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AN OVERVIEW OF INDIAN PRICKLY ASH (*ZANTHOXYLUM RHETSA* ROXB. DC.): A VALUABLE UNDERUTILIZED SPICE

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ABSTRACT

Indian prickly ash [*Zanthoxylum rhetsa* (Roxb.) DC.] is a tropical tree belonging to Rutaceae family that has been traditionally used in various culinary items and medicines by the local folks of India. Tree species are found growing in wild forms in forests of the Western Ghats and other parts of India. Tree have been mainly used as medicinal material, food flavourant, insect repellents, carpentry wood, firewood, handicrafts, handles of tools *etc*. It is well documented for medicinal and pharmaceutical properties against many human ailments as it is anti-diabetic, anti-spasmodic, anti-diuretic, anti-inflammatory, anti-nociceptive, anti-diarrheal, anticestodal, antibacterial and anti-cancerous. The fruits of Indian prickly ash possess typical strong lemon skin aroma and has a good volatile contents. It is a richest source of essential oils, antioxidants and other biological compounds. Hence, it could be utilized for the preparation of manifold commercial products like perfumes, essential oils and preservatives. Indian prickly ash has not been yet domesticated and presently wild forests are the only source of produce. Probably this species is ignored because of its thorny nature, tall height, changing lifestyles, unawareness of its use or benefits *etc*. This review focus on *Tirphal* as a potential spice tree with the peculiar botanical characters, traditional, medicinal and commercial importance.
***Keywords*:** Biochemical composition; botany; cultivation; essential oil; underutilized spice

Introduction

Indian prickly ash [*Zanthoxylum rhetsa* (Roxb.) DC.] is a multipurpose tree species found in the tropical regions of the world. It belongs to the botanical family Rutaceae, of which economically important *Citrus* species are the prime members. It is naturally distributed in the evergreen forests of Meghalaya, Western Peninsula, Coromandel, Western Ghats, Konkan, Goa, Mysore, Malabar, Annamalai, Travancore, Odisha, Chitttagong and Assam regions of India (Brandis, 1971; Hooker, 1998; Antony *et al*., 2019). Apart from India, Indian prickly ash is also found growing in Sri Lanka, Myanmar, China, Thailand, Peninsular Malaysia, Java, the Philippines, Indonesia, Southern Papua, New Guinea and North Queensland (Hartley, 1966; Hartley, 1970; Boer *et al*., 1998).

Fruit skin (fresh and dried), seeds, shoots, bark and stem prickles are the parts of economic importance, which are used traditionally for variety of purposes. Multipurpose nature of the species including traditional knowledge has been scantily documented by some researchers. It has been reported as an underutilized spice for imparting unique flavor in Asian countries (Naik *et al*., 2015; Duangyod *et al*., 2020; Karanjalker et al., 2021), as a constituent of traditional medicines (Yadav and Tangpu, 2009; Lalitharani *et al*., 2010; Medhi *et al*., 2013) and as a source of industrially important phyto-chemicals (Mahadkar *et al*., 2013; Vidyamadhavi *et al*., 2014; Rana and Blazquez, 2010; Naik *et al*., 2015) with considerable biological activities (Patino *et al*., 2012).

Although *Zanthoxylum rhetsa* is one of the common species of the forests of Western Ghats of India, it has not received enough attention to warrant its domestication. Presently, forests are the only source of produce for meeting the growing requirement of local people and traditional medicines. Thorny nature

of the species, tall growing habit, lack of awareness about the uses and importance, competition from more remunerative cash crops *etc*. could be the probable reasons for the non-domestication of this species. The present article concerns highlighting the significance of this underutilized genetic resource. This could help in its conscious conservation and promotion of cultivation in years to come. Field observations and findings of experiments conducted by authors have also been included to improve the understanding of the species.

Botany

Zanthoxylum rhetsa belongs to the botanical family Rutaceae. This family consists of ca. 150 genera, important being *Fagara, Zanthoxylum, Ruta, Glycosmis, Eriostemon, Atalantia, Citrus, Murraya* and *Aegle* (Roy and Rahman, 2016). The genus *Zanthoxylum* has ca. 549 species distributed throughout the world, most of which are known to possess significant ethnobotanical value, phytochemical diversity and biological activities (Patino *et al*., 2012). Out of these, 12 species are *Zanthoxylum rhetsa* (Roxb.) DC, *Z. acanthopodium* DC., *Z. armatum* DC., *Z. ovalifolium* Wight., *Z. tomentellum* Hook. f., *Z. scandens, Z. myriacanthum* Wall. Ex Hook. f., *Z. pseudoxyphyllum* Babu, *Z. tetraspermum* W. A., *Z. burkillianum* Babu, *Z. nitidium* (Roxb.) DC. and *Z. oxyphyllum* Edgew (Hajra *et al*., 1997; Kumar *et al*., 2019). The name *Zanthoxylum* is derived from Greek word "*xanthonxylon*" meaning "yellow wood" and hence some authors also use the word *Xanthoxylum* for its nomenclature (Patino *et al*., 2012). William and Wallich (1820) described *Fagara rhetsa* as native of mountainous parts of the coast. Later de Candolle and Augustin in 1824, renamed genus *Fagara* as *Zanthoxylum*, and mentioned its source as India. This suggests that it might have been originated from Indian mountainous coastal region of Western Ghats.

Tree morphology: It is a tall tree that grows upto the height of 25–30m (Shankaracharya, 1994; Brophy *et al*., 2000) with diameter at breast height (DBH) of 80-100 cm. The trunk is corky and straight. It has sparse and upright shaped canopy with 3-5 main branches (Karanjalker and Karanjalker, 2023). As indicated by the name Indian prickly ash, trunk as well as stems of the tree is known to have ash coloured thorn like conical projections. Spines are hard, conical shape with 50µm at upper pointed portion and 200µm at the basal portion (Lalitharani *et al*., 2010). Thorns at DBH vary from 5 to 7 number of prickles/10cm^2 on main stem and from 22 to 25 number of prickles at terminal branch. Prickles on a tree play role in self-defense against wild animals and extreme stress conditions. Bark is thick (1.0-1.2cm), odorless, bitter in taste, covered with woody ash color from outer surface, while inner surface is pale brown (Pai *et al*., 2009).

Both vegetative and reproductive parts of the tree including shoots, leaves, flowers and fruits are characterized by presence of refreshing flavor lemon skin. Plant exhibits deciduous or evergreen nature (Yadav and Tangpu, 2009, Hartley, 2013; Karanjalker *et al*., 2021). It is winter deciduous under the tropical conditions of Goa, India (Karanjalker *et al*., 2021) where flowering appears in the months of July-August. However, in Australian conditions, flowering is reported to occur during months of November to February (Hartley, 2013).

Leaf: Leaves appears in clusters at the terminal and axillary branches with following characters. Leaf is compound imparipinnate type. Leaf base is pulvinus, ex-stipulated and sessile. Leaf laminar is oblong lanceolate with slightly acuminate or caudate apex. Leaflets have pinnate or unicostate reticulate venation with serrated margins. Leaf arising from each node has 25 to 37cm length with spiral or alternate arrangement. Number of leaves per terminal branch vary from 14 to 27 (Karanjalker and Karanjalker, 2023). On each leaf, leaflets vary from 8-12 in numbers and arranged in opposite manner on rachis with 9-15 cm length and 3-5 cm width. Leaflets are asymmetrical and glabrous: Leaves are observed with thin pointed spines throughout their rachis. After fruit maturation plant sheds their leaves. New growth starts in March-April under Goan conditions.

Flowers: The tiny yellow coloured flowers are borne in the cymose of about 20cm length at the terminal and axillary branches. Two types of flowers *viz*. male and female are evident on the panicle. Male flowers have 3 mm long stamens and are of disc or conical shape, lobed or grooved along with rudimentary gynoecium, whereas female flowers are of disc or columnar shaped, 1.5 mm long with single/double carpelled gynoecium, excentric style and flattened stigma (Hartley, 2013).

Fruits: Fruits are simple, true, follicles borne at axillary and terminal branches. Follicles are single seeded that vary from 5.48 to 6.55 mm in diameter (Karanjalker and Karanjalker, 2023). Commonly follicle is formed into pairs of fruits. Each fruit has single suture which breaks on maturity and expose the seed. As fruit pericarp is not distinguished with three layers it is not fleshy fruit and falls under dry and simple fruit.

Fruits require around 30 to 60 days from flowering to fruiting. Fruits are observed on tree for around 6 months from flowering. Sometimes fruits

possess reddish blushes on its upper surface. During maturation a fruit turn from green to brownish-black, later split up and shatters seeds. Fruit doesn't show complete ripening on the plant and thus judging correct maturity is often difficult. Raw and dried fruits are highly aromatic that taste like lemon skin (Rao, 2000; Duangyod *et al*., 2020).

Seeds: Seeds are globose shape, smooth surface, hard, size 5-7mm and bluish-black in color. Morphological characterization of seven collections from various parts of Goa observed 5.53 to 6.525 mm in seed length and 4.83 to 6.37 mm in seed width (Karanjalker and Karanjalker, 2023). Weight of 100 seeds varied between 8.403 to 14.77g. After dehiscens, seed dispersal occurs due to wind influence by Censer mechanism. Seed showed epigeal type of germination. The cotyledons look like flat green leaves formation that turns pale yellow, shrivels and fall off. These are visible after 10-20 days after sowing followed by plumule development.

Traditional uses

The species has been used traditionally in rural India as wood, folk spice and medicine. Tree wood is resistant to termites (Boer *et al*., 1998) and hence it is excellent for making houses and wooden artifacts including handicrafts, carpentry, jewelry box, walking stick, tool handle, *etc*. It is mainly used as firewood by the forest dwellers. The *Adi* tribe of East Siang District of Arunachal Pradesh, India use shoots (called as *Onger* locally) as vegetables (Payum *et al*., 2013). Fresh and dried fruits have been traditionally used as spice for flavoring food as it is an aromatic and astringent. People from Goa use dried fruits as flavoring agent in culinary items *viz*. fish curry, *solkadhi*, biryanis, pumpkin dish *etc*. (Karanjalker *et al*., 2021). Fruits are also used in Karnataka for preparation of fish curry and other culinary products (Naik *et al*., 2015).

Locals of Western Ghats add few raw fruits for preservation of raw mango (canned mango) (Karanjalker and Karanjalker, 2021). This indicated possible role of fruits as food preservative. Preliminary studies conducted by the lead author suggested that fruit skin could delay rancidity of ground nut when used during storage. Earlier study claimed that dry fruit powder of this species could significantly control rancidity in peanut (Antony *et al*., 2019), wherein one gm dry fruit coarse powder stabilized the peanut oil by controlling peroxide and paraanisidine values with 16.8 and 17.4 meqO2/kg respectively.

Indian Prickly ash has been used in Indian tradition as folk medicines. The *Naga* tribes of North East use leaves of *Z. rhetsa* for deworming (Yadav and Tangpu, 2009). *Kanikkar* tribes of Tamil Nadu, use paste of the spines as remedy against breast pain and to increase lactation in nursing mothers (Lalitharani *et al*., 2010). Bark is chewed and applied for treatment of snake bites (Medhi *et al*., 2013). In Thailand, fruits are traditionally used against toothache, dizziness and bloating (Duangyod *et al*., 2020).

Pharmaceutical significance

The plant has been used for multiple medicinal and pharmaceutical purposes. Plant parts are mainly used as antimicrobial, antiseptic and antidiabetic agent (Wongkattiya *et al*., 2018). Considering the traditional knowledge about use of leaves for deworming, Yadav and Tangpu (2009) scientifically investigated therapeutic effects of *Z. rhetsa* extract against cestode parasite using *Hymenolepis diminuta* (Cestoda) rat model. They found that *Z. rhetsa* leaf extract poses significant anthelmintic efficacy without showing any acute toxicity to the experimental animals. Stem bark extract was found to reduce abdominal contraction induced by diarrheal episodes in mice (Rahman *et al*., 2002).

Fruit skin essential oil was evaluated for chemical composition, antioxidant, antibacterial, antidiarrheal and spasmolytic activities by Naik *et al*. (2015). They studied an effect of isolated compound (terpinen-4-ol) against *Staphylococcus aureus* ATCC 6538a, *Escherichia coli* ATCC 8739 and *Klebsiella pneumonia* and proved its utility as an antibacterial agent. Reddy and Beena (2011) also tested seed essential oils against Gram positive *Staphylococcus aureus* and Gram-negative *Escherichia coli*, *Proteus vulgaris* and *Klebsiella pneumonia* with significant antibacterial effect. They concluded that acid distilled seed essential oils could be potentially used into drug formulations. Essential oil extracted from the fresh and dried carpel possessed antimicrobial activity against *Escherichia coli*, *Salmonella typhi*, *Staphylococcus aureus*, *Shigella flexneri*, *Klebsiella aerogenes* and *Enterofaecalis* (Priya *et al*., 2017). Theeramunkong *et al*. (2018) indicated that volatile oils obtained from fresh fruits and dried fruits were cytotoxic to lung cancer cells. Essential oils extracted from fruits when studied for biological activities, showed inhibitory action against breast cancer cell lines (Wongkattiya *et al*., 2018). The biological activities of essential oils from *Z. rhetsa* were also reported recently by Quan *et al.* (2021) and Pham *et al.* (2021). Quan *et al.* (2021) reported the inhibitory activities of essential oils on amylase, α-glucosidase, xanthine oxidase and Meg-01

cell line demonstrating its anti-diabetic, anti-gout and anti-leukemia properties. A cytotoxic and antimicrobial effect of essential oils were also demonstrated against *F. oxysporium* by Pham *et al.* (2021).

The tree is reported for its use against human ailments as it is anti-cancerous (Theeramunkong *et al*., 2018), antibacterial (Pooja, 2012), anti-diabetic, anti-spasmodic, anti-diuretic, anti-inflammatory, anti-nociceptive and anti-diarrheal (Pai *et al*., 2009; Duangyod *et al*., 2020). Essential oils extracted from fruit skins are also suggested for the treatments of stress and gastrointestinal diseases (Naik *et al*., 2015). Seeds are used for treatment of asthma, toothache and rheumatism (Medhi *et al*., 2013). The extensive literature on ethnomedicinal properties and photochemistry of the species has been reviewed by Maduka and Ikpa, 2021).

Biochemical composition

Proximate composition in fruits: The moisture content of 37.87% was observed in the samples collected from Goa. However, Gurav and Jadhav (2018) reported 49.2±0.35% moisture from Kolhapur district of Maharashtra. The differential values for ash content 3.5±0.36% (Gurav and Jadhav, 2018) and 11.50±0.86% (Duangyod *et al*., 2020) were reported. Parameters *viz*. crude fiber 4.8±0.30%, crude fat 4.0±0.50, crude protein 1.0±0.45, reducing sugar 0.23±0.04g, total sugar 0.3±0.2g, starch1.02±0.05g, carbohydrate 1.32±0.04g, energy 172.4±22.68 KJ/100g was measured by Gurav and Jadhav (2018).

Alkaloids, Phenolic and flavonoid compounds: Various researchers (Payum *et al*., 2013; Mahadkar *et al*., 2013; Santhanam *et al*., 2013; Prabhash *et al*., 2014; Vidyamadhavi *et al*., 2014) have reported presence of phenolic compounds in leaves (62.3 µg/ml), aerial parts (258 µg to 533 µg/g equivalent of tannic acid), shoots (117.95±3.22 mg Gallic Acid Equivalent (GAE)/g), fruits (0.061±0.29 g/100g FW) and bark (14.14±0.185 to 20.47±0.09 mg GAE/g DW). The presence of major phenolic compounds *viz*. Ferulic acid (2100 µg/g), Caffeic acid (404.60 µg/g), Sinapic acid (247.24 µg/g), p-Coumaric acid (177.56 µg/g), t-Cinnamic acid (119.20 µg/g) and Gentisic acid (104.24 µg/g) was observed in dried pericarp of fruit from the samples collected from Goa (Karanjalker *et al.*, 2022). The presence of Chlorogenic acid (2.61 mg/100g FW), Coumaric acid (1.26 mg/100g FW), Caffeic acid (0.65 mg/100g FW), Quercetin-3-βD-glucoside (7.66 mg/100 gFW) and Quercetin-3-O-β-D-glucopyranoside (5.80 mg/100 g FW) was observed in the leaves of *Z. rhetsa* (Shaheen *et al.,* 2021).

Flavonoids have been reported to be present in this species. Total flavonoid content extracted from bark varied from 1.59±0.12 to 3.07±0.24 mg Quercetin Equivalent (QE)/gDW (Santhanam *et al*., 2013). Vidyamadhavi *et al*. (2014) highlighted role of various solvents on extraction of flavonoids from aerial parts of tisal. They have reported significant variations in the flavonoids content as the yield of 166µg to 584µg equivalent of rutin was observed from aerial parts.

Owing to presence of these compounds, the species is known to have considerable antioxidant properties. A study conducted in Arunachal Pradesh suggested presence of 117.95±3.22 mg GAE/g of total phenolic content and 120.14±2.31 µMRE (Rutin equivalent/g of total flavonoids in shoots of tisal, which contributed to antioxidant properties (Payum *et al.,* 2013). Total antioxidant capacity in fruits was found to be 6.88±0.31 (mg AAE/g DW) (Mahadkar *et al*., 2013). Findings of Vidyamadhavi *et al*. (2014) also supported antioxidant activity attributed to presence of phenolic and flavonoid compounds in aerial parts.

The presences of alkaloids were reported from the various plant parts. Major alkaloids *viz*. benzophenanthridine, chelerythrine, nitidine, arnottianamide, fagaridine, oxynitidine has been isolated from the Z. rhetsa plants (Aziz et al. 2022). They reviewed the presence of alkaloids in bark (Rhetsine, Rhetsinine Rhetine), heartwood (Skimmianine), bark (Hydroxy evodiamine, 8-Methoxy-N-methylflindersine, Columbamine, Reticuline, Allocryptopine, Usambanoline, Dihydronitidine, N-Methyllaurotetanine, Chelerythrine, Nitidine), spines (Quinazoline-6-carboxylic acid, 1-Methoxy-7,8-dehydrorutaecarpine, 6-Acetonyldihydro-chelerythrine), stem bark/ roots (Dihydrochelerythrine, 8-Acetonyldihydronitidine, Dictamine, Chelerybulgarine, Simulanoquinoline, 2′-Episimulanoquinoline, 2,11-Didemethoxyvepridimerine B, Rhetsidimerine, Zanthodioline, Arnottianamide, Fagaridine, Oxynitidine).

Macro and micronutrients: Presence of major (N, P, K, Ca, Mg and Na) and minor (Cu, Fe, Zn and Mn) elements has been reported from fruits of tisal (Mahadkar *et al*., 2012). Fruits were found to have good contents of Nitrogen (720±3.00 mg/100g of DW), Phosphorous (240±10.53mg/100g of DW), Potassium (340±12.52mg/100g of DW), Calcium (731.2 ±5.61mg /100g of DW), Magnesium (316.8±4.92mg/ 100g of DW), Sodium (350±6.08mg/100g of DW), Copper (4±0.14mg/100g of DW), Iron (9.52±0.33mg/ 100g of DW), Zinc (1.06 ±0.13mg/100g of DW) and Manganese (0.70 ±0.06mg/100g of DW).

Essential oil and oleoresins: Vegetative and reproductive parts of plants of tisal possess pleasant flavour. As the aroma is akin to lemon, fruit skin oil could be used as cheap substitute for the citrus oil. Essentials oils extracted from various parts of plants and fruits could be used in manifold commercial products like perfumes, essential oils and preservatives, cosmetic natural sunscreen, anti-ageing cosmetic, antiseptics, *etc*. (Shantanu *et al*., 2011; Reddy and Beena, 2011; Antony *et al*., 2019; Santhanam *et al*., 2019).

As synthesis and accumulation of essential oils in a species is governed by several internal and external factors, variability has been reported for this trait. Theeramunkong *et al*. (2018) observed volatile oil yield of 8.1 to 13.6% (v/w) from fresh fruit skin, while it was 13.17 to 15.33% (v/w) in skin from dried fruits collected from Thailand (Northern Nan, Southern Nan, Phayao and Chiang Rai). Volatile oil recovery of 2.3% (v/w) has been reported by Duangyod *et al*. (2020) in dry fruits collected from Thailand, while mere 1.94% essential oil was recovered in a study by Rana and Blazquez (2010), who obtained the dry seed coats from Imphal, Northeast India. Essential oils are generally determined by hydro-distillation method.

We studied essential oil and oleoresin content in seven collections of tisal from Goa, India (Karanjalker and Karanjalker, 2023), that showed the presence of high essential oil (6.0- 8.4%) content in dried fruit skin. Oleoresin content determined using acetone revealed as high (8.86%-12.22%) content with appealing 'golden yellow to light green' in colour.

Essential oil composition: Several studies are available to describe essential oil profiling of different parts of tisal from different regions of the world and perusal of the data suggest distinct variations amongst them. In general, terpenoids, xanthyletins, sesamins, alkaloids, flavonoids, essential oil and sabinene have been reported to contribute to flavor of tisal (Mathur *et al*., 1967; Ahsan *et al*., 2000; Shankaracharya, 1994; Rao, 2000; Joy *et al*., 2006; Pai *et al*., 2009).

Naik *et al*. (2015) reported presence of compounds belonging to monoterpene family *viz*. terpinen-4-ol (25.4%), sabinene (16.5%), β-pinene (10.4%), α-Terpineol (7.6%), γ-Terpinene (5.6%), α-pinene (4.3%) and linalool (3.3%) in fruits collected from Karnataka, India. Composition of oils from pericarp using GC-MS revealed sabinene (56.62%), 4-terpineol (13.82%), germacrene (10.1%), gamma-terpinene (5.5%) and alpha-terpinene (3.5%) as major volatile compounds (Duangyod*et al*. 2020). This study was conducted using samples collected from Thailand. Terpinen-4-ol (32.1%), α-Terpineol (8.2%), sabinene (8.1%), β-phellandrene (7.4%) and 2-undecanone (7.1%) in pericarp of essential oils from Imphal region were reported by Rana and Blazquez (2010).

Compounds Sabinene (22.51%) and terpinene-4-ol (32.33%) were reported from essential oil of fruits collected from Thailand (Wongkattiya *et al*., 2018). Monoterpene hydrocarbons and monoterpene alcohols have been found to be the imparters of aroma in seed oil (Jirovetz, 1998). Shafi *et al*. (2000) evaluated compound from leaves and seed oils. Leaf oil contained caryophyllene oxide (12.7%), β-Caryophyllene (9.6%), β-Copaene (5.3%) and spathulenol (3.3%) as the main components, while seed oil contained sabinene (66.3%), α-Pinene (6.6%), β-Pinene (6.3%) and terpinen-4-ol (3.5%) as the major components (Shafi *et al*., 2000). Presence of 55% sabinene (Shankaracharya *et al*., 1994) and 50% sabinene (Joy *et al*., 1986) have been reported in fruits. Our study on profiling of essential oils in dry fruit pericarp using GC-MS/MS, showed the presence of Sabinene (28.63%), β-Phyllandrene (22.47%), α-Pinene (12.762 %), 4-Terpineol (8.742%), γ-Terpinene (5.926%) and α-Elemene (3.342%) as major compounds (Karanjalker *et al*., 2013).

Essential oils from the samples of fresh and dried fruits, collected from different parts of Thailand, showed α-limonene (Phayao, Southern Nan and Chiang Rai), β-phellandrene (Northern Nan) and (+)-sabinene (Southern Nan) as major compounds (Theeramunkong *et al*., 2018). Seed coat oils had terpinen-4-ol (32.1%), alpha-terpineol (8.2%), sabinene (8.1%), b-phellandrene (7.4%) and 2-undecanone (7.1%) as prominent constituents (Rao, 2000). GCMS analysis of spines (Lalitharani *et al*., 2010) concluded presence of 1,2-Benzenedicarboxylic acid, diisooctyl ester (91.6%), Oleic acid (2.83%) and n-Hexadecanoic acid (2.02%) as compounds of significance. Importance of the essential oils compound The compounds Sabinene, α-Pinene, 4-Terpineol and γ-Terpinene have been significantly known for antimicrobial, antifungal and antioxidant properties (Sharma *et al.,* 2019; Pham *et al.* 2021, Nazir and Ahmad 2022). The biological importance of the essential oils from *Z. rhetsa* has been discussed earlier. Hence, *Z. rhetsa* could be the potential source of the essential oils for commercial and pharmaceutical purposes.

Cultivation hints

Being a hardy species with low in maintenance, it has vast potential for backyard and commercial cultivation under the challenged areas, where other

crops could not be grown. It could be grown up to an altitude of 1800 m above MSL (Yadav and Tangpu, 2009; Thambi, 2014) in almost all types of soils. It can survive even hard, calcareous and problematic soils. It can survive very well in the temperature ranges of 22 to 32°C, rainfall of 2000-2500mm and high relative humidity of 85-95%.

Natural regeneration was evident in the nearby areas of the plant, thereby confirming role of seeds in natural dissemination of the species in wild. When referring there were no reports found on the standardization of propagation methods. Preliminary studies conducted on seed germination by us revealed that germination of about 50 to 60% could be obtained using Soil and farmyard manure (1:1, v/v) as substrate. Germination required about 15-16 days. Seed shows epigeal germination, wherein green, flat, leaf like cotyledon pushes upward from soil surface due to elongation of hypocotyl. Detailed studies on standardization of nursery techniques could help in mass multiplication of this species. Further, development of vegetative propagation techniques would be required to multiply elite germplasm in large number. The fruits are observed to with a dieback disease that dries up the branches from the tip. The fruits during maturity are observed with underdeveloped hard seeds without pericarp in a dried panicle.

Fruiting in *Z. rhetsa* is seasonal and fruits are available only for short duration from November to March under West coast of India. During maturity colour of fruits changes from light green to dark green and such fruits are harvested. Fruits do not show full ripening. Indian prickly ash is characterized by presence of thorns all around its trunk and branches. Climbing is difficult due to thorny nature of the plant and hence, fruits are carefully harvested from terminal branches by using chisel made of hook. Terminal panicles are dropped on ground and collected in gunny bags or bamboo baskets. Panicles are tied in bunches and sold in local markets in Goa. Fresh or dried fruits are marketed during peak season of November to March. Drying is generally done on home scale by the collectors. Generally, fruits are sun or shade dried for 5-10 days. Dried and stored fruits are sold in the off season before monsoon as the part of preparation for upcoming monsoon season. The fruit splits open and sheds seeds during maturation or artificial drying.

As dried fruits fetch good prices in the local market, dry recovery could play a major role in determining the profits. Earlier study suggested 16.04% dry recovery (Duangyod *et al*., 2020). Our study on seven collections suggested variations among the trees for dry recovery. Dry recovery varied between 6.0 and 8.4% (Karanjalker and Karanjalker, 2023). After drying, fruits split up with easy separation of seeds. After separation of seeds, fruit skin is stored in air tight containers for about 2 years without any quality deterioration. The dried fruits in Goa are sold locally at the rate of 1000 Rs./Kg. There could be more demand in the domestic markets if marketing channel is systematized for its worth. Systematic studies on mechanical drying and storage could help in obtaining and retaining quality of the produce. The scientific strategies are required to standardize horticultural practices. The studies on diversity and germplasm evaluation could be helpful in understanding the morphological, biochemical and genetic characters of plant as prerequisite for its utilization and promotion of this traditional spice crop.

Conclusion

Considering significant traditional, pharmaceutical and commercial importance, Indian prickly ash could be a promising genetic resource. In present overview, we highlighted some of the basic aspects of the species so that various stakeholders could be made aware of this valuable species to utilize it into pharmaceutical and cosmetic industries. Small groups could be formed to promote systematic but sustainable exploitation of the produce and promotion of cultivation in appropriate areas in the tropics. Considering the refreshing aroma, it could be a suitable candidate for aroma industries.

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