Zanthoxylum: A Low-Profile Asian Crop with Great Potential

ECHO Asia Notes
A Regional Supplement to ECHO Development Notes
Issue 8, January 2011
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Figure 1: Zanthoxylum rhetsa tree

Introduction

The genus *Zanthoxylum* (family Rutaceae) contains a fascinating group of plants found around the world from the tropics to temperate zones. With over 200 species, ranging from small shrubs to large trees, *Zanthoxylum* spp. are characterized by sharp thorns on either the stem or leaves. Various *Zanthoxylum* spp. are well recognized as Asian spices, including *Sichuan pepper* or *hua jiao* in China, *sansho* in Japan and *chopi* and *sancho* in Korea (Austin and Felger 2008). In South and Southeast Asia, various parts of *Zanthoxylum* plants are used as a spice in stews, marinades and soups.

Recent literature shows that the anaesthetizing effect of alpha-hydroxy-sanshool, a compound produced by *Zanthoxylum*, has potential as a commercial product to reduce skin irritation. This same compound also induces the numbing sensation experienced by eating certain (central to western) Chinese cuisines containing Sichuan pepper. In South Asia and Africa, *Zanthoxylum* is used in traditional remedies for toothaches, malaria and diarrhoea. A scan of scholarly publications indicates that some scientists are also interested in investigating *Zanthoxylum* spp. as a source of medicinal compounds to be used against major diseases including malaria and diarrhoea.

Two recent studies in northern Thailand have piqued ECHO Asia's interest, since *Zanthoxylum* is an important genus in community-level agroforestry with potential as an under-utilized food source and as an income generator.

Table 1: Zanthoxylum species found around the world. (Morikawa and Burnette, 2006)

Region/Country	Name	Common Name
China, Japan, Korea	Z. *bungeaum*, Z. *piperitum*, Z. *schinofolium*, Z. *simulans*	Sichuan pepper, sansho, sancho, chopi
Thailand	Z. *rhetsa*	Kamchat ton, luuk ra maat, ma khuang
	Z. *nitidum*	Kamchat nuai, nguu hao
	Z. *armatum*	Mak kak
Laos	Z. *rhetsa* or *limonella*	Ma khaen (Indian ivy-rue)

A brief survey of *Zanthoxlum's* food uses in Asia

Commercial Spice

Zanthoxylum is well-known as a spice in Asia; people in China, Japan and Korea consume vast amounts. Dominant *Zanthoxylum* species of commerce are native to these countries. According to a 2002 FAO study, China produced 31,000 million tonnes of *Z. bungeaum* fruit for both national consumption and international export. In cases where *Zanthoxylum* fruit is used as a spice, the pericarp or outer casing (in which the shiny black seed is contained) contains the essential oils that provide the intense numbing effect loved by millions.

Hua jiao or Sichuan pepper gives the mouth a characteristic numbing (*ma)* effect that is essential to the sacred duo of *ma la* (numb and hot), found in the fiery stews and soups of Sichuan cuisine in western China. Without the *ma* effect, connoisseurs would consider such food lifeless and flat. As a condiment, *Hua jiao* is mixed with salt to make a spicy dip called *hua jiao yan* and is a mandatory ingredient in the famous "Chinese five spice mixture" found in stores and restaurants (Landis, 2004).

Although called Sichuan pepper, studies indicate that this particular species (*Zanthoxylum piperitum*) may actually be grown only in Japan and Korea rather than China. Of 41 types of *Zanthoxylum* found in China, it appears that *Z. bungeaum* is the only species being used as a condiment.

In Southeast Asia, the predominant *Zanthoxylum* species used for spice are *Z. armatum* (synonym *Z. alatum, Z. planispinum*), *Z. nitidum, Z. rhetsa* (synonym *Z. limonella*), *Z. avicennae* and *Z. acanthopodium*. Consumption habits vary between China, Japan and Korea, but the dried pericarp is still used for flavouring stews, soups and meats.

Joshi Tuisum is on the staff of NEICORD, a relief and development organization that works among various ethnic groups in northeast India. He has observed that *Zanthoxylum* products are used throughout that region to spice food. Not only is the ground pericarp used to flavour curries, *Zanthoxlyum* leaves are also cooked with fermented fish and pork. Having seen these products collected in the wild, grown in kitchen gardens and sold in local markets, Joshi reports that depending on the season, bundles of fresh leaves sell for 10 to 30 Indian rupees ($1.00 US currently equals 45 INR).

Figure 2: Zanthoxylum seed and pericarps

Figure 3: Edible Zanthoxylum leaves

Zanthoxylum is a ubiquitous spice in Thailand's north, but not as well known in central or southern regions. In northern Thailand, products are used to flavour curries and other dishes, such as *laab khua*, a meat dish. Young shoots, green fruit and dried fruits of *Z. rhetsa* (*ma kwaen* in the Northern Thai dialect*)* are added to food to impart a sweet, lemon-like taste (Chiramongkolgarn and Paisooksantivana 2002). Compared to *hua jiao*, *ma kwaen* doesn't have the same fiery taste. It imparts a smooth citrus flavour to prepared foods, rather than numbing the palate.

Several Northern Thai women interviewed at local markets mentioned that 30 years ago, *ma kwaen* was shared freely among neighbours until farmers began selling the product in the market for 1 baht per kg. Vendors in Chiang Mai's sprawling *Gat Mueang Mai*, a wholesale market supplying local restaurants, state that *ma kwaen* currently sells from 100 to 160 baht per kg in the city, indicating that its economic value has risen considerably. Meanwhile, in the Mae Ai district, three hours north of Chiang Mai city, the spice sells from 60 to 100 baht per kg.

In northern Thailand, *ma kwaen* is typically harvested during the cold season between the months of November and January. In Chiang Mai province, *ma kwaen f*armers and middlemen bring the products from outlying districts to sell to spice vendors in *Gat Mueang Mai*. In Nan province, middlemen buy and repack *ma kwaen* purchased from producers in Laos at bimonthly border markets (Hoare et al. 1997). In a recent conversation with a northern Thai farmer, we learned that the green fruit sells for 30 baht per kg. But if dried (resulting in a product that is 90 percent lighter than the fresh weight) the fruit sells for 100 baht per kg.

Figure 4: Z. rhetsa foliage and fruit

In Laos, *Zanthoxylum* is known as *ma khaen*. It is primarily harvested by women and is a source of cash. As in northern Thailand, the product is used as a spice to flavour meats and soups. A 2001 FAO study stated that *ma khaen* was the fifth most important non-wood forest product gathered in a region northwest of Luang Prabang. However, the reported harvesting method of *Zanthoxylum* in Laos threatens the long term availability of the product, because whole trees are felled to gather the seed pods. The farm gate price (i.e. price of the product at the farm) of dried *ma khaen* is 800 Lao kip per kg ($1.00 US is currently 8060 LAK). The average tree first bears fruit at around 5 to 6 years of age, and yields 5 kg of seeds (FAO, 2001).

Medicinal Uses of *Zanthoxylum* spp.

Paresthesia is the mouth-numbing effect believed to be caused by hydroxyl-alpha-sanshool, an alkylamide found in *Zanthoxylum* spp. Anyone who has bitten into a Sichuan pepper can attest to the unique sensation of mild electric shock or "pins and needles" in their mouth. Researchers have likened this experience to that of "touching their tongue to the terminals of a 9-volt battery", which is quite different from the burning pain of chilli peppers or the punch of fresh wasabi.

The numbing and analgesic effects of *Zanthoxylum* have been exploited for centuries as a natural remedy to alleviate acute and chronic pain. In Nigeria, the roots are used as a chewing stick to give a warm and numbing effect. This use is believed to be beneficial to the elderly and to those with sore gums and other oral disease conditions. *Zanthoxylum americanum* is commonly known as toothache tree in North America and can be found in the eastern US as well as Ontario and Quebec in Canada.

Zanthoxylum spp. have traditionally been administered for a variety of maladies in addition to oral diseases. In India, the leaf is used against fever, dyspepsia and bronchitis. In Manipur, India, the seed oil is applied against baldness and bark powder is used to treat toothache (Singh and Singh 2004). In a 2008 report titled "Indigenous Vegetables of India with a Potential for Improving Livelihoods," ML Chadha from the ARVDC Regional Center for South Asia reports that *Z. hamiltonianum* is used as both a vegetable and a remedy; dried, tender leaves are eaten as a vegetable and powdered fruits are consumed to increase the appetite. The young stems are employed as a toothbrush in cases of toothache and bleeding gums, whereas the roots and bark are used to cure malaria. Though generally eaten as a vegetable, the leaves of *Z. rhetsa* are also consumed to kill tapeworms and reduce infection (Chadha 2008).

Scientific studies are validating the traditional medical role of various *Zanthoxylum* products. Research has demonstrated the potential of *Z. rhetsa* leaf extract as a de-worming remedy; it has been found to have a pronounced effect against larval eggs, comparable to a commercial drug (Yadav and Tangpu 2009). Bark extract from *Z. rhetsa* has been shown to lessen abdominal contractions and diarrhoea in mice (Rahman 2002). Other potential pharmaceutical applications include cancer treatment and anti-oxidant, anti-coagulant and anti-bacterial agents.

At the industrial level, *Z. armatum* has been shown to contain high amounts of linalool (Jain et al. 2001), a compound used commercially as a precursor to vitamin E production and also in soaps, detergents and insecticides. Clearly, *Zanthoxylum* spp. have potential beyond traditional uses as spices and folk medicine.

A valuable agroforestry component

In addition to its food and medicinal uses, *Zanthoxylum* has great potential for reforestation (Hau and Corlette 2003, Condit et al 1993) and for intensifying shifting cultivation (Hoare et al 1997).

Zanthoxylum is adapted to a wide range of conditions and can grow in areas as high as 2100 metres (6594 ft.). Boer *et al*. (2004) state that Z. *rhetsa* can grow in ranges up to 500 m (1640 ft.) and can be planted in the open or in shade, although below 400 m (1312 ft.) shade planting is recommended. In northern Thailand, Gardner *et al* (2000) state that the range of Z. *rhetsa* is 800 m (2625 ft.) and higher.

Case study in Nan province, northern Thailand

In 1997, Peter Hoare (then a project coordinator for the Upper Nan Watershed Management Project in Northern Thailand) investigated the potential of *ma kwaen* in intensifying shifting cultivation in priority watershed areas where the Thai government retains land tenure rights but allows the harvest and sale of minor forest products. Nan province, bordering Laos, is one of Thailand's most important river basins. Natural forest destruction in the watershed area has been driven by shifting agriculture, logging and uncontrolled forest fires. Local communities number about 20,000 people among 28 villages. Hoare and his investigators wanted to involve these people in the rehabilitation and protection of forests. One livelihood option for involving locals in forest conservation was through *ma kwaen* cultivation.

Prior to the 1997 study, there was a steady increase in the market price of fresh *ma kwaen,* from $0.10 US per kg to $2.00. The market for *miang,* a local fermented tea, was in decline, and farmers were looking to diversify their agricultural production in other ways. Extended cultivation of *ma kwaen* offered one such alternative. The main benefits from intensified management of fallow land using *ma kwaen* include increased farmer income (especially as *ma kwaen*'s market price increases) and improved fire management in watershed areas. Fire control

was expected to improve, because highly valued *ma kwaen* trees are very susceptible to fire damage (p. 616).

Table 2: Yield Data for ma kwaen trees of different ages (Hoare et al. 1997, p. 618)

Age of Trees (years)	Average yield per tree (kg fresh weight)	Average return per tree at USD$2/kg
3-5	2	4
6-10	10	20
11-15	30	60
21-25	50	100

According to local extension information obtained by Hoare and team, the economic benefits of intensified *ma kwaen* production are tremendous. Sales from trees in the 2,164 *rai* (346 ha or 607.9 acre) study area were estimated at $120,000 to $160,000 US. Each 20-year-old tree provided an income of approximately $104 without any cash inputs for agricultural chemicals. Family labour was required only between November and January for harvesting fruit and making firebreaks.

Hoare *et al*. reported that one *rai* (0.16 ha or 0.4 acres) of 6-to 10-year-old *ma kwaen* trees planted at a higher density of 4 x 4 metres would have produced an annual income of USD $2,000 in 1996; this is more than the income generated by one hectare of traditional upland crops of maize and cotton.

According to Hoare and team, in communities where *ma kwaen* has been planted, fire management has improved since trees are highly susceptible to fire damage; radiant heat from just a few metres away is lethal. In many villages where *ma kwaen* has been planted, heavy fines have been imposed on farmers who lit fires that damaged trees. One community levies a fine of $4,000 US for every 13 trees killed by fire (p. 617).

Zanthoxylum propagation and establishment challenges

In the past, *ma kwaen* propagation was simple. Farmers merely gathered seedlings underneath parent trees. Hoare *et al*. observed another common method of establishing *ma kwaen* gardens with a large number of trees: many parent trees were planted at the top of a slope so that seeds were spread down slope by birds and soil movement. Seedlings would be established naturally in the slash-and-burn fields below.

They also described attempts to improve the system by burning straw under mature trees, to scarify hard seed coats and to accelerate the usual two-month-long germination period. However, despite efforts to scarify seeds, farmers reportedly experienced losses of young seedlings as high as 60 percent due to heavy rains.

Challenges related to germinating Zanthoxylum seeds and establishing seedlings are widely reported. For instance, as the genus is dioecious (meaning that individual plants are either male or female), both male and female trees must be in close proximity to each other to allow for pollination. Seed production is also challenged if trees are located in shaded areas (Popp and Reinartz, 1988).

Hoare *et al*. (1997, p. 618) reported that immature seed is often planted, because *ma kwaen* fruit are harvested when the seed coat is still green. However, germination with immature seeds gives poor results.

In 2005, the Upland Holistic Development Project (UHDP) interviewed farmers in northern Thailand, including ethnic Lahus, Karen and Northern Thais. Farmers reported that *ma kwaen*

Figure 5: An ant-proof shelf with legs placed above ground protects seeds from ant preditation.

germination takes place over a 45-day to 3-month period, during which germinating seeds are subject to predation by ants. One farmer remedied this issue by sowing seeds in tubs and surrounding the basins with rags soaked in diesel fuel to form a barrier against ants.

Young seedlings are also susceptible to fungal damping off diseases. It is important to control soil moisture during this period in order to avoid high losses of seedlings. Small seedlings are usually transplanted at the two-leaf stage, about a week after germination, using a spoon. At this point, *Zanthoxylum* roots are very fragile and susceptible to damage, often resulting in high losses (Hoare, *et al*. p. 618).

Young transplants are also intolerant of extended periods of high moisture in the field. According to Hoare and team, farmers reported losses of up to 60 percent when seedlings were transplanted in fields during the heavy rains in July and August. In Chiang Mai's Mae Ai district, a woman selling *ma kwaen* in the local market said that for every 10 seedlings planted, only one will survive.

Figure 6: Plastic tubs holding germination medium for ma kwaen seed trials at UHDP.

Evidence suggests that losses can be reduced by starting the nursery as early as February and having the seedlings well established before the heavy rains begin [*Ed: Regular watering would be required until the rains begin*.] Alternatively, seedlings can be transplanted into the field at the end of the wet season and watered during the dry season from November to March (Hoare *et al*. p. 619).

Propagation and transplant trials at the Upland Holistic Development Project

Upland Holistic Development Project (UHDP) partnered with Plant with Purpose (http://www.plantwithpurpose.org/) during 2005-2008 to investigate the challenges of intensively propagating *ma kwaen.* The investigation took place at UHDP's Agroforestry and Small Farm Resource Center in Chiang Mai's Mae Ai district. Implementing agriculture and community development work in villages along the Thai-Burma border, UHDP includes a wide range of indigenous non-timber forest product species in its agrofoestry programming

Z. rhetsa is a native plant grown in northern Thailand, and as such is recognized by UHDP as a natural agroforestry component. Many local ethnic groups use the fruit as a spice in cooking (personal communication, Jamlong Pawkam).

The first set of experimental trials, conducted in 2005-2006, evaluated germination differences of *ma kwaen* seeds harvested at different times. It also looked at the effectiveness of various seed germination treatments and transplantation methods. During 2007-2008, additional trials evaluated the effect of water application and soil moisture on young seedlings in a nursery setting. For each trial, seeds were collected from *ma kwaen* farmers who harvested them from trees over four years of age.

Several key observations were made from the experimental trials:

1. **The best germination rates came from fully mature seeds that were freshly harvested in the same season the trials were conducted.** In northern Thailand, the *ma kwaen* harvest usually takes place between October and December when less-mature fruit (with still-green pericarps) are collected. The less-mature fruit are more palatable (and marketable) as they have a stronger, more desirable scent of lemon. More mature seeds are not as aromatic.

   From the 2005-2006 trial, the UHDP nursery staff noted that:

   - The best germination of seeds (almost 100%) was from fresh post-marketable seeds harvested and propagated between December and January.
   - Seeds purchased from the market and/or obtained directly from producers at a marketable stage in November had a much lower germination rate (estimated at less than 70%).
   - Seeds kept over from previous years (i.e. 2004) had little or no germination.

2. **Seeds soaked in soapy water for 2 hours had better germination rates** than seeds soaked in soapy water and then rinsed, or seeds soaked only in water. Our literature searches have encountered references to the use of soapy water to prepare *Zanthoxylum* seeds for germination. However, thus far, we have not come across any plausible scientific explanation that explains why exposure to soapy water effectively improves germination rates.
3. **Proper timing and careful handling is needed to maintain the viability of very young *Zanthoxylum* seedlings being transplanted into seedling bags.** During the 2006 trial, *ma kwaen* germination rates were so high that only a small portion of seedlings were transplanted, due to time and labour constraints. But during that time, we learned that the optimal period for transplanting new seedlings is when the young plants develop their first true leaves. This occurs about 15 to 30 days after germination, while the seedling root systems are not yet highly developed.

   During the trial, 90 percent of seedlings transplanted with two to four true leaves survived 40 days after transplanting, whereas 40 percent of seedlings transplanted with only cotyledons survived. (Cotyledons provide stored energy to seedlings until the first true leaves appear, which have the photosynthetic ability to start producing food for the plant.)

   Take care not to destroy delicate roots when removing seedlings from the germination medium and transferring them into nursery bags. Sand is good *ma kwaen* germination medium, because it allows for the easy removal of germinated seedlings. Transplant carefully but quickly; roots exposed to air for too long during movement into nursery bags will dehydrate, thereby reducing seedling viability.

4. **To better ensure *Zanthoxylum* seedling survival and vigor, take steps to protect seedling root systems from excessive moisture.** During the 2007-2008 trial, *Zanthoxylum* seedlings were transplanted into nursery bags in April (during the hot and dry season) and observed through the rainy season until October, when the rains started to diminish. Seedlings with the best survival rate and tallest average height were those that were placed aboveground on a wire mesh platform, hand-watered, and protected from the rain (by clear plastic sheets placed overhead to divert rain water).

After seven months of observation, 51% of these seedlings (with an average height of 24.1 cm) had survived, compared to only 5% of seedlings (average height 12.9 cm) that were placed on the nursery floor but otherwise treated the same. The soil mix of the seedlings that were allowed to sit on the nursery floor drained poorly. *Ma kwaen* is known not to like "wet feet," and the seedlings in contact with the wet nursery floor could not tolerate the near-waterlogged conditions.

Similarly, seedlings that were watered by natural rainfall were subjected to more frequent waterlogged conditions during the rainy season and did not survive past four months after transplanting into nursery bags.

The quality of potting soil is another critical factor to consider. During the trial, the research technician was unable to fill all nursery bags with the same potting soil mix. Some bags were filled with higher proportions of rice husks than others. The healthiest seedlings were found in bags containing soil mix with larger amounts of rice husks, but greater incidence of stunting occurred among seedlings in bags with more clayish soil. Ultimately, a higher proportion of rice husks in the soil mix enabled improved water drainage and healthier *Zanthoxylum* seedlings.

Conclusion

Zanthoxylum spp. is a widely distributed and well-documented genus of plants, with an extensive array of uses and cultural practices throughout the world. *Zanthoxylum* is a popular spice and table condiment in China, Japan and Korea, with dominant native species used for commercial production. In Southeast Asia, the growth of *ma kwaen* markets in northern Thailand and Laos are evidence of the potential of *Zanthoxylum* to be developed as a cash crop. In Africa, the Indian sub-continent and the Americas, interest continues in *Zanthoxylum*'s potential as a source of medicinally important compounds found in all parts of the plant. Few technical documents on specific nursery propagation and field production methods are available. Continued exploration and documentation of intensive *Zanthoxylum* propagation and other cultural practices will enable better employment of this underutilized species as a source of food and income.

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