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Traditional, nutraceutical and pharmacological approaches of *Tamarindus indica* (Imli)

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ABSTRACT: Plants have provided a source of inspiration of novel drug compounds, as plant derived medicines have made large contributions to human health and well-being. An estimate of 75-90% of rural population of the world still relies on herbs for their healthcare. Ayurveda, supposed to be the oldest medical system in the world, provides potential leads to find active and therapeutically useful compounds from plants. Epidemiological studies have consistently demonstrated that consumption of plant- derived foods rich in bioactive phytochemicals have a protective effect against different aliments related to human health. *Tamarindus indica* is having numerous reported activities like antidiabetic, hypolipidemic, hepatoprotective, anti-ulcer, anti-inflammatory, analgesic, antivenom, antimicrobial, antihelmintic and molluscicidal properties. In spite of these medicinal values this plant is also consumed by rural people as vegetable. It also use as flavoring agent to impart flavor to various dishes and beverage. The present comprehensive review is therefore an effort to give detailed information about botanical description, phytochemical, traditional, nutraceutical and pharmacological approaches of *Tamarindus indica*.

Keywords: Ayurveda; Nutraceutical; *Tamarindus indica*; Molluscicidal; Phytochemicals.

1. INTRODUCTION

Medicinal plants are the back bone of traditional and natural medicine since decads [1, 2]. Traditionally the use of plant preparation passed from generation to generation, because of the ethnomedicinally important chemical compounds which may lead to drugs discovery. Research on medicinal plant has increased recently all over the world because drugs which obtained from nature are pharmacologically potent and low or no side effect [3]. Globally, medicinal plants are being studied in order to develop new molecules for use in pharmacology, nutraceutical, food supplements, and folk medicines etc. *Tamarindus indica* is one kind of widely used medicinal plant for health issue in various medicinal systems, as they have potential against numerous human aliments. Almost every part of the plant is found to be therapeutically important. Its fruits, leaves, and bark contains high amount of ascorbic acid and β-carotene

which are proved to be potent antioxidant, antilipoperoxidant, and antihepatotoxic [4, 5]. *T. indica* provide the potentially rich nutrients and plays an important role in healthcare system, mainly in the developing countries [6]. The fruit extracts were used as refrigerants in fevers and as laxatives and carminatives alone or combinations with limejuice, honey, milk, dates spices and camphor. The pulp was used in digestive, as remedy for biliousness and bile disorders [7]. As an anti scorbutic, it was applied to heal inflammations and sore throat, mixed with salt to treat rheumatism and administered to alleviate sunstroke, dasine poisoning and alcoholic intoxication in Southeast Asia [8]. The aim of the present review is to provide the scientific validation about the morphology, phytochemical constituents, medicinal and pharmacological activities and commercial utilization of the every parts of the plant, so that *T. indica* can be potentially understood as multipurpose tree species.

Classification of the *Tamarindus indica* (Common name - Imli, Family - Leguminosae):

Kingdom - Plantae

Phylum - Spermatophyte

Class - Angiosperm

Order - Fabales

Family - Leguminosae

Genus - *Tamarindus*

Species - *indica*

2. MORPHOLOGICAL DESCRIPTION

Tamarindus indica is moderate to large size evergreen tree up to 24 m height and 7 m in girth with an exceptionally beautiful spreading crown and fragranted flower with wide range of geographical distribution in the tropic and subtropic areas except in the Himalayan and western country [9]. It has short, thick and seldom straight trunk. Bark is brownish or dark grey longitudinally and horizontally fissured (Figure 1). Leaves alternate, compound, with 10-18 pairs of opposite leaflets; leaflets narrowly oblong, 12-32×3-11 mm, petiole and rachis finely haired, midrib and net veining more or less conspicuous on both surface (Figure 2). Flowers are borne in a lax racemas, with attractive pale yellow color with pink strips. Flower buds completely enclosed by 2 bracteoles, which fall very early; sepals 4, petals 5, the upper 3 well developed, the lower 2 minute. Flowers are bisexual. Fruit is a pod, indehiscent, subcylindrical, 10-18 ×4 cm, straight or curved, velvety, rusty-brown; the shell of the pod is brittle and the seeds are embedded in a sticky edible pulp (Figure 3). Seeds are 3-12, abovate, ablong exalbuminouse and testa hard, shiny, and smooth (Figure 3). *T. indica* is commonly known as “Tamarind” and “Imli” in Hindi. It is used in traditional medicine in India Sudan, Nigeria, Bangladesh, and almost of the topical countries. Almost all part of the tree find some use or other in food, chemical, pharmaceuticals and textile industries, fodder, timber and fuel [10].

Figure 1. *Tamarindus indica* (bark).

Figure 2. *Tamarindus indica* (leaves).

Figure 3. *Tamarindus indica* (fruits & seeds).

3.VERNICULAR NAME

Assam: Teteli

Bengal: Ambli, Tentul, Tinturi, Nuli

English: Tamarind tree

Gujarat: Ambli, Amli

Hindi: Imli, Amli,

Malayalam: Amlam

Odiya: Tentuli

Punjab: Imli

Tamil: Ambilam, Amilam

Telugu: Amlika, Chinta, Sinja, Sinta

Urdu: Imli

Nepal: Titri

4. CHEMICAL CONSTITUENTS

Phytochemical investigation carried out on *T. indica* revealed the presence of active constituent such as phenolic compound, cardiac glycosides [11], L-(-) mallic acid [12], tarteric acid, mucilage and pectin, arabinose, xylose, glactose glucose and uronic acid [13, 14]. Root bark of *T. indica* indicates presence of n-hexacosane, eicosanoic acid, βsitosterol, (+)-pinitol. octacosanyl ferulate, 21-oxobehenic acid [15, 16]. Alkaloids, saponin hordenine and proanthocyanidin are to be found in bark of Tamarind [17-19]. Seeds are rich in phenolic compounds, polymeric tannins, fatty acids, flavonoids, saponins, alkaloids, glycosides [20]. The content of *T. indica* seed comprised only procynadine, represented mainly by oligomeric procynadine tetramer procynadine hexamer and procynadine pentamer with lower amount of procynadine B_2, epicatechine [18, 19, 21]. Its pulp contains different organic acids like: tartaric acid, acetic acid, citric acid, formic acid, malic acid, and succinic acid and the rich source of micronutrients such as calcium, phosphorus, vitamin A, C and tartaric acid [22, 23]. Rana and Sharma [6] demonstrate the presence of flavonoids and tannins in pulp and saponins in seed.

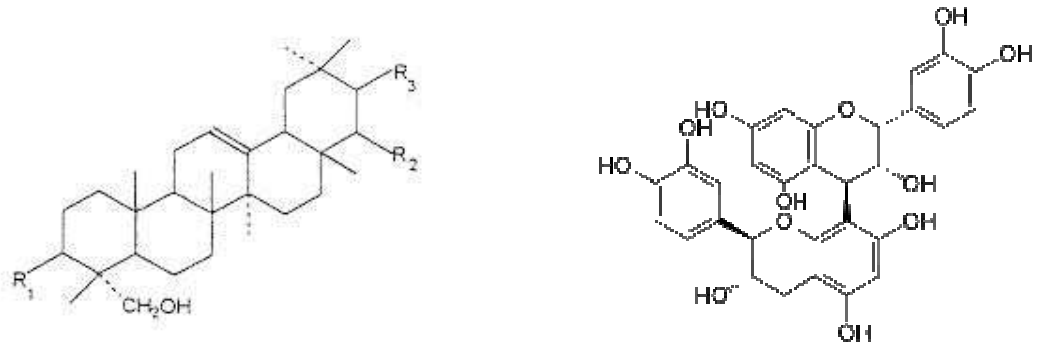

Figure 4. Left: Saponin; Right: Procyanadine.

5. APPROACHES IN TRADITIONAL MEDICINE SYSTEM

Tamarindus indica has uncountable use in traditional herbal medicine. The pharmacological value of tamarind responsible for its therapeutic efficacy are already mentioned in traditional Sanskrit literature [24]. Tamarind products such as leaves, fruits and seeds have been extensively used in traditional Indian and African medicine [7]. The bark of plant has been used as a tonic and in lotions or poultices to relieve sores, ulcers, boils and rashes [24]. A decoction is used in cases of gingivitis, asthma and eye inflammations [8]. Tamarind is used to cure chronic or acute constipations, liver and gall bladder ailments, bilious vomiting, alcohol intoxications, fever, pharyngitis, stomatitis and hemorrhoids [25]. It is used in scorpion sting, scurvy, bilious fever, splenomegaly. Fruit increases intestinal liquid volume and acts as aperients [26]. It is also used to cure tuberculosis, asthma, bronchitis, leprosy, wounds, ulcers, inflammation, stomachaches, diarrhea, dysentery, burning sensation, giddiness, vertigo, diabetes [20] and amenorrhoea [17]. Tamarind pulp has been reported to be used in the treatment of a number of ailments, including the alleviation of sunstroke and the intoxicating effects of alcohol and cannabis. Tamarind gargling is very effective to cure aphthous sores and

sore throats [17]. Root is used to treat ankylostomiasis (hookworm) in some parts of Tanzania. *Tamarindus indica* L. was used as a traditional medicine for the management of diabetes mellitus [7]. Fruit increases intestinal liquid volume and acts as aperients, appetizing, laxative heating, tonic to the heart, heals wound and fracture, biliousness and bile disorder [27].

6. NUTRACUETICAL APPROACHES OF TAMARIND

Nowadays fruits and vegetables are gaining popularity in treating various physiological malfunctioning as they are riches of the medicinal as well as nutritional approaches. In this row the plant of *T. indica* have a great importance because of the leaves, flowers, and immature pods are edible and contained good level of protein, fat, fibber, and some vitamin such as thiamine, riboflavin, niacin, ascorbic acid and B-carotene [28]. The leaves and flowers are the cheapest and most common source of nutrients and used in curries, salads, stews, and soups in many countries to enhance the test and aroma along with the dietary fiber and thus reducing the risk of obesity and metabolism related disorder [29].

Tamarind is mostly valued for its fruit, especially the pulp, which provide the additional vitamins and micro-nutrients like calcium, phosphorus, vitamin A, C and tartaric acid to the diet and are important source of phytochemical [23]. The pulp is used for a wide variety of domestic and industrial purposes because its have the potential to enhance the nutritional value and flavor of food [30]. In India, the pulp is used to make sweet meats mixed with sugar called Tamarind balls though it is also eaten raw and sweetened with sugar [31, 32]. The acidic pulp is used as a favorite ingredient in culinary preparations, such as curries, chutneys, sauces, ice cream, and sherbet in countries where the tree grows naturally as it provide intense flavor, vivid color and rich texture. Tamarind pulp has a very valuable economic important as it is used as a raw material for the manufacture of several industrial products of the nutraceutical importance such as tamarind juice concentrate, tamarind pulp powder, tartaric acid, pectin, tartarates, and alcohol [33, 34].

Tamarind seeds and kernels that is the by-product of the commercial utilization of the fruit, are high in protein content, while the seed coat is rich in fibre and tannins (anti-nutritional factors). These proteins have a favorable amino acid composition and could supplement cereals and legumes poor in methionine and cystine. Hence, they can be used as a cheaper source of protein to alleviate protein malnutrition [35]. Apart from the medicinal value it is also commercially available as a food additive for improving the viscosity and texture of processed foods [36]. The seed power after removing kernel showed jelly forming properties and the carbohydrate character as it is contain the high amount of polysaccharide [37, 38]. It has been recommended for use as a stabilizer in ice-cream, mayonnaise, and cheese and as an ingredient or agent in a number of pharmaceutical products.

7. PHARMACOLOGICAL APPROACHES

7.1. Antimicrobial activity

Tamarindus indica was known to have board spectrum anti-microbial activity against the different strain of harmful bacteria, it was due to the presence of therapeutically important chemical constituents. Methanol and acetone extract of *T. indica* showed the potent antimicrobial activity against *Klebsiella*

pneumonia by using suitable animal model and test. The activity was compared with antimicrobial amikacin and piperacillin [39]. The aqueous, ethanolic and acetone extract have potent antimicrobial activity against *Salmonella typhi* and *Staphylococcus aureus* [40]. Other study showed the potential antimicrobial activity of different part of *T. indica* against various strains of bacteria [41]. Fresh and sun dried leaves, as well as ethanol extract and pure essential oil from Tamarind leaves were tests against different strain of bacteria such as *Salmonella typhimurium*, *Pseudomonas aeruginosa* and *Candida albicans*. The result the study demonstrated that among all preparations essential oil showed the good spectrum of antimicrobial activity [42]. The antimicrobial activity of ethanolic extract of bark of *Tamarindus indica* was studied by Kapur and John [43]. Antimicrobial activity of this plant extract was carried against gram positive bacteria (*Staphylococcus aureus, Bacillus cereus*) and gram negative bacteria (*Klebsiella pneumoniae, Escherichia coli*) by well diffusion method. The large zone inhibition was observed in *Staphylococcus aureus, Bacillus cereus.* Biswas and Shinha [44] studied to investigate the antibacterial activity of *Tamarindus indica* against urinary tract infection causing pathogens bacteria isolated infected women. The findings demonstrate that different solvent preparations of *T. indica* leaves cause highest antibacterial activity against different strain of bacteria. The leaves and fruit extract of *T. indica* were tested against the clinical isolates of *Escherichia coli* and *Shigella* spp. from the stool of pregnant women attending antenatal clinic. The result of the experiments showed that ethanol extract have the maximum activity as compared to aqueous extract [28]. Majitha et al. [45] investigated the antibacterial activity of Tamarind on cement dust polluted and non-polluted leaf, bark parts with different solvents against bacteria such as *Bacillus cereus, Escherichia coli, Pseudomonas aeruginosa, Pseudomonas/Aeromonas* and *Staphylococcus aureus*.

7.2. Anti-oxidant activities

All the extract of *Tamarindus indica* showed the good antioxidant potential specially seed and pericarp, due the presence of phenolic compound [21]. The crude extract of *T. indica* fruit pulp showed significant antioxidant and hypolipidemic properties in hypercholestrolemic hamsters in vivo and in vitro [46]. Vyas et al. studied the antioxidant effect of ethanolic extract of *T. indica's* seed coat by DPPH (2,2-diphenyl1-1- picryl hydrazyl) free radical scavenging method using ascorbic acid as a standard. The result of the study concluded that at the cellular level antioxidant compound present in the extract are capable of enhancing the efficiency of antioxidant defense system by attributed to its free radical-scavenging ability and thereby preventing damage of cell structure [47]. Ethyl acetate extracts prepared from the seed coat that is the byproduct of the gum industry also had strong anti-oxidant activity and can be used as a source of safe and inexpensive antioxidant [48]. Hydroalcoholic and aqueous extracts of *T. indica* leaves posses antioxidant activity like Fe^{+3} reducing potential, NO·, OH· and DPPH· radical scavenging potential [49]. Natukundu et al. [50] studied the antioxidant properties of *T. indica* seed. In his findings he demonstrated that incorporation of the tamarind seed powder into mango juice and cookies significantly increases their content of bioactive phytochemical with an associated increase in the antioxidant activities and have an important protective effect against the oxidative damage.

7.3. Anticancer activity

Tamarindus indica plant was scientifically reported for its several therapeutically important bioactive molecule that have the potent anticancer effect. *T. indica* seeds can enhance the antioxidant activities of treated cancer cells which can provide protection against oxidative damage [51]. Hussien et al. [52] examine the cytotoxicity potential of methanolic extract of *T. indica* seed on two cancer cell lines rhabdomyosarcoma cancer (RD) and human lymphoma cell line (SR). The result of the investigation suggested that seeds extract possess strong carcinogenic potential against cancer cell lines. In order to evaluate the anticancer potential of ethanolic extracts of *T. indica* bark Srinivas et al. [53] carried out the study of the in vitro effect of ethanol bark extract on human colorectal adenocarcinoma cell line (HT29) by using MTTs assay. The findings of the study demonstrates the bark extract showed the significant cytotoxic effect against human cancer cell line.

7.4. Wound healing

Tamarindus indica frequently claim in Ayurvedic text and folk medicinal system concerning with the treatment of cuts, wound and abscesses due to the presence of therapeutically active tannins and flavonoids. *T. indica*, bark and leaves have more efficacy in wound healing properties and is applied externally on the wound, either as decoction or as a powder or poultice, alone or in combination with other species [54, 55]. Tamarind fruit is used as wound healing medicine [56]. Thejaswi et al. [57] examine the wound healing potential of the cork and seed ash of *T. indica* of Wistar albino rats. The findings of the study suggested that the cork and seed having highly significant wound healing activity and can be used as a potential therapeutic agent against wound caused by tissue injury.

7.5. Antidiabetic activity

An aqueous extract from *T. indica* seed poses the significant antidiabetogenic activity in streptozotocin-induced diabetic male rat. The aqueous extract of *T. indica* seed was given to mild diabetic and severe diabetic rats and hyperglycemia was significantly reduced and it measured by different fasting blood glucose levels [58]. Further the aqueous extract of seed coat was found to reduced the hyperlipidemia in streptozotocin-induced diabetic male rat [59]. Bhadoria et al. [60] studied the antidiabetic potential of polyphenolic-rich fraction of *Tamarindus indica* seed coat in alloxan-induced diabetic rats. The study revealed that hydroethanolic seed coat extract of *T. indica* have potent hypoglycaemic action by virtue of its phytoconstituents and it can be used as a herbal medicine for diabetes.

7.6. Antivenom activity

Tamarindus indica seed extracts are the rich with the pharmacological active molecule that may be considered for antagonize the snake venom hence it has been used as the traditional healer against snakebite in folk medicine. The seed extract showed the in vitro inhibitory effect on the major hydrolytic enzyme such as phospholipase A, protease, hyaluronidase, l-amino acid oxidase, and 5’-nucleotidase enzyme activity of venom in a dose related fashion [61]. The extract antagonized the effect of venom by neutralizing the degradation of β chain of human fibrinogen and the indirect hemolysis caused by venom and thus prolonged

the clotting time moderately. The different clinical effects such as mexotoxic effect, edema and hemorrhage, induced by the venom were neutralized significantly when extract were intraperitoneally injected in does dependent fashion. The result of the study concluded that the use of tamarind seed extract as an alternative for the serum therapy [61].

7.8. Hepatoprotective activity

The methanolic extract of *T. indica* leaves exhibited significant antihistamic, adoptodenic and mast cell stabilizing activity in laboratory animals [62]. Aqueous extract of different part of *T. indica*, such as fruits, leaves and unroasted seed were administrated and a significant hepatoprotective effect was observed for the aqueous Tamarind leaves, fruits, and unroasted seed as judged from the different biochemical parameters parameter studies [63]. Aqueous extract of different parts of *Tamarindus indica* such as fruits, leaves and unroasted seeds showed significant hepatoprotective effects in paracetamol induced hepatotoxicity in rats [63]. Mahesh et al. [64] conducted the study to find the hepatoprotective potential tamarind flower. The result of the study confirmed that ethanolic extract of flower has hepatoprotective effect in Wistar albino rats, hepatotoxicity was induced by Ethanolic extracts of *T. indica* flower was shown hepatoprotective effect in Wister rats hepatotoxicity induce by isoniazid and rifampicin. Meena et al. [5] evaluated the hepatoprotective activity of the ethanolic extract of *Tamarindus indica* stem bark against the induced Drug induced hepatic damage during chemotherapy in Sprague Dawley rats. The result of the study revealed that 200 mg/kg body weight of ethanol extract showed the better protection against hepatic damage and confirmed the hepatoprotective activity against development of drug induced damage.

7.9. Anti-inflammatory and analgesic activity

Tamarindus indica has been traditionally used in the treatment of pain. Various extract of *T. indica* was screened out for preliminary phytochemical availability, which showed the presence of sterol and triterpenes in extract; hence these compounds might be responsible for analgesic activity [65]. Anti-inflammatory activity is also supported by presence of flavonoids, saponins and tannins in Tamarind seeds [20]. Bhadoria et al. investigated the in vitro anti-inflammatory effect of hydroethanolic extract of *T. indica* leaves on carrageenan induced hind paw edema in male Wistar albino rats [2]. The result of the study confirmed that oral administration of extract has significant dose dependent action in the treatment of anti-inflammatory disorder.

7.10. Effect on enzyme

Due to the presence of large number of potentially active biocompound the seed of Tamarindus indica were reported for its proteinase inhibitors with high inhibitory activities against human neutrophil elastase [66]. A proteinaceous inhibitor from *T. indica* seed (TTI) showed remarkable activity against insect digestive enzyme form different order of Coleoptera and Diptera. This experiment was performed by using in vivo bioinsecticidal assay in which the larvae were feed TTI-incorporated artificial diets at different concentration. The mode of the action of TTI was non competitive. The concentration of TTI added to artificial diet cause 50% mortality (LD_{50}) [67]. Useh et al. studied the effect methanolic extract of *T. indica* bark on neuraminidase activity from *Clostridium chauvoei* (Jakari strain). The result of the experiment concluded that

the extract inhibited the neuraminidase activity in a dose dependent manner and the mode of inhibition was non competitive [68]. Seed are excellent source of proteinase inhibitor, some of which have satietogenic and slimming action. It has been reported that the isolated trypsin inhibitor from *T. indica* seed reduced weight gain by reducing food consumption, an effect that may be mediated by increased cholecystokinin [69].

7.11. Anti-ulcer activity

Tamarindus indica was found to possess anti-ulcerogenic as well as ulcer healing properties, against ulcerated rats. The result of the study suggested that anti ulcer activity is due to antioxidant property of *T. indica* [70]. Kalra et al. [71] studied the antiulcer effect of methanolic extract of seed coats of *T. indica*. The result showed significant reduction in the total volume of gastric juice, free and total acidity of gastric secretion in pylorus ligation induced ulcer model as is comparable with the standard drug ranitidine. There was also a significant reduction in ulcer index.

7.12. Anti-helminthic activity

Tamarindus indica leaves are used in the extraction of Guinea worms, and the decoction of the leaves extract is the one of the most important agent to clean the wound, caused by parasite [72]. An extract of the leaves and root is used to treat tankylostomiasis (hookworm) in some part of Tanzania [73]. The ethanolic and aqueous extract of *T. indica* bark and leaves were tested against the *Pheretima posthuma* and *Tubifex tubifex* worms. Both of the extract causes paralysis and death of the worms within the shorter time as compared with the standard drug piprazine citrate [74]. Mute et al [75] studied the anthelmintic effect *Tamarindus Indica* leaves juice against *Pheritima posthuma*. The results of study indicated that the juice of *T. indica* leaves showed the effect paralysis, and also caused death of worms especially at higher concentration as compared to standard anthelmintic drug piperazine citrate. Bondada et al. [76] also studied the anthelmintic activity of aqueous and ethanolic extract of *T. indica* leaves against earthworms.

7.13. Antiamebic activity

More recently Mehndi et al. [77] work on the antiamebic activity of *Tamarindus indica* leaves extract against *Entameoba histolytica*. In the result of his study he established that aqueous and ethanolic extract of *T. indica* leaves reduced the no. of *E. histolytica* count up to zero after 72 and 96 hour of adding in culture media. It is also revealed that there is no cytotoxicity against erythrocytes even when high concentrations of plant extract were used.

7.14. Molluscicidal activity

The plant of *Tamarindus indica* have great potential source of ethno-botanical molluscicides against fasciolosis vector snails *Lymnaea acuminata* and *Indoplanorbis exustus* [18, 19]. The 96h LC_{50} of column purified fraction of bark against *L. acuminata* was (13.78 mg/l) and against *I. exustus* was (33.10 mg/l), respectively. Toxicity of 96h LC_{50} of column purified fraction of *T. indica* seed against *L. acuminata* is 0.71 mg/l and 21.37 mg/l against *I. exustus* respectively. *In vivo* and *in vitro* sublethal treatment of active component of column purified bark and seed of *T. indica* and its active component saponin caused significant

inhibition in AChE, ACP and ALP activity in the nervous tissue of *L. acuminata* [78, 79]. The result of the kinetics study of enzyme inhibition showed that inhibition of AChE by Column purified fraction and saponin is competitive while inhibition of AChE by column purified fraction and procynadine of *T. indica* seed is uncompetitive. Inhibition of ACP by column purified fraction and saponin were uncompetitive, ACP Inhibition by of column purified fraction and procynadine of *T. indica* seed was competitive. Inhibition of ALP by both of treatments was competitive. Withdrawal of snail from 80% of 96h LC_{50} of different preparations for next 96h untreated water caused trend to recovery in enzymes activities indicates that treatment of column fraction of *T. indica* bark and its active component saponin caused reversible inhibition of these enzyme. Since the molluscicides are cost effective to kill the vector snail though it does not exert any ecotoxicological effect on non target animal in aquatic biota [80].

8. CONCLUSION

This review comprehensively validates the broad spectrum information about the, pharmacology, traditional and nutraceutical application along with the scientifically claimed medicinal uses of *T indica* and its bioactive constituents. *Tamarindus indica* is a long lived, large sized, famous and common tree of India. Traditionally *Tamarindus indica* are being used in asthma, bronchitis, leprosy, tuberculosis, wounds, ulcers, inflammation, stomach algia, diarrhea, dysentery, burning sensation, giddiness, vertigo, and diabetes. Although the plant of *Tamarindus indica* gives a promising result of potential application in pharmaceutical industry still there is a lots of study required to explore the full therapeutic potential of various parts of the plant in order to establish it as a standard drug.

Conflict of Interest: The author declares no conflict of interest.

Authors Contributions: NS conceived of the present literature and provided it a manuscript form. VKS encourage to investigate and supervised the findings of this review. Both the authors discussed the result and contributed to the final manuscript.

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