Twists, turns and trade: A new look at the Indian Screw tree (*Helicteres isora*)

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**ABSTRACT**

Ethnopharmacological relevance: This is the first study of global trade in fruits of the widely used traditional medicine, *Helicteres isora* L. It is used in Ayurvedic, Siddha, Unani medical systems and/or local folk traditional medicines in Bangladesh, India and Pakistan. The roots are used in Traditional Chinese Medicines in China and the fruits in *jamu* products in Indonesia, Malaysia and Thailand. In addition, *H. isora* fruits are also used in "traditional" medical systems far beyond the natural distribution of this species, for example in Zulu herbal medicine (South Africa) and Kurdish herbal medicines (Iraq).

*Aims of the study:* This study had three aims: (i) to assess the global trade in *H. isora* fruits; (ii) to study the *H. isora* trade from West Timor to Java in terms of actors and prices along the value chain and (iii) to get a better understanding of the potential of this species to improve household income in eastern Indonesia.

*Materials and methods:* This study uses historical records, a contemporary analysis of global trade data (2014–2016) and field assessments of value chains and the biological factors influencing *H. isora* fruit production.

*Results:* Globally, the major exporter of *H. isora* fruits is India, which exports *H. isora* fruits to 19 countries, far beyond the natural geographical distribution of this species. Over a 36-month period (January 2014–December 2016), India exported 392 t of *H. isora* fruits, with a Free-On-Board (FOB) value of Indian rupee (INR) 18,337,000 (US$ 274,055). This represents an average annual export quantity of about 130,526 kg/year. Over this three year period, most of these exports (85.5%) were to Indonesia (346.58 t), followed by Thailand (6.85%). Indian *H. isora* exports are also used in many other medical systems, including Kurdish and Zulu "traditional" medicines in Iraq and South Africa. Formation of an Indian diaspora in Bahrain, Mauritius, South Africa, Tanzania and Trinidad and Tobago over the past 130 years is one of the drivers of *H. isora* fruit trade outside the natural geographic distribution of the species. In Indonesia, demand for *H. isora* fruits is supplemented by an intra-island trade in Java and an inter-island trade from East Nusa Tenggara. West Timor, for example, exports around 31–37 t of air-dried *H. isora* fruits per year to Java. At the farm gate, local harvesters in West Timor get 4000 IDR (c. 0.3 US$) per kg, with businesses in Java paying 25,000 IDR (c.US$2) per kg for *H. isora* fruits. This is similar to the price paid for *H. isora* fruits imported from India to Java.

*Conclusions:* India is the major exporter of whole dried *H. isora* fruits, including to countries where this species has never been in traditional use. In Indonesia, *H. isora* fruit extracts are used in the cosmetic industry as well as in *jamu* herbal medicines, including “Tolak Angin”, the country's most popular commercial “jamu” preparation. Indonesia also is the major importer of *Tolak Angin* fruits from India. In eastern Indonesia, improved income to local villagers from the *H. isora* fruit trade could come from improved *H. isora* fruit quality due to better drying techniques. This would also reduce health risks along the supply chain from to mycotoxins that have been recorded on poorly dried *H. isora* fruits. There also is an opportunity for cultivation of *H. isora* in small-holder teak plantations in Indonesia, with harvest of *H. isora* fruits as well as the medicinal bark.
1. Introduction

The Indian Screw tree (*Helicteres isora* L., Malvaceae) is a shrub occurring in dry deciduous woodlands through tropical and sub-tropical East, South and South-east Asia as far south as monsoonal northern Australia. In the 19th century, *H. isora* bark was used for making rope and sacks, but was outcompeted by jute (from *Corchorus* species) as a fibre source (Sebastine, 1954). *H. isora* wood was also preferentially used to make charcoal for gunpowder manufacture. In addition, the distinctive spirally twisted fruits of *H. isora* are used in many local herbal traditions, including in Bangladesh (Islam et al., 2015), India (Ayyanar and Ignacimuthu, 2005; Gairola et al., 2013; Kumar et al., 2013), Iraq (Mati and de Boer, 2011), Malaysia, Thailand, Indonesia (Brink and Escobin, 2003) and South Africa (Cunningham, 1988; Wojtasik, 2013).

Nearly 130 years ago, *H. isora* fruits were described in India as ‘... one of the commonest bazaar drugs in most parts of the country.’ (Watt, 1890). Today, *H. isora* is still commonly traded and is one of India’s 178 herbal medicine species whose trade exceeded 100 t/year (Ved and Goraya, 2008). In India, traditional use of fruits and bark of *H. isora* is widespread (Ekkia, 2011; Gairola et al., 2013; Jadeja et al., 2006; Murthy et al., 2010; Padal et al., 2013; Pandey and Shukla, 2008; Punjani and Kumar, 2002; Pushpakanani and Natarajan, 2014; Sonawane et al., 2012; Swain and Mohapatra, 2013; Wagh et al., 2010; Xavier et al., 2014). *H. isora* fruits are sold in local marketplaces across India as well as being exported (Soundrapandi and Narasimhan, 2006; Wojtasik, 2013). The pharmacology and chemistry of this species are also well studied, particularly in India, including research on the bioactive compounds of the leaves showed antimicrobial activity (Kumar et al., 2013), as well as anti-inflammatory activity of the stem bark (Badgurar et al., 2009), hypolipidaemic effects (Kumar and Murugesan, 2008) and anti-diabetic properties of the bark (Kumar and Singh, 2014) and fruits (Aleykuttty and Akhilla, 2012; Subramaniam et al., 2014).

*H. isora* has also been adopted into trade for “traditional” medical systems far beyond the natural range of this species. In the Kurdish Autonomous Region, Iraq, for example, it is traded in the Qaysari market for use in herbal preparations to treat infant colic (Mati and de Boer, 2011). It has also been widely adopted into African traditional medicine in South Africa (Cunningham, 1988), where Wojtasik’s (2013) study in traditional medicine markets in Johannesburg, South Africa showed that *H. isora* fruits were the most commonly stocked of all imported herbal medicines across all categories of herbal traders. *H. isora* fruit extracts also form 10% of the content of Tolak Angin (“expel wind”), a flagship ‘jamu’ herbal product produced by PT Sidu Muncul that has been the leading brand in Indonesia Top Brand Index in the health-care and pharma sector between 2014 and 2017 (Kabareyssy and Handoyo, 2017; YouGovBrandIndex, 2017). Despite a long history of trade, this is the first quantitative study have been done on the global trade in *H. isora* fruits exported from India.

*H. isora* was recorded in Timor over 300 years ago (Rumphius, 1755), yet this is also the first study of *H. isora* value-chains within Indonesia. One of the reasons for this is that sandalwood (*Santalum album* L.) wood, *Aquilaria* (garrau) resin impregnated wood, and bird nests (saranang walet) from the swiftlets (*Collocalia fuciphaga* Thunberg and *C. maximus* Hume), *H. isora* fruits are part of a “hidden economy” and are not traded in local marketplaces. Instead, the *H. isora* trade is largely through Buginese and Chinese-Indonesian trade networks from private premises rather than local informal sector marketplaces (Fig. 3a). During a detailed survey of local marketplaces on four islands in East Nusa Tenggara (ENT) in eastern Indonesia, for example, none of the 11,428 stalls of informal sector sellers we surveyed (Cunningham et al., 2011) sold the distinctive fruits of *H. isora*.

This study had three aims. Firstly, to understand the *H. isora* fruit trade historically and in a global context. Secondly, to study the *H. isora* trade from West Timor to Java, Indonesia in terms of actors along the value chain, prices and the volumes being sold. Thirdly, to get a better understanding of the potential of this species to improve household income in West Timor, in eastern Indonesia.

2. Methods

The identity of *H. isora* was confirmed through a voucher specimen collected in West Timor (A. B. Cunningham 7082 RBG). This matches Allan Cunningham’s voucher specimen from Kupang collected almost 200 years ago (Allan Cunningham 326 RBG) that is still in the collection at Royal Botanic Gardens, Kew (Orchard and Orchard, 2013). Four methods were used in this study.

Firstly, we reviewed literature for records of the historical use and trade in *H. isora* products, supplementing the review with a search through the Economic Botany Collection at the Royal Botanic Gardens, Kew. Secondly, global trade data for *H. isora* were accessed and analyzed for a 36-month period (January 2014 to December 2016). This was complex, as the Directorate General of Foreign Trade (DGFT), responsible for the Indian Trade Classification (ITC) HS Codes has not assigned a species-specific tariff code for *H. isora* plant parts. Therefore its export trade could not be quantified using Government of India’s Export Import Data Bank (TRADESTAT). However, export trade data based on export shipment declarations from all major ports in India is gathered and analyzed by a private firm Zauba Technologies & Data Services Private Limited. Because different individual exporters describe the plant using different vernacular names and some using incorrect general tariff codes, several search terms were used in order to capture all declared shipments. Search terms included the Ayurvedic medicine names ‘marodphali’, ‘murukkan thippili’ and ‘murudshing’, Tamil and Siddha medicine names ‘valampuri’ and ‘valampurikai’, Unani medicine name ‘marorphali’, Latin binomial ‘Helicteres isora’, pharmacopoeial name ‘Isorae Fructus’, Sanskrit name ‘avartani’, and variously spelled trade names ‘mardasing’, ‘mardasingh’, and ‘mardasingi’. *H. isora* is also exported by different companies under five different 8-digit tariff codes. Some of these are clearly incorrect codes for the described shipments, including HS 07089000 (Other: Other leguminous vegetables), HS 12110929 (Other: Leaves, powder, flowers and pods), HS 12110948 (Roots and Rhizomes: Sweet flag rhizomes), HS 12110949 (Other: Roots and rhizomes) and HS 12110909 (Other: Other plants and parts of plants used in perfumery or pharmacy, or for insecticidal/ fungicidal purposes).

Thirdly, in order to understand the value chains involved, interviews were conducted in Bahasa Indonesia by WI and WDK with consolidators (“permampung besar”) buying and drying *H. isora* fruits in West Timor and shipping them from Kupang to Java. We also visited three businesses in Java that buy *H. isora* fruits from India and Indonesia, discussing the quality of the *H. isora* fruits these large commercial enterprises use in relation to *H. isora* samples we obtained from local villagers in West Timor.

Fourthly, we supplemented previous field visits to dry woodlands and medicinal plant markets in South Asia with fieldwork in West Timor, Indonesia in order to understand *H. isora* fruit production and villagers perspectives on *H. isora* trade. As our study aimed to gain a better understanding of how income to harvesters might be improved, we also did a rapid field assessment of fruit production biology in West Timor, Indonesia.

As part of this process, as several traditional healers in Africa had pointed out that *H. isora* screw-like fruits can be “threaded” to the left or the right (Fig. 3d), we examined a random sample of 252 fruits collected from a trader in Kupang and a smaller sample (68 fruits) from a natural population of *H. isora* near Bosen, West Timor.
3. Results

3.1. Twists and turns: 140 years of change in the H. isora trade

There has been a major shift in the international trade in H. isora products over the past 140 years, from bark for fibre in the 19th century to H. isora fruits in the 21st century. In the 19th and early 20th centuries, the commercial focus was the fibrous bark. In India and Indonesia H. isora bark fibre was used to make rope and sacks, but was outcompeted by jute sacking made from Corchorus bark (Brink and Escobin, 2003; Sebastine, 1954). There also was interest in Europe in H. isora bark as a source of fibre for paper making. In 1879, for example, the Indian Forest Department supplied a sample of H. isora bark to Thomas Routledge, the manager of a paper mill in Sunderland, UK (EBC 64951, RBG, Kew). H. isora wood was also preferentially used to make charcoal for gunpowder manufacture and for traditional medicine, but in Travanore, then a princely state in southern India, the principal use until the 1920’s was for kaivun fibre used to make bags for transporting pepper and rice (Sebastine, 1954). The early economic interest in H. isora fibre is evident from 19th century samples in the Economic Botany Collection (EBC) at the Royal Botanic Gardens, Kew, supplied from India in 1878 (EBC 64960) and 1891 (EBC 64962) (Fig. 1).

3.2. Global trade in H. isora fruits

Over the 36-month period (January 2014 to December 2016) India exported 391,578 kg of H. isora with a corresponding customs value (FOB) of INR 18,337,000. This is equivalent to US$ 274,055 total or an average of about US$ 0.70 per kg within the 36-month period of January 2014 to December 2016, based on a currency exchange rate of 1 INR = 0.0149455 USD. Indonesia, followed by Thailand, is the largest importer of H. isora from India, accounting for 85.5% of India’s H. isora fruit exports in terms of volume and nearly 86.3% in terms of reported FOB value (Fig. 2, Table 1).

3.3. Value chains for H. isora and the trade context in West Timor, Indonesia

The value chains for H. isora start with wild harvest in seasonally dry woodlands and degraded shrublands in West Timor (Fig. 3). Most harvests take place in May–June in areas such as Bena. When harvested, the wet mass of H. isora fruits in West Timor is 465 fruits/kg (extrapolated from a sample of 70.9 g for 33 fruits). After drying, by the time fruits are ready for packing into bags by large-scale traders consolidating fruits to send to Java, it takes 1620 fruits (air-dry mass) for 1 kg (based on a sample of 124 fruits at 76.5 g).

Fig. 2. The quantities of H. isora fruits exported from India to other countries over a 36-month period (January 2014 to December 2016), showing Indonesia and Thailand as the main importing countries. Smaller import quantities have been rounded off to the nearest 100 kg from data in Table 1. Exports for the 3 year period to New Zealand (50 kg), Trinidad and Tobago (250 kg), the Russian Federation (50 kg), the USA (2 kg) and Yemen (50 kg) are not shown here, but are included in Table 1. The role of an Indian diaspora from the 19th century onwards is likely to have driven expansion of the H. isora trade to Bahrain, Mauritius, South Africa, Tanzania and Trinidad and Tobago.

In stark contrast to the lack of any H. isora being sold in any of the informal sector markets surveyed in eastern Indonesia (West Timor, Flores, Sumba and Savu) (Cunningham et al., 2011), the traders we interviewed in West Timor were exporting 31–37 t of sun-dried H. isora fruits per year to Surabayab and Semarang in Java. Based on discussions with the consolidators and exporters we interviewed, some of who are no longer trading, we suggest that a total of 60–80 t of sun-dried H. isora fruits are exported to Java per year. At the current FOB price in Java, this would be worth $589 million IDR (US$44 200 per yr).

3.4. Harvest, fruit production and population biology

Surprisingly, given the extensive use of this species in India for...
Table 1

The Republic of India's total export quantities and values sorted by importing country in order of predominance over the 36-month period (January 2014 to December 2016), based on export trade data from Zauba Technologies & Data Services Private Limited (https://www.zauba.com/).

<table>
<thead>
<tr>
<th>Importing country</th>
<th>Quantity (kg)</th>
<th>Value (INR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Republic of Indonesia</td>
<td>346,580</td>
<td>15,826,544</td>
</tr>
<tr>
<td>Kingdom of Thailand</td>
<td>26,830</td>
<td>1,469,942</td>
</tr>
<tr>
<td>Malaysia</td>
<td>6368</td>
<td>369,436</td>
</tr>
<tr>
<td>Democratic Social Republic of Sri Lanka</td>
<td>2897</td>
<td>244,396</td>
</tr>
<tr>
<td>Kingdom of Bahrain</td>
<td>2375</td>
<td>175,359</td>
</tr>
<tr>
<td>People's Republic of Bangladesh</td>
<td>2000</td>
<td>31,992</td>
</tr>
<tr>
<td>United Republic of Tanzania</td>
<td>1200</td>
<td>29,959</td>
</tr>
<tr>
<td>Republic of Iraq</td>
<td>1000</td>
<td>47,090</td>
</tr>
<tr>
<td>Republic of Singapore</td>
<td>511</td>
<td>17,976</td>
</tr>
<tr>
<td>Hashemite Kingdom of Jordan</td>
<td>500</td>
<td>32,238</td>
</tr>
<tr>
<td>Republic of South Africa</td>
<td>405</td>
<td>24,022</td>
</tr>
<tr>
<td>Islamic Republic of Pakistan</td>
<td>250</td>
<td>9283</td>
</tr>
<tr>
<td>Republic of Mauritius</td>
<td>250</td>
<td>17,766</td>
</tr>
<tr>
<td>Republic of Trinidad and Tobago</td>
<td>250</td>
<td>12,290</td>
</tr>
<tr>
<td>Kingdom of Saudi Arabia</td>
<td>50</td>
<td>4318</td>
</tr>
<tr>
<td>New Zealand</td>
<td>50</td>
<td>3576</td>
</tr>
<tr>
<td>Republic of Yemen</td>
<td>50</td>
<td>3683</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>10</td>
<td>5972</td>
</tr>
<tr>
<td>United States of America</td>
<td>2</td>
<td>123</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>391,578</strong></td>
<td><strong>18,307,998</strong></td>
</tr>
</tbody>
</table>

4. Discussion

One of the advantages that the Indian Forest Department had to support the 19th century British interest in economic botany was access to indigenous knowledge through discussions with Indian forest rangers who were trained at the Dehra Dun Forest School (Cornish, 2013). Samples of *H. isora* fruits and bark supplied to the Royal Botanic Gardens, Kew are evidence of international interest in the potential economic value of this species (Fig. 1). Most contemporary trade is in *H. isora* fruits for medicinal purposes rather than *H. isora* bark. What has driven globalization of the *H. isora* fruit trade? Several factors account for a global trade in *H. isora* fruits for “traditional” medicine.

4.1. Popularity and demand: more than just the "doctrine of signatures"

In the 19th century *H. isora* was a common component in the herbal medicine trade (Watt, 1890), a trend that continues in India over a century later (Ved and Goraya, 2008). There is no doubt that the unusual shape of the fruits has drawn attention cross-culturally. This is reflected in the meanings of vernacular names for *H. isora* in local languages within and outside the range of the species, which refer to the rope-like twisted shape of the fruits. Examples are the Hindi name (maror phali, meaning “twisted pod”), Mandarin name (火索麻 *Huoshuo ma* in pinyin, meaning “fire rope”), Bahasa Malaysia (chabai tali (where tali means rope) and the isizulu name, ijikantamo (meaning “pull the rope”). A common outsider assumption was that use of folk medicines from *H. isora* fruits to treat intestinal problems “had more to do with their intestinal-like twisted appearance than with their medicinal properties" (Brink and Escobin, 2003) and that the Doctrine of the Signature was resulted in *H. isora* in “most prescriptions for the cure of griping in the bowels and flatulence, especially in the cases of children. Its chief virtue seems to be its harmfulness”. But as Brink and Escobin (2003) and studies referred to earlier in this paper indicate, research shows that *H. isora* fruits contain active ingredients.

4.2. Popularization outside the natural geographic range of *H. isora* by an Indian diaspora

Based on detailed discussions with members of the Natal Herb Traders Association, one of the primary drivers of globalization of the *H. isora* trade in the 19th century were the indentured labourers sent to former British colonies to develop the sugar industry (L. Govender and B. Naidoo, pers. comm with Cunningham, 1988). This stimulated small business development by Indian settlers in KwaZulu-Natal, South Africa (Hiralal, 2008), Mauritius (Brennan et al., 1998) and Trinidad and Tobago (Lai, 1993), including, we suggest, importation of *H. isora* and other South Asian herbal medicines. A similar historical dynamic, driven by an Indian diaspora, accounts for Trinidad and Tobago being the largest importing destination for *Boswellia serrata* Roxb. ex. Coelebr. In Bahrain, the high number of migrant workers from Bangladesh, India and Pakistan may also account for the trade there (Fig. 2).

4.3. Old ingredient, new production processes and packaging

In the 21st century, *H. isora* is an ingredient of Ayurvedic products made in India as well as Indonesian *jamu* herbal preparations in well organized, modern factory facilities. An Indian example is AyuLax, an Ayurvedic product produced by Welex Laboratories Pvt. Ltd (Maharashtra, India) that contains 40 mg of *H. isora* fruits in addition to eight other herbal ingredients. These are imported into Indonesia by PT. K-Link Indonesia (Java, Indonesia). Within Indonesia, the rapid growth of the local traditional medicines (*jamu*) industry also reflects growing demand for *H. isora* fruits from several well-known *jamu* companies, including Nyonya Meneer and PT. Sido Muncul.

For PT. Sido Muncul, the herbal medicine sector was the most important contributor to company profits, with 13.3% year on year growth (Phillip Capital, 2015). *Jamu* is produced in three main forms: powder (30%), liquid (67%) and tablets (3%) (Phillip Capital, 2014). And the most popular of PT. Sido Muncul’s products is the Tolak Angin brand, which is in liquid form in easy to consume sachets (Fig. 3e). In 2012, PT. Sido Muncul had 75% share in the herbal cold remedy market (Phillip Capital, 2015). Based on the labeling on Tolak Angin sachet, each contains 5.67 g of herbal extract, 10% of which is from *H. isora*. With sales of Tolak Angin at around 80 million sachets/month, this represents an monthly demand of 4536 kg of *H. isora* dry fruits/month (or 54.4 t/year) by this single large company. Based on the mass of fresh vs. air-dry *H. isora* fruits in our study, there are 465 fruits/kg (fresh
mass) or 1620 fruits/kg (air-dry mass). So Indonesian imports from India would represent around 220 million fruits/year. However, the cost of *H. isora* fruits imported from India is similar to the price paid by *jamu* companies for *H. isora* fruits imported from West Timor. This is due to relatively long supply chains from a “farm-gate” price of 4000–5000 IDR/kg (about US$0.30–0.38/kg) to harvesters in rural West Timor to 25,000–30,000 IDR/kg (about US$1.88–2.25/kg) when sold to *jamu* companies in Surabaya and Semarang (Fig. 4).

4.4. Growing demand through branding and celebrity support

Tolak Angin has been the leading brand in Indonesia Top Brand Index in the health-care and pharma sector between 2014 and 2017 (Kabaressy and Handoyo, 2017; YouGovBrandIndex, 2017). This is not a matter of chance in a very competitive market. It is the result of significant investments in advertising and branding evident from the remarkable number of Indonesian studies have focused on what
influences customer choice and brand loyalty to Tolak Angin (Martopo, 2015; Pribadi and Dharmestma, 2011; Setyawati, 2017), competitive advantages of Tolak Angin (Fedora, 2013; Puspita and Nugrahani, 2014) and advertising tactics (Santoso et al., 2014), that include the use of celebrity support (Audrine, 2012).

4.5. Abundant wild stocks combined with low impact harvest

To sustain commercial trade, the demand for H. isora fruits has to be matched by sufficient supplies and sustainable harvest. In eastern Indonesia, where field observation in dry forests of Sumba and West Timor shows that H. isora populations are scattered and at a relatively low density. In contrast, H. isora can be a dominant species in some woodlands in India. In a study in dry forest in southern India, for example, H. isora one of the four most abundant dry forest species in the study site (Sukumar et al., 1992). And unlike several other commercially harvested medicinal plants described in this special issue, where harvest has a high impact (Cunningham et al., 2018), harvest of H. isora fruits has a low impact. Debarking by wildlife inside some conservation areas in India can result in high mortality of H. isora (Khan et al., 1994). Nevertheless, while other factors, such as climate and insect attack can influence fruit production (Muthukumar et al., 2017), destructive effects of harvest are low and the opportunity for sustainable harvest is high.

4.6. Is there scope for H. isora cultivation?

Over 60 years ago, Sebastine (1954) concluded that “in view of the shortage of natural fibre, a systematic and large scale cultivation of Kaivun may be of great value” and proceeded with H. isora cultivation trials. Since then, commercial interest in natural fibres first waned, with the availability of synthetic fibres, such as nylon, but has now grown again. Driven by higher levels of public awareness about the environment, about waste disposal and about depletion of petrochemical resources, there is a new impetus for growth of new materials and products based on natural fibres and biopolymers, some of which can compete with synthetic products. In addition, there is growing interest in non-timber forest products that could add value to teak plantations in Indonesia to diversify and improve income to local people.

With projected sales of Tolak Angin reported to be 140–150 million sachets per month (Standard Chartered Equity Research, 2014), H. isora production in agroforestry systems or teak plantations in eastern Indonesia is worth careful consideration. The results of Sebastine’s (1954) study are still useful today. Key results were that: (i) spacing of seedlings (2–3 feet (0.6096–0.9144 ft) vs. 20 feet (6.096 m) apart) influenced H. isora growth form. With the close spacing, a single main stem grew up above smaller stems, but with wide spacing, H. isora formed multi-stemmed bushes; (ii) planted just before the monsoon, H. isora seedlings grew rapidly. At one-year old, the main stem was 1.27–1.9 cm (0.5–0.75 in. in Sebastine, 1954) in diameter and the trees were 1.22–2.13 m (4–7 ft) high. At two years old, H. isora trees stem diameter ranged from 1.9 to 2.54 cm (0.75–1 in.) and trees were 2.13–3.66 m (7–12 ft) high. Trees grew rapidly after manure was added to the soil and started to flower and fruit. At two years old, the trees were cut for fibre, sprouting vigorously after cutting. Sebastine (1954) noted that the best quality fibre (for sacking) was from long, straight branches recommending annual cutting for fibre. If bark is needed for extraction of active ingredients for anti-diabetic or anti-inflammatory use, then a different approach may be needed and studies on how active ingredient content is influenced by tree (or bark) age and coppice rotation history would be useful.

In India, with large wild H. isora stocks, cultivation may be less viable than in Indonesia. But it is worth assessing how relevant Sebastine’s (1954) recommendation for H. isora production in India’s teak (Tectona grandis) plantations would be to Indonesia? There certainly is scope in Indonesia today, where teak is the most popular timber species grown by farmers. Most teak production occurs in Java, but in East Nusa Tenggara, Indonesia’s driest and poorest province, over 19,300 households grow teak (Hardiyanto and Prayitno, 2008), including in West Timor, where H. isora currently is wild harvested. But large-scale involvement of small-holder farmers in H. isora cultivation needs to be considered very carefully before any implementation takes place. With the large volume of H. isora fruits exported from India and the competitive prices paid of these H. isora fruits, the scope for price increases at the farm-gate in West Timor is limited.

There may also be a market for H. isora bark in the future. There is renewed interest for example, in H. isora bark fibre as a reinforcing component in bio-composites (Joshy et al., 2006; Mathew et al., 2011). Expansion of bark processing for the jamu industry in Java may also be possible through extraction of the anti-inflammatory (Badgajar et al., 2009) and anti-diabetic (Aleykutty and Akhila, 2012; Kumar and Singh, 2014) properties of the bark for jamu in Indonesia. These uses of the bark, in conjunction with growing demand for herbal products from H. isora fruits, offer an opportunity to build on Sebastine’s (1954) cultivation trials, where both old and new commercial uses of H. isora could add to the economic viability of H. isora cultivation as a multi-use understory shrub in teak plantations.

4.7. What are the priorities for future research?

Three steps are suggested prior to implementation of cultivation trials. Firstly, better insights are needed into the micro-economics of H. isora production in teak plantations. These could be achieved through modeling “what if?” questions to test whether a shift from extensive wild harvest of fruits to more intensive on-farm production of multiple products (fruits, bark, charcoal) from H. isora may be a viable option.

Secondly, given the similarity in prices paid for H. isora fruits imported from India and locally harvested fruits in Indonesia, the competitive edge in sales to Indonesian companies is likely to come from improving the quality of dried H. isora fruits and improved drying, storage and grading of fruits at the household level. In West Timor, dried H. isora fruits are often stored in the same location as food crops traditionally stored: traditional “cooking huts”, where smoke keeps away insects that could cause post-harvest loss. However, this can also cause smoke and soot contamination of H. isora fruits that are then sold to the jamu industry. In addition, from field observation, both imported and locally harvested H. isora fruits are susceptible to fungal infection, due to packing before the fruits are sufficiently dry. In India, a study of 15 medicinal plant species collected at random from herbal medicine shops showed that 17 fungal species were found on H. isora, including the species in the three most mycotoxic genera (Aspergillus, Penicillium and Fusarium species). out of all 15 medicinal plant species sampled, stored H. isora were affected by the third highest number of fungi after Plantago ovata (21 fungal species) and Carum coticum Benth (18 species). Fungi occurring on H. isora in Dhale’s (2013) study are sources of aflatoxins (Aspergillus), ochratoxins (Aspergillus and Penicillium) and trichothecones and fumonisins (Fusarium), all of which pose potential health risks in the supply chain (Bryden, 2007). Research on potential mycotoxins in the H. isora supply-chain is needed in Indonesia, as are practical actions to improve drying and storage techniques. For example, solar driers at village level “bulking up” centres could double-up in drying other products (such as candlenut (Aleurites moluccana) seeds in addition to drying H. isora fruits.

Thirdly, fruit and seed production could be improved, for example through cultivation and possibly more effective pollination. In India, the recent study by Muthukumar et al. (2017) found that 35–41% of fruits contained non-viable seeds. But this is a complex problem to solve in populated landscapes. Any plans to cultivate H. isora from seed need to recognize the poor dormancy of H. isora seeds, which need to be planted within a maximum of 6 months. In India, Muthukumar et al. (2017) found that 88.2% of seeds were viable up to 6 months, but after 2 years in storage, seed viability had dropped to 24.2%, with best
germination achieved after acid treatment of the seeds. Without taking action on at least some of these steps, however, *H. isora* fruit production is likely to remain a small income supplement to Timorese households.

5. Conclusions

*H. isora* is widespread and locally abundant in dry forests and woodlands in India, which is the major exporter of whole dried *H. isora* fruits. Major importers are Indonesia and Thailand, where *H. isora* occurs naturally. In addition, due to the influence of an Indian diaspora over more than 150 years, smaller quantities of *H. isora* are also exported to countries where this species has never been in traditional use (Bahrain, Iraq, Mauritius, Tanzania, Trinidad and Tobago and South Africa). Consequently, in addition to use in medicinal systems in India (Ayuvedic, Unani, Siddha and folk medical systems), China (Traditional Chinese Medicine) and Indonesia (*jamu*), *H. isora* fruits have been adopted into other “traditional” medical systems, from Iraq (Kurdish herbal medicines) and South Africa (Zulu traditional medicine). In Indonesia, *H. isora* fruit extracts are used in the cosmetic industry and for “Tolak Angin”, the country’s most popular commercial “*jamu*” preparation. Indonesia is the major importer of *H. isora* fruits from India. In eastern Indonesia, where there are natural populations of *H. isora*, improved local populations from the *H. isora* fruit trade is more likely to come from increased *H. isora* fruit quality after better drying and storage methods. This would also reduce potential health risks from smoke contaminated fruits stored above cooking fires and from mycotoxins on poorly dried *H. isora* fruits. There also is an opportunity for cultivation of *H. isora* in small-holder teak plantations in Indonesia, with multiple-use of both *H. isora* fruits and of the medicinal, fibrous bark.

Acknowledgements

We gratefully acknowledge financial support for this study from the Australian Council for International Agricultural Research (ACIAR) under the project “Development of Timber and Non-Timber Forest Products’ production and Marketing Strategies for Improvement of Smallholders’ Livelihoods in Indonesia” (FST 2012/039). We would also like to thank the local farmers and *H. isora* traders in West Timor as well as staff at PT. Sido Muncul, Nyonya Meneer and PT. Maarta Tilaar for time spent on discussions and Willy Kadati for his help and advice. Three anonymous reviewers are thanked for suggesting improvements to this paper.

Authors contributions

A.B. (Tony) Cunningham and William Ingram carried out the fieldwork for this study in West Timor, Indonesia and Josef Brinckmann collected and analysed the international trade data. The photographs for Fig. 3 were taken by Tony Cunningham, who also prepared the maps and value-chain figure. Mark Nesbitt contributed information on the 19th century trade, including specimens of *H. isora* products in the Economic Botany Collection at the Royal Botanic Gardens, Kew (Fig. 4).

Conflict of interest

One of the co-authors (Josef A. Brinckmann) was contracted by the senior author (A.B. Cunningham) to access and analyze trade data on *H. isora*. He is an employee of Traditional Medicinals, Inc., but has no vested interest in the study. The authors declare that there are no conflicts of interest.

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