashmir to Bhutan at altitudes up to 2,500 m, also occurs throughout North East India [3]. It is also found throughout most of China, Taiwan, Nepal, Philippines, Malaysia, Pakistan and Japan at altitudes of 1,300-1,500 m. Valleys and thickets in the mountains, wasteland and the under-storey of mixed forest are customary locations of the species [4].

It is a small tree or large spiny shrub. Leaves are distinctively trifoliolate with the leaf-stalk winged. Leaflets are stalk less, 2.0-7.5 × 1.0-1.7 cm, elliptic to ovate-lace like, entire to slightly toothed, sharp tipped, base sometimes oblique. Minute yellow flowers arise in leaf axils. Flowers have 6-8 acute sepals. Petals are absent. Male flowers have 68 stamens and large anthers because of which the flowers look yellow. Female flowers have 1-3 celled ovary, pale red, splitting into two when ripe. Seeds are round 3 mm in diameter with shining black color. The plant is adapted to subtropical climate of lower warm valleys of the Himalayas with sufficient rainfall [5]. The flowering period is from March to April (Figure 1). The taxonomical profile is detailed below (Table 1).

Kingdom:	Plantae
Class:	Angiosperms
Order:	Sapindales
Family:	Rutaceae
Genus:	*Zanthoxylum*
Species:	***Z. armatum***
Binomial name	
Zanthoxylum armatum	

Table 1: Taxonomy of *Z. armatum.*

Figure: Parts of *Z. armatum*

Traditional Uses

The bark, fruits and seeds of *Zanthoxylum armatum* are extensively used in indigenous system of medicine as a carminative, stomachic and anthelmintic drug. The fruit and seeds are employed as an aromatic tonic in fever and dyspepsia [6]. An extract of the fruits is reported to be effective in expelling round worms. Because of their deodorant, disinfectant and antiseptic properties, the fruits are used in oral hygienic preparations, and their lotion for scabies [7]. They are also used to insect repellant agent. The natives of North America crush the bark and apply on their gums for relief hence it is known as the toothache tree. It is used in China and India as snake bite remedy. In China the dried fruits are marketed, and appear as small red carpels containing the black, shinning, pungent and somewhat acrid-tasting seeds, which are about 3.1 mm across [8]. The fruits have also been used, since classical times, for pickling. The traditional uses of *Z. armatum* are listed in Table 2.

Sl No.	Country	Parts of plant	Traditional Uses	Reference
1	India	Seeds and bark	fever, dyspepsia cholera.	6
		Aerial parts	Insecticidal	6
2	Japan	Seed	GIT problems and depression.	9
3	Nepal	Fruit	Decoction is used for abdominal pain.	8
		Berries	Carminative, antispasmodic, anti-rheumatic and skin diseases.	8
		Bark	Cholera, diabetes and asthma.	8
		fruits	Pickles are useful for cold & cough, tonsillitis, high altitude sickness, limbs numbness, vertigo/dizziness. Dried powdered decoction against diarrhoea, dysentery and stomachache.	8
4	Pakistan	Fruit	Spice and condiment. Powder of its dried fruit along with *Mentha longifolia* dried leaves, *Trachyspermum ammi* seeds and black salt is taken with water during cholera and indigestion. Twigs are used as toothbrush during gum problems and toothache.	9 8
5	China	Aerial plant	An infusion in vinegar is used to expel bugs or worms infecting ear. Scabies is treated by the plant, using a lotion applied to the skin.	10
6.	Malaysia, Thailand	Branches and stems	Stomach tonic, to treat snake bites	11

Table 2: The traditional uses of *Z. armatum*.

Phytochemistry

Various phytochemical constituents like terpenoids, flavonoids, alkaloids, phenolics, lignins, coumarins, glycosides have been extracted from different parts of the plant. Monoterpenes like linalool and limonene are the major constituents of the essential oil. Seeds contain hydroxylic (4Z) enolic acid and various volatile compounds. GC-MS analysis of essential oil revealed presence of Linalool (53.05%), Bergamot mint oil (12.73%), Limonene di epoxide (11.39%) , α-pinene (4.08%), β-Myrcene (3.69%)and β-Limonene (3.10%) as major constituents [12-14]. A number of alkaloids and coumarins viz. berberine, fagarine, magnoflorine, laurifoline, nitidine, chelerythrine, tambetarine and candicine, and coumarins viz. xanthyletin, zanthoxyletin, alloxanthyletin has been isolated and reported have been isolated and reported from different parts of the plant [15]. A new amide designated as armatamide along with two lignans, asarinin and fargesin, have been isolated from the bark extract [16]. From the alcoholic extract of the stem bark, a new flavonoid glycoside has also been isolated [17]. The main components of the oil are oleic acid, palmitic acid, linoleic acid methyl ester, limonene

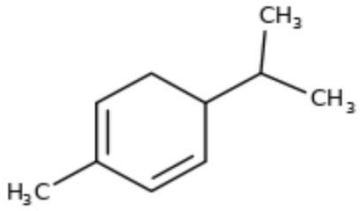
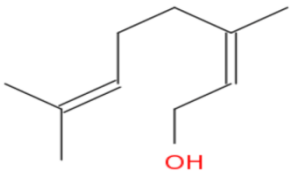
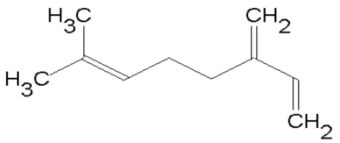
and linalool [18]. The carpels yield a volatile oil, resin, yellow acid principle, and crystalline solid body, xanthoxylin [19]. Various types of phytoconstituents and their structures are summarized in Table 3 & 4 respectively.

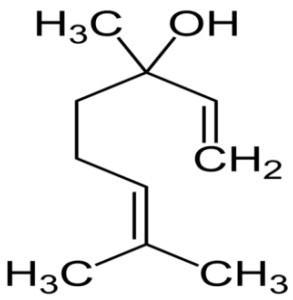
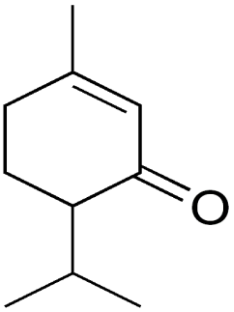
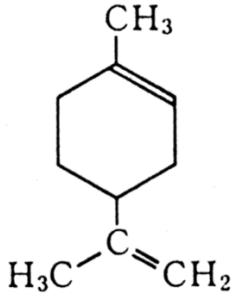
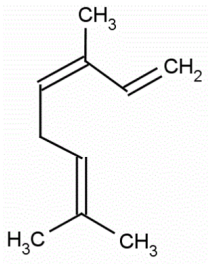
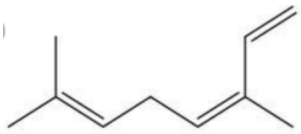
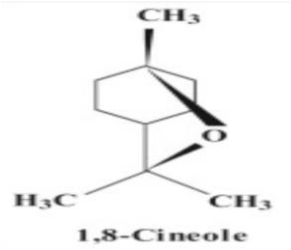
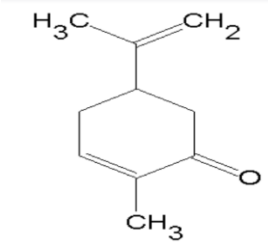
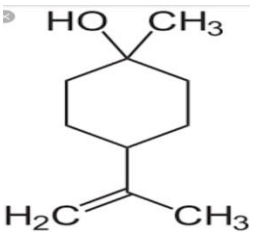
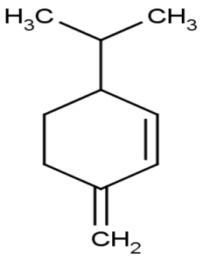
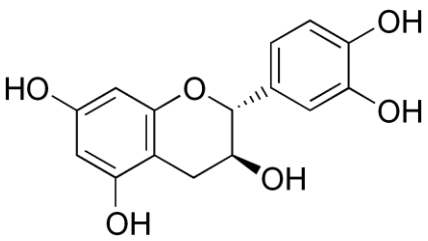
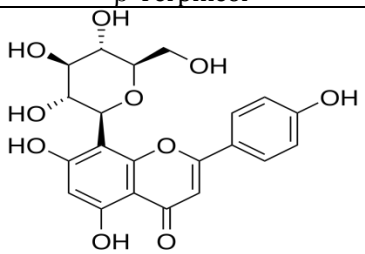
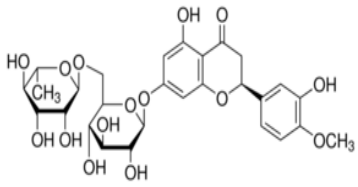
Sl. No.	Class	Compound	Plant parts	References
A. Terpenoids				
1		α-Fenchol	Seed	12
2		α-Terpinene	Seed	12
3		α-Thujene	Seed	12
4		α-Thujone	Seed	12
5		α-Pinene	Seed	12
6		α-copaene	Leaf oil	12
7		α-Terpineol	Seed	12
8		alpha-phellandrene	Leaf oil	12
9		β-Pinene	Seed	12
10		beta- Myrcene	Leaf oil	12
11		β -Cymene	Leaf oil	12
12		β-Phellandrene	Seed	12
13		β-Terpeneol	Leaf oil	12
14		Camphene	Seed, leaf oil	12
15		Carvone	Seed	12
16		Citral	Dry fruit	12
17		Citronellol	Seed	12
18		Citronellal	Seed	12
19		1,8-Cineole	Seed	12
20		β-ocimene	Leaf oil	12
21		Trans-beta-Ocimene	Leaf oil	12
22		cis-beta-Ocimene	Seed, leaf oil	12
23		Geraniol	Dry fruit	12
24		γ-terpinene	Seed/leaf oil	12
25		(E)-Carveol	Seed	12
26		(E)-Linalool oxide	Seed	12
27		Limonene	Seed/leaf	12
28		D-Limonene	Leaf oil	12
29		Limonene	Seed/leaf oil	12
30		Bornyl acetate	Leaf oil	12
31		Linanyl acetate	Dry fruit	12
32		Myrcene	Seed	12
33		Terpinolene	Leaf oil	12
34		α-terpinolene	Leaf oil	12
35		Nerol	Seed	12
36		1-α-Phellandrene	Seed	12
37		cymene	Leaf oil	12
38		p-Cymene	Seed	12
39		Piperitone	Seed	12
40		Sabinene	Seed	12
41		Tagetonol	Seed	12
42		Terpinen−4-ol	Seed	12
43		(Z)-Sabinene hydrate	Seed	12
44		(Z)-Linalool oxide	Seed	12

45		(Z)-Pinene hydrate	Seed	12
46		allo-Aromadendrene	Seed	12
47		α-Caryophyllene	Seed	12
48		trans-caryophyllene	Leaf oil	12
49		(E)-Nerolidol	Seed	12
50		α-Amyrins	Bark	12
51		β-Amyrone	Bark	12
52		β-Amyrins	Bark	12
53		Lupeol	Bark	12
54		Eucalyptol	fruit	12
B. Flavonoid				
55		Catechin	Leaf	13
56		Hesperidine	Leaf	13
57		Vitexin	Leaf	13
58		Isovitexin	Leaf	13
59		3,5-Diactyltambulin	Bark	13
60		Kaempferol	Bark	13
61		Tambulin	Bark	13
62		3,5,3′-Trihydroxy−6,7- dimethoxy− 4′-(7″-hydroxygeranyl−1″-ether) flavone	Seed	14
63		3,5,3′,4′-Tetrahydroxy−7,8-dimethoxy flavone	Seed	14
64		Tambuletin	Seed	14
C. Alkaloids				
65		Berberine	Bark	15
66		Dictamnine	Root	15
67		γ-fagarine	Bark	15
68		β-fagarine	Bark	15
69		Chelerythrine	Bark	15
70		Magnoflorine	Root	15
71		Nevadensin	Seed oil	15
72		Skimmianine	Bark	15
73		Zanthonitrile	Bark	15
D. Lignins				
74		Asarinin	Bark leaf	15
75		Eudesmin	Leaf	15
76		Epieudesmin	Leaf	15
77		Fargesin	Bark leaf	15
78		Kobusin	Leaf	15
79		Planispine-A	Leaf	15
80		L-Asarinin	Bark	15
81		L-Sesamin	Bark	15
82		L-Planinin	Bark	15
83		Magnolin	Bark	15
84		Phylligenin	Bark	15
85		Planinin	Bark	15
86		Sesamin	Leaf/Bark	15
E. Sterols & Steroids				
87		β-Daucosterol	Bark	12
88		β-Sitosterol	Bark	12

89		Stigmasta−5-en−3β-Dglucopyranoside	Seed	12
90		β-Sitosterol-β-D-glucoside	Bark	12
F. Amides				
91		Armatamide	Bark	15
92		α-Sanshool	Leaf	15
93		Hydroxyl-α-sanshooil	Pericarp	15
G. Coumarins				
94		xanthyletin	Bark	16
95		zanthoxyletin	Bark	16
96		alloxanthtin	Bark	16
97		Bergapten	Bark	16
98		Umbelliferone	Bark	16
99		psoralen	Leaf	16
100		Cuminol	Bark/Fruit	15
101		Cuminaldehyde	Seed	15
102		Phellandral	Seed	15
103		2-Tridecanone	Leaf-oil	16
104		Undecan−2-one	Aerial parts	12
H. Aromatic compounds				
105		1-Hydroxy−6,13-anthraquinone	Seed	17
106		2-Hydroxybenzoic acid	Seed	17
107		2-Hydroxy−4-methoxy benzoic acid	Seed	17
108		trans-Cinnamic acid	Seed oil	17
109		Vanillic acid	Bark	17
110		(E)-Methyl cinnamate	Seed	17
111		Methyl cinnamate	Seed/fruit	17
112		(Z)-Methyl cinnamate	Seed	17
113		3-Methoxy−11-hydroxy −6,8-dimethylcarboxylate biphenyl	Seed	17
114		3,5,6,7-Tetrahydroxy−3′,4′-dimethoxy flavone−5-β-D-xylopyranoside	Seed	17
115		Monoterpenetriol−3,7- dimethyl−1-octane−3,6,7-triol	Seed oil	17
116		1-Methoxy−1,6,3-anthraquinone	Seed	17

Table 3: Phytoconstituents present in *Z. armatum*.

		
α phellandrene	**Nerol**	**Myrecene**

		
Linalool	Piperitone	D-Limonene
		
β-Ocimene	Cis- Ocimene	1,8-Cineole
		
Carvone	β-Terpineol	β-Phellandrene
		
Catechin	Vitexin	Hesperidin

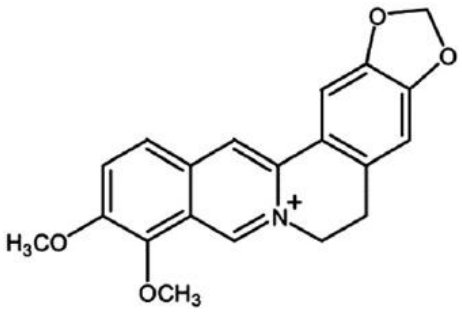
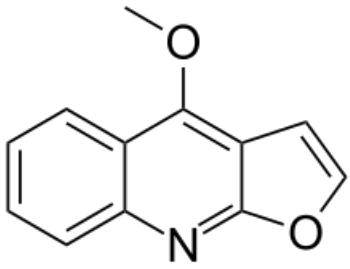
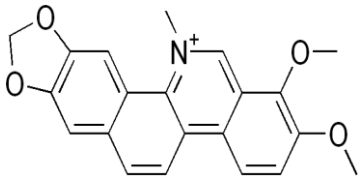
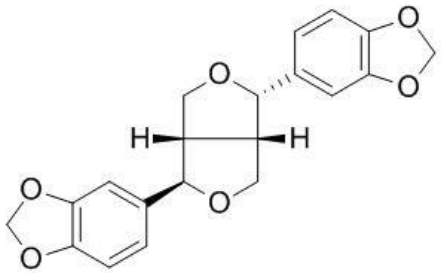
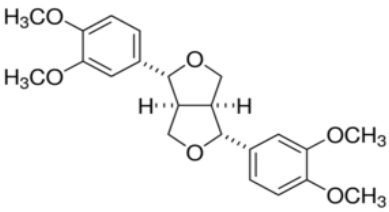
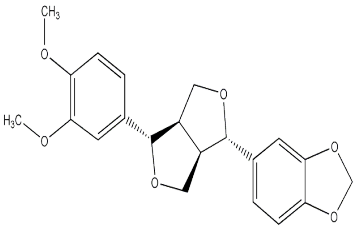
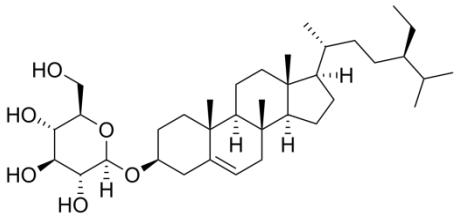
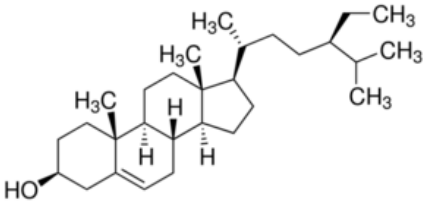
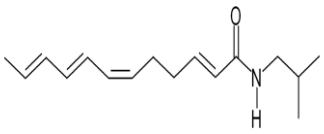
		
Berberine	Dictamnine	Chelerythrine
		
Asarinin	Eudesmin	Kobusin
		
Daucosterol	β-Sitosterol	α-Sanshool

Table 4: Structures of isolated phytoconstituents from *Z. armatum.*

Pharmacology

Antioxidant Activity

Leaves extract of *Z. armatum* showed potent antioxidant activity in *in-vivo* models. Administration of the extract (100, 200 mg/kg b.w.) significantly enhanced the activities of antioxidant enzymes (SOD, CAT and GSH) in the treated animals. Both the doses showed increase in SOD, CAT and GSH level significantly ($p < 0.05$ and $p < 0.01$ respectively), whereas lipid peroxidation level was decreased in dose dependent manner [18].

Hepatoprotective Activities

Ethanolnic extract of *Z. armatum* leaves was evaluated *in-vivo* for hepatoprotective activity against CCl_4 induced hepato toxicity. Silymarin (100 mg/kg) was used as a positive control. CCl_4 intoxication in normal rats elevated SGOT, SGPT, ALKP, SBLN level and cause hepatic inflammation. Extract (500 mg/kg p.o. once daily for 14 days) showed a significant ($p< 0.001$) decrease in the entire marker enzyme levels and reduce hepatic inflammation, comparable with standard drug [19].

In another experiment, hepatoprotective activity of ethanolic extract of *Z. armatum* bark against CCl_4 induced hepatotoxicity was evaluated *in-vivo*. CCl4 and olive oil (1:1) administration caused a significant increase in the serum activities of ALT, AST, ALP, direct billirubin and

total billirubin. Ethanolic extract (100, 200, and 400 mg/kg once daily for7days) significantly reduced the above elevated parameters in dose dependant manner and was comparable to silymarin (25mg/kg) [20].

Antispasmodic Effect

The crude extract of *Z. armatum* (100 and 300 mg/kg; p.o.) showed 20% and 60% protection from against castor-oil-induced diarrhea in mice and was comparable with standard drug Loperamide (10 mg/kg) (21). In another experiment, essential oil of *Z. armatum* leaves was evaluated for possible anti-diarrheal activity on spontaneous and potassium chloride induced contracted smooth muscle of the isolated rabbit jejunum. The spasmolytic effect of volatile oil started from 0.03 mg/ ml and showed 100% effect at10 mg/ml dose. The extracts relaxed the contracted muscle which may be due to calcium channel blocking from the sarcoplasmic reticulum [22].

Keratinocyte Inhibition

Anti-proliferative activity of methanolic extract of *Z. armatum* bark (concentrations between 0.008 and 0.4 mg/ml) was evaluated against the growth of rapidly multiplying human keratinocytes (HaCaT cells). The extract significantly inhibited the growth of keratinocytes and highly active with an IC_{50} value of 11 mg/ml [23].

Larvicidal Activities

Essential oil of the seeds of *Z. armatum* (dose: 200, 150, 100, 50, 25 and 10 ppm) was evaluated in-vitro for larvicidal activities against three mosquitoes species: *Aedes aegypti, Anopheles stephensi* and *Culex quinquefasciatus*. Results indicated that essential oil was most sensitive against *Culex quinquefasciatus* was the with LC_{50} and LC_{95} values of 49 and 146 ppm respectively compared to other species. Temephos, a synthetic larvicidal agent (dose: 0.005-0.1 ppm) was used as positive control [24].

Anti-Inflammatory

Bergapten, a coumarin extracted from the plant exhibited significant inhibition of pro-inflammatory cytokine viz. tumor necrotic factor-α (TNF-α) and interleukin-6 (IL-6) in a concentration dependent manner [25].

Antibacterial, Antifungal Activities

3,5-diacetyltambulin an isolated Flavonoid from *Z. armatum* showed significant antibacterial activity against Gram positive bacteria (*Bacillus subtilis, B. megaterium, Staphylococcus aureus*) and Gram negative bacteria (*Escherichia coli, Shigella dysenteriae, S. sonnei, S. flexneri, Pseudomonus aeruginosa, Salmonella typhi*). The MIC values against these bacteria ranged from 8-64 µg/ml. However, this flavonoid and monoterpenoid (geraniol) shows weak antifungal activity [26].

Toxicology and Side Effects

Zanthozyllum species volatile oil showed insecticidal activity which may be associated with its acetylcholinesterase activity. Potent fumigant toxicity was observed with cuminaldehyde, thymol, (1S)-(-)-verbenone, (-)-myrtenal, carvacrol, (S)-(Z)-verbenol, *Z. piperitum* steam distillate, cuminyl alcohol, Zanthoxylum armatum seed oil, piperitone, (-)-(Z)-myrtanol, and citronellal (LC_{50}, 0.075-0.456 µg/cm3). An *in-vitro* bioassay using female fly heads indicates that strong acetylcholinesterase inhibition was produced by citronellyl acetate, α-pinene, thymol, carvacrol, and α-terpineol (1.20-2.73 mM), but no direct correlation between fly toxicity and AChE inhibition by the test compounds was observed [27,28].

Conclusion

Zanthoxylum armatum is one of the important medicinal plants having a wide array of household, commercial and ethno-medicinal applications. The fruits, leaves, seeds and stem bark are used in head-ache, fever, toothache, tonsillitis, diarrhea, dysentery, altitude sickness. The fruits contain essential oil that possesses antiseptic, disinfectant properties so it has its wide application in pharmaceuticals and flavoring industries. The main constituents of the essential oil are limonene and linalool. Different chemical compounds like alkaloids, flavonoids, terpenoids, phenols, coumarins etc present in different parts of the plants have attributed to several biological activities like antimicrobial, anti- viral, hepatoprotective, larvicidal, antioxidant etc. The different traditional ethno-medicinal practices have been validated by several in vitro and in vivo ethno-pharmacological studies, as evidenced in this review, suggesting for further potential biological applications of *Zanthoxylum armatum*. Many active components have been identified from the plant that might be developed into novel drugs. Therefore further emphasis *Z. armatum* is one of the diverse medicinal plants having a wide range of therapeutic applications among the tribes of North Eastern region of

India. Owing to its diverse applications, the species can be developed as an important commodity for alleviation of poverty in rural areas. The extracts, volatile oil and lead molecules are traditionally utilized in cerebral pain along with other disorders. Volatile oil is mainly used as fumigant and disinfectant. Various secondary metabolites like alkaloids, flavonoids, terpenoids, etc. are responsible for its pharmacological properties. The different customary ethno-therapeutic practices have been validated by modern *in-vitro* and *in-vivo* assays to support the scientific basis of uses of *Z. armatum*. Numerous active components have been distinguished from the plant that may be formed into novel medications. Along these lines further accentuation ought to be on screening, isolation and characterization of bioactive phytoconstituents along with their mechanism based study will be essential. The correlation between ethnopharmacological, phytochemical and pharmacological examinations could set up a solid linkage between the ages old indigenous restorative practices and present day scientific inquires about that could unearth the enormous hidden abilities of medicinal plants and their applicable folklore uses. *Zanthoxylum armatum* is one of the important medicinal plants having a wide array of household, commercial and ethno-medicinal applications. The fruits, leaves, seeds and stem bark are used in headache, fever, toothache, tonsillitis, diarrhea, dysentery, altitude sickness. The fruits contain essential oil that possesses antiseptic, disinfectant properties so it has its wide application in pharmaceuticals and flavoring industries. The main constituents of the essential oil are limonene and linalool. Different chemical compounds like alkaloids, flavonoids, terpenoids, phenols, coumarins etc present in different parts of the plants have attributed to several biological activities like antimicrobial, anti- viral, hepatoprotective, larvicidal, antioxidant etc. The different traditional ethno medicinal practices have been validated by several in vitro and in vivo ethno-pharmacological studies, as evidenced in this review, suggesting for further potential biological applications of *Zanthoxylum armatum*. Many active components have been identified from the plant that might be developed into novel drugs. Therefore further emphasis Zanthoxylum armatum is one of the important medicinal plants having a wide array of household, commercial and ethno-medicinal applications. The fruits, leaves, seeds and stem bark are used in headache, fever, toothache, tonsillitis, diarrhea, dysentery, altitude sickness. The fruits contain essential oil that possesses antiseptic, disinfectant properties so it has its wide application in pharmaceuticals and flavoring industries. The main constituents of the essential oil are limo- nene and linalool. Different chemical compounds like alkaloids, flavonoids, terpenoids, phenols, coumarins etc present in different parts of the plants have attributed to several biological activities like antimicrobial, anti-viral, hepatoprotective, larvicidal, antioxidant etc. The different traditional ethno-medicinal practices have been validated by several in vitro and in vivo ethno-pharmacological studies, as evidenced in this review, suggesting for further potential biological applications of *Zanthoxylum armatum*. Many active components have been identified from the plant that might be developed into novel drugs. Therefore further emphasis.

Acknowledgement

We sincerely acknowledge faculty of pharmaceutical science, Assam down Town University, Gandhi Nagar, Panikhaiti, Guwahati-26; for providing the basic infrastructure to prepare this manuscript.

Conflict of Interest Statement

The authors declare no conflict of interest.

References

1. Chopra RN, Nayar SL and Chopra IC (1986) Glossary of Indian Medicinal Plants (Including the Supplement), Council of Scientific and Industrial Research, New Delhi.

2. Mathur AC, Srivastava JB and Chopra IC (1961) Insecticidal properties of *Zanthoxylum alatum* Linn, Curr Sci 30: 223-224.

3. Geweli MB and Awale S (2008) Aspects of Traditional Medicine in Nepal, Institute of Natural Medicine University of Toyama, Japan. pp: 140-142.

4. Barkatullah, Ibrar M and Hussain F (2009) Ethnobotanical studies of plants of Charkotli Hills, Batkhela District, Malakand, Pakistan, Front Biol China 4: 539-548.

5. Abbasi AM, Khan MA, Ahmed M and Zafar M (2010) Herbal medicines used to cure various ailments by the inhibitants of Abbottabad district, North West Frontier Province, Pakistan, Indian J Trad Know 9: 175-183.

6. Thokchom PS, Okram MS (2011) Phytochemical and pharmacological profile of *Zanthoxylum armatum* DC-An overview. Indian Journal of Natural Products and Resources 2(3): 275-285.

7. Ahmad A, Misra LN, Gupta MM (1993) Hydroxyalk-(4z)-Enoic acids and volatile components from the seeds of *Zanthoxylum armatum*. J Nat Prod 56(4): 456-460.

8. Barkatullah M , Muhammad N , Rehman I, Rehman M U, Khan A (2013) Chemical composition and biological screening of essential oils of *Zanthoxylum armatum* DC leaves. J Clin Toxicol 3(5): 1-6.

9. Negi JS, Bisht VK, Bhandari AK, Singh P, Sundriyah RC (2011) Chemical constituents and biological activities of the genus *Zanthoxylum*: a review. Afr J Pure Appl Chem 5(12): 412-416.

10. Singh G, Kapoor IPS, Singh P, Carola SH, Lampasona MP, et al. (2013) Chemistry and antioxidant properties of essential oil and oleoresins extracted from the seeds of tomer (*Zanthoxylum armatum* DC). Int J Food Prop 16(2): 288-300.

11. Tiwary M , Naik S N, Tewary D K, Mittal P K, Yadav S (2007) Chemical composition and larvicidal activities of the essential oil of *Zanthoxylum armatum* DC (Rutaceae) against three mosquito vector J Vector Borne Dis 44(3): 198-204.

12. Kokate SD, Venkatachalam SR, Hassarajani SA (2001) *Zanthoxylum alatum* extract as mosquito larvicide. Proc. Nat. Acad. Sci., India Sect. B-Biol. Sci. India, pp: 229-232.

13. Yoshihito U, Yuriko N, Masayoshi H, Shuichi H , Seiji H (2000) Essential oil constituents of fuyu-sanshoo (*Zanthoxylum armatum* DC.) in Nepal. Koryo, Terupen oyobi Seiyu Kagakuni kansuru Toronkai Koen Yoshishu 44: 59-61.

14. Neetu J, Srivastava SK, Aggarwal KK, Ramesh S, Sushil K (2001) Essential oil composition of *Zanthoxylum alatum* seeds from northernIndia. Flavor Fragr J 16(6): 408-410.

15. Luong NX, Hac L V, Dung NX (2003) Chemical composition of the leaf oil of *Zanthoxylum alatum* Roxb. from Vietnam. J Essent Oil Bear Plants 6: 179-184.

16. Perry LM (1980) Medicinal Plants of East and Southeast Asia. Massachusetts Institute of Technology, USA.

17. Li H, Li P, Zhu L, Xie M, Wu Z (2006) Studies on the chemical constituents of Zanthoxylum armatum DC. Zhongguo Yaofang. Chin Pharm 17: 1035-1037.

18. Li X, L Z, Zheng Q, Cui T, Zhu W, et al. (1996) Studies on the chemical constituents of Zanthoxylum armatum DC. Nat Prod Res Dev 8: 24-27.

19. Kalia NK , Singh B, Sood P (1999) A new amide from *Zanthoxylum armatum*. J Nat Prod 62(6): 311-312.

20. Bhatt V, Sharma S, Kumar N, Sharma U, Singh B (2016) Simultaneous quantification and identification of flavonoids, lignans, coumarins and amides in leaves of *Zanthoxylum armatum* using UPLC-DAD-ESI-QTOF-MS/MS. J Pharm Biomed Anal 132: 46-55.

21. Ramidi R, Ali M (1999) Two new flavonoids from the seeds of *Zanthoxylum alatum* Roxb. Pharmazie 54 (10): 781-782.

22. Kayat HP, Gautam SD, Jha RN (2016) GC-MS Analysis of hexane extract of *Zanthoxylum armatum* DC fruits. J Pharm Phytochem 5(2): 58-62.

23. Ranawat LS, Bhatt J, Patel J (2010) Hepatoprotective activity of ethanolic extracts of bark of *Zanthoxylum armatum* DC in CCl4 induced hepatic damage in rats. J Ethnopharmacol 127(3): 777-780.

24. Vashist H , Sharma RB, Sharma D, Upmanyu N (2016) Pharmacological activities on *Zanthoxylum armatum*-a review. World J Pharm Pharm Sci 5(12): 408-423.

25. Akhtar N, Ali M, Alam MS (2009) Chemical constituents from the seeds of *Zanthoxylum alatum*. J. Asian Nat Prod Res 11(1): 91-95.

26. Venkatachalam SR, Hassrajani SA, Rane SS (1996) Cis-10-Octadecenoic acid, component of *Zanthoxylum alatum* seed oil. Indian J Chem 35(5): 514-517.

27. Hieu TT, Kim SI, Ahn YJ (2012) Toxicity of Zanthoxylum piperitum and Zanthoxylum armatum oil constituents and related compounds to Stomoxys calcitrans (Diptera: Muscidae). J Med Entomol 49(5): 1084-1091.

28. Nirmala P, Pramod KJ, Pankaj PR, Sangeeta R (2018) Zanthoxylum armatum DC: Current knowledge, gaps and opportunities in Nepal. J Ethnopharcol 32(4): 84-96.