

Botany, morphology, ecology, cultivation, traditional utilization and conservation of *andaliman* (*Zanthoxylum acanthopodium*) in North Sumatra, Indonesia

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Abstract. Nurlaeni Y, Junaedi DI, Iskandar J. 2024. Botany, morphology, ecology, cultivation, traditional utilization and conservation of *andaliman* (*Zanthoxylum acanthopodium*) in North Sumatra, Indonesia. *Nusantara Bioscience* 16: 68-80. This study examines the botany, ecology, cultivation, utilization, and traditional conservation of *andaliman* (*Zanthoxylum acanthopodium* DC.) in North Sumatra, Indonesia. This information were collected through in-depth interviews. The collected data consisted of primary and secondary data. Primary data were obtained in the field through in-depth interviews, participatory observation, and documentation. Meanwhile, to strengthen the results of the interviews, a literature study was conducted, which was obtained from academic sources that can be scientifically accounted for it grows naturally in relatively cool forests, foothills, and cultivated areas. *Z. acanthopodium* is distributed around Lake Toba at 800-1,300 masl (meters above sea level), a temperature 17-22°C, and a 5-40% slope. In North Sumatra, there are nine varieties: Siholpu, Siganjangpat, Sihalus, Sihorbo, Simanuk, and Sirangkak, and three varieties that have not been named yet. *Z. acanthopodium* is planted by maintaining wild plants, burning the land to be planted, collecting dead or old parts of the plant then burned, and collecting mature seeds as material for seeding then burned. The plant does not require fertilization and pesticides. The preservation of *Z. acanthopodium* in North Sumatra is based on local communities' traditional agricultural and ecological management.

Keywords: *Andaliman*, conservation, cultivation, ecology, morphology

INTRODUCTION

Plants of the genus *Zanthoxylum*, family Rutaceae, are of economic importance. The genus is widely distributed in tropical and subtropical regions, including China, Japan, Korea, India, and others. The genus *Zanthoxylum* to date, more than 250 species have been identified worldwide. The genus has high economic value as spices, oils, medicinal plants, and culinary applications (Chen et al. 2022; Zhang et al. 2023). The biodiversity of North Sumatra, Indonesia contains specific and endemic species. A unique spice plant considered a primary commodity in North Sumatra is *Andaliman* (*Zanthoxylum acanthopodium* DC.). Hartley (1966) reported the distribution of *Z. acanthopodium* in India, Nepal, Sikkim, East Pakistan, Myanmar, Thailand, China, and Sumatra (Indonesia). In Indonesia, this plant is naturally distributed in the provinces of North Sumatra and Aceh. *Z. acanthopodium* fruit is often used by the Batak tribe in North Sumatra as a seasoning for traditional dishes such as *sambal*, *arsik* (the fish is cooked with a mixture of *Z. acanthopodium*, kecombrang, galangal and lemongrass. The spices are mashed and then coated on the fish, cooked in a little oil, on low heat until slightly dry), *na tinombur* (grilled fish served with a thick sauce full of spices that has a distinctive *Z. acanthopodium* flavour), *dengke mas na*

niura (fresh raw fish without cooking but not fishy. The fish is given acid and spices, one of which is *Z. acanthopodium*, allowed to stand for about 3-5 hours, after the fermentation process it is ready to eat), *saksang* (meat that is chopped into small pieces and seasoned with spices such as *Z. acanthopodium*, cooked with blood from the slaughtered animal or regular spices without blood), *manuk napinadar* (the chicken is grilled and then doused with chicken blood, mixed with *Z. acanthopodium* and garlic powder and cooked. The mixture of spices with chicken blood makes the soup thicker and more savoury), *mie gomak* (large stick noodles are boiled using a traditional stove and topped with a sauce containing *Z. acanthopodium* spices and sambal). As spices, *Z. acanthopodium* can add delicious flavor and distinctive aroma to food, increase appetite, and increase endurance. This spice plant is only known in Batak cuisine and is considered as Batak pepper. The name of *andaliman* itself varies in each region such as in Simalungun District calls it *tuba*; in South Tapanuli District, it has the name of *sinyarnyar*; in Karo District, it is called *itir-itir*; and usually, the Toba people call it *tuba* or *andaliman*.

Z. acanthopodium is a wild plant that grows in forests and fields and is useful as a spice. In traditional Batak cuisine, *Z. acanthopodium* is one of the spices that must be

present. It is a habit that every traditional Batak cuisine uses it as a spice. Batak cuisine feels bland if it doesn't use *Z. acanthopodium*. In meat-based dishes, it is used as a fishy odor reducer in meat and fish, so the dish has a distinctive taste. The shape of the fruit is small and clustered, large like a green pepper. *Z. acanthopodium* has a fresh, citrus-like taste when eaten, with a distinctive sharp, pungent smell and a biting taste on the tongue, with a distinctive tartness. The sensation produced when consuming *Z. acanthopodium* feels tart on the tongue due to the content of hydroxy alpha sanshool compounds. This plant has a delicate citrus-like aroma that increases appetite.

Zanthoxylum acanthopodium has high medical benefits and economic value and has been widely studied in many researches. Several studies have been conducted including as a producer of carminative and anthelmintic (Gupta and Mandi 2013), essential oils (He et al. 2018; Diep et al. 2023), a source of traditional medicine (Kholibrina and Aswandi 2021), improving the human immune system (Yonzone and Rai 2016), improving the livestock immune system (Faradillah et al. 2020), antimicrobial (Julistiono et al. 2018; Muzafri et al. 2018; Susanti et al. 2020; Diep et al. 2023), antioxidant (Wijaya et al. 2019; Napitupulu et al. 2020), anticancer (Rosidah et al. 2019; Arsita et al. 2019; Panggabean et al. 2020; Sibero et al. 2020; Simanullang et al. 2022; Situmorang et al. 2022; Ilyas et al. 2022; MCF-7, dan HepG2), anti-inflammatory (Yanti 2016; Natasutedja et al. 2020; Susanti et al. 2020; Diep et al. 2023), anti-aging and anti-acne (Hanum and Laila 2018; Angraini et al. 2022; Kintamani et al. 2023), antifertility (Batubara et al. 2020), pesticides (He et al. 2018), insecticides, an insect repellent, larvicidal activity (Gupta and Mandi 2013; He et al. 2018), antipreeclampsia (Situmorang et al. 2021), wound healing activity (Pasaribu et al. 2020; Manurung 2021). The fruit and seeds are also prescribed for treating rheumatism, dysentery, and stomach ache. Seeds and barks are also aromatic and tonic in fever, dyspepsia, and cholera (Gupta and Mandi 2013).

The demand for *Z. acanthopodium* is increasing due to the dependence of the people of North Sumatra, which is used as a spice in typical Batak cuisine. *Z. acanthopodium* is used as a spice when holding Batak rituals such as weddings, births, entering a new house, deaths, and other events. The price of *Z. acanthopodium* in April to July is

usually low, then rises in August, and the highest price in December to January. Based on interviews with *Z. acanthopodium* farmers and traders in traditional markets located in Samosir, Simalungun, Dairi, and Karo. The selling price of *Z. acanthopodium* fruit fluctuates greatly from IDR 20,000 to IDR 200,000, sometimes lower or higher than this range. The *Z. acanthopodium* cultivation is traditionally done; the plant is not cultivated widely or specifically in large areas. Generally, farmers cultivate this plant by raising wild seedlings in their fields, as the seeds are difficult to germinate. Most farmers collect its seedlings that grow wild around existing *Z. acanthopodium* plants, collecting seedlings that grow from burnt land with some remnants of old plants and collected at the edge of the land. This is one of the obstacles for most farmers to propagate and cultivate the plant en masse (Nurlaeni et al. 2021; Siregar 2022).

The distribution of *Z. acanthopodium* is especially in North Sumatra and a small part of Aceh. People in the area have local wisdom to maintain the existence of *Z. acanthopodium*. Some community farming techniques to date have maintained the existence of *Z. acanthopodium* and the environment properly. Not many people know what *Z. acanthopodium* is, the shape of the plant, and other related issues. Moreover, no research has thoroughly explored the botany, morphology, ecology, cultivation, utilization, and traditional conservation in North Sumatra. This study aims to explore the botany, morphology, ecology, cultivation, utilization, and traditional conservation in North Sumatra.

MATERIALS AND METHODS

Study area

The study was conducted in Samosir (Tanjungan Village, Simanindo Sub-district; Salaon Dolok Village, Ronggur Nihuta Sub-district), Simalungun (Sibaganding Village, Girsang Sipangan Bolon Sub-district; Sipangan Bolon Village, Girsang Sipangan Bolon Sub-district), Toba Samosir (North Lumban Rang Sionggang Village, Lumban Julu Sub-district), Dairi (Tanjung Beringin Village, Sumbul Sub-district), and Karo (Berastagi Market on Jalan Penghasilan Tambak Law Mulgap II, Berastagi District, Tanah Karo), North Sumatra, Indonesia (Figure 1).

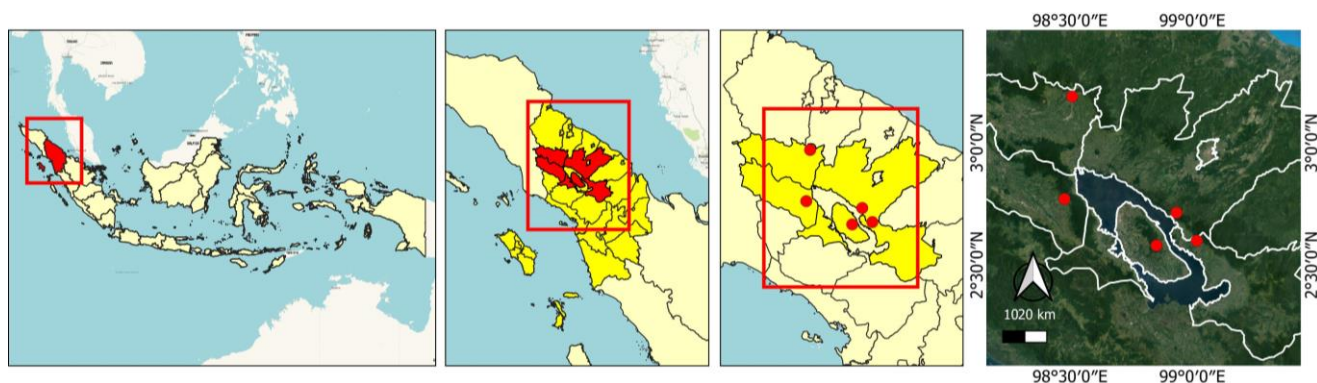


Figure 1. Map of the study area in Samosir, Simalungun, Toba Samosir, Dairi, and Karo, North Sumatra, Indonesia

Observation at the *Z. acanthopodium* planting area

This research was conducted in 2018 and 2019 at Samosir, Simalungun, Toba Samosir, Dairi, and Karo, North Sumatra, Indonesia. The research studied botany, morphology, ecology, cultivation, utilization, and traditional conservation of *Z. acanthopodium* in forests, forest margins, fields, agricultural land, and surrounding community settlements. In addition, interviews were also conducted with landowners and farmers. We also visited two traditional markets in North Sumatra and observed directly the traders who traded *Z. acanthopodium*. During the COVID-19 pandemic, the research was stopped until it was resumed in 2020-2022. Throughout 2020-2022, indirect activities were carried out by conducting interview activities that were carried out by telephone or video call to respondents.

In-depth interviews

Information on the botany, ecology, cultivation, utilization, and traditional conservation of *Z. acanthopodium* was collected by in-depth interviews with selected key informants. Data were collected using qualitative methods that consisted of primary and secondary data. Primary data was obtained in the field through in-depth interviews, participatory observation, and documentation. Participatory observation was conducted by observing the condition of the research sites and participating in the botany, ecology, cultivation, utilization, and traditional conservation of *Z. acanthopodium*. The interview guideline contained topics explored by discussing them in depth with informants via interview processes. An informant is someone who has a great deal of knowledge about an aspect of the local culture (Martin 1955). Interviews with informants were selected based on the snowball method. The interviews were qualitative, also called semi-structured interviews, with informants using interview guidelines. Informants were selected by purposive sampling based on their competence from the population and snowball sampling, considering diversity (triangulation) based on existing categorization. There were a total of 73 respondents interviewed. The informants in this study included 10 farmers in Samosir, 5 farmers in Simalungun, 5 farmers in Dairi, 5 farmers in Humbang Hasundutan, 5 farmers in Toba Samosir, 5 farmers in Toba, an observer in Tobasa, 6 entrepreneurs in Samosir, 2 entrepreneurs in Tobasa, 6 entrepreneurs in Simalungun, three traders in Medan City, a farmer and a trader in Takengon-Aceh District, 2 researchers who have conducted *Z. acanthopodium* research in North Sumatra, 10 spice traders in traditional markets selling *Z. acanthopodium* and 10 samples of household consumers. Interviews were conducted from June to December 2022.

The qualitative data from observations and semi-structured interviews with informants were analyzed by cross-checking, summarizing, synthesizing, and then narrated in a descriptive analysis. Qualitative data analysis is carried out by analyzing the consistency of two perspectives, namely the perspective of the informant

(emic) and the researcher's analysis (etic) (Newing 2010; Partasmita et al. 2016); during the data collection, researchers must always check the validity of the data. This is done by cross-checking by triangulating or comparing data from several informants to obtain their objectivity and reliability or comparing informants with the results of direct research observations. Then, summarizing is done to select the data needed to be combined into a narrative (synthesizing).

Literature review

Meanwhile, to add to the comprehensiveness of the interview results, a literature study was conducted, obtained from scientifically accounted-for sources. Information on the botany, ecology, cultivation, utilization, and traditional conservation of *Z. acanthopodium* was searched through digital reference using keywords: "botany, ecology, cultivation, utilization and traditional conservation of *Z. acanthopodium*." The relevant articles obtained from these keywords were taken from national and international journal articles until September 2023. The articles' language was limited to English and Bahasa Indonesia, and the information on the potential of *Z. acanthopodium* was manually extracted from the collected articles. This research was conducted from January 2018 to September 2023.

RESULTS AND DISCUSSION

Botany of *Z. acanthopodium*

Based on observations at the research site, *Z. acanthopodium* plants have a low-branched shrub habitus with a height of up to 5 meters and have thorns on stems, branching, and twigs. The stem is woody, the shape of the stem is round, there are spines on the surface of the stem, and it is covered with blackish-red or brownish dark green hair. Some varieties have spines on their stems, and some have no spines. On stems with spines, the spines are usually pointed triangles or hook-like. The stem also has branches. The branching appears on the main stem or away from the main stem. The surface of the bark is gray-green or light gray-brown. The leaves are green with serrations on the edges. The leaves are odd-numbered compound leaves characterized by of leaflets at the ends of the main leaf bones. Gasal-pinnate compound leaves or, also called triple leaves, leaf length ranges from 2-25 cm with 3-7 leaflets, overgrown by spines, ovate to obovate-lanceolate, measuring 1-12×0.5-4.5 cm, blunt base, flat or wrinkled glandular edges, pointed or tapered tip. The leaf shape is lanceolate, with serrated leaf margins, dark green leaf color, and leathery leaf surface. The shape of the thorns they are very concave with a brown thorn color, 3-membered compound leaves, dorsiventral, containing oil glands, the leaf seating arrangement is scattered, stalked, leaf length and width 5-20×3-15 cm (Figure 2).



Figure 2. A. *Zanthoxylum acanthopodium* tree, B. Leaves, C. Stem, D. Flower, E. Fruit, F. Ripe fruit with visible seeds

Flowers grow in the leaf axils or on the stem. Flowers are bisexual and pale yellow, including limited compound flowers. The petals are slightly yellowish-green or slightly reddish-green. There are about 5-7 petals on each flower. The fruit is shaped like a pepper and is green when unripe, reddish when ripe, and black when dry. Each fruit has only one seed. Ripe fruits are protected by hard skin and are round, 2-3 mm in size; each fruit has 1 seed: round seed shape, hard skin, shiny black seed surface, smooth surface; young seeds are white while old seeds are black. The fruit gives off a distinctive aroma in the form of a tart taste on the tongue and a citrus-like aroma. The fruit is utilized as a cooking ingredient and traditional medicine. Seeds have a skin with a very hard structure that can inhibit water imbibition and gas exchange during the germination process. Therefore, the germination and regeneration capacity of *Z. acanthopodium* is low.

The root system in *Z. acanthopodium* is a taproot, an institutional root that will continue to grow into a main root that branches out eventually into smaller roots with fine hairs all over its surface. Generally, farmers are very careful when clearing weeds in the area around the roots. Some farmers even argue that the area around the root does not need to be cleaned; it is intended to keep the roots from being damaged by the tools used when cleaning the land, resulting in the plant dying.

Morphology and characteristics of *Z. acanthopodium* varieties

Based on the field observations, it is known that the name *Z. acanthopodium* itself is different in each region in North Sumatra. *Andaliman* in Simalungun is called "*tuba*," in South Tapanuli, it has the name "*sinyarnyar*," in Tanah Karo, it is called "*itir-itir*," and usually the Toba Batak people call it "*tuba*" or "*Andaliman*." In Dairi, it is better

known as "*tuba*." In general, the people of North Sumatra recognize three kinds of *Andaliman* cultivars: Simanuk, Sihorbo, and Sitanga (Figure 3). Simanuk is derived from the word '*manuk*' in the Batak language, meaning chicken; it has smaller fruit characters, a stronger aroma than the Sihorbo cultivar, and higher fruit production, while Sihorbo is derived from the word '*horbo*' in the Batak language meaning buffalo; it has larger fruit but less aromatic aroma and lower fruit production compared to Simanuk. Sitanga is derived from the word '*tanga*' in the Batak language, which means ladybug. Sitanga has a very sharp aroma fruit characteristic that resembles the smell of a ladybug, high production but less favored by the public because of its aroma similarity with the smell of a ladybug.

The *Z. acanthopodium* cultivars reported in publications are Simanuk, Sihorbo, Siparjolo, and Sitanga. Batak people in the Toba Samosir area recognize different cultivars: Siramping, Silokot, and Sikoreng. There are two varieties, i.e.: *tuba sihorbo* and *tuba siparjolo*, in Dairi, and three varieties: Simanuk, Sihorbo, and Sitanga, around Lake Toba. Raja and Hartana (2017) found that there are four *Z. acanthopodium* cultivars: Simanuk, Sihorbo, Silokot, and Sikoreng, spread across Toba Samosir, Simalungun, Dairi, and North Tapanuli. Meanwhile, according to Simbolon et al. (2018), there are two *Z. acanthopodium* varieties: Simanuk and Sihorbo in Dairi, Toba Samosir, and Simalungun. Moreover, Kintamani et al. (2019) stated in North Sumatra, there are nine varieties of *Z. acanthopodium*: Siholpu, Siganjangpat, Sihalus, Sihorbo, Simanuk, Sirangkak, and three unnamed varieties. Each variety grows at a different altitude and has its morphological characteristics. Kintamani et al. (2019) suggested further research on the essential oil content of each *Z. acanthopodium* variety and its ecological conditions should be studied.



Figure 3. *Zanthoxylum acanthopodium* habits and fruits. A. Simanuk, B. Sihorbo, C. fruit of the simanuk variety, D. fruit of the Sihorbo variety

Siholpu variety has greener leaves, smaller leaf size, more prickles in the middle of the leaf, and short petioles. The fruit has a smaller size and a greener color, and the stalks are short and swarming, with more fruit production than the Siganjangpat variety, fruiting throughout the year; the local community prefers the fruit due to more spiciest taste and the most fragrant. The stem is brown and smaller; the stem prickles and leaves are longer and harder. The siganjangpat variety has yellowish leaves, bigger leaf size, leaves have fewer prickles, and long petioles. Larger-sized fruits, fewer green fruits, longer fruit stalks, less fruit production (only bear fruit twice a year), fruit has a less spicy taste and less fragrant. The stem has a lighter color and bigger size; there are less prickles on the stems and the leaves. The sihalus variety has a smaller leaf size, tight spacing between leaves, and long petioles. The fruit is smaller and more durable to store and produces more fruit; the fruit has the same taste and aroma as the Sihorbo variety. The stem has a smaller size and slightly prickles. The Sihorbo variety has long and large leaf sizes; the fruit has a large size, green and clumps like kaffir lime with the highest fruit production; the fruit has a less spicy taste and is less fragrant; the stem is light green and is very tight prickles. The sirangkak variety has green and red leaves, with more fruit production; the fruit has a spicy taste and is fragrant, and the stem is gray. There are many prickles (Kintamani et al. 2019).

Variety 1 has green-reddish leaves, bigger and longer size. The fruit has a bigger size, less fruit production, and a spicy and fragrant taste. The stem is reddish, and there are many prickles. Variety 2 has small leaves, green and short in size, with smaller fruit and less fruit production; fruit tastes spicy and fragrant. The stem is gray and has short prickles. Variety 3 has greener leaves, moderate and smaller prickles in the middle of the leaf, and a short petiole. The fruit has a smaller size, greener fruit color, short fruit stalk, and the highest fruit production comparable to Siholpu and Siganjangpat varieties; the fruit has a spicy taste and fragrant, and the stem size is bigger and higher than Siholpu and Siganjangpat varieties; has

medium prickles, fewer prickles than Siholpu variety but more prickles than Siganjangpat variety (Kintamani et al. 2019).

Ecology of *Z. acanthopodium*

Generally, the study site is at an altitude of 800-1300 masl with a temperature of 17-22°C and a 5-40% slope. *Z. acanthopodium* grows wild in the forest, on forest margins, and some are cultivated along with other crops in farmlands. *Z. acanthopodium* in North Sumatra were harvested from several planting condition types. They are: grow naturally in the forests, as agroforestry planted under pine trees, planted on areas with fairly steep slopes, and planted in the valleys.

***Zanthoxylum acanthopodium* grows wild in the forest.** *Z. acanthopodium* is a wild plant commonly found in North Sumatra's forests (Figure 4.A). Naturally, it will grow after the forest area is burned. Based on information from the community and some farmers, *Z. acanthopodium* is a wild plant that has grown in the forest for decades. The community initially searched for this plant in the forest during certain events, for example, during traditional events, celebrations of holidays involving the entire village population, and family events.

Using an agroforestry system planted under pine trees. *Z. acanthopodium* is planted under pine trees with a spacing of 5x5 meters to 10x10 meters (Figure 4.B). In addition, pine is a type of tree that is large and tall and has a wide crown so that it functions to shade the plants. It is a type of wild plant that cannot tolerate direct sunlight.

Planting *Z. acanthopodium* on areas with fairly steep slopes. *Z. acanthopodium* is found to be planted in areas with a slope of 40% to 50% (Figure 4.C). Generally, these areas were previously vacant, farmers utilize these areas to plant *Z. acanthopodium*.

Planting in the valley. Some farmers utilize the valley area as a location for planting *Z. acanthopodium* (Figure 4.D). This is a wild plant type that cannot tolerate direct sunlight, and the valley area is suitable for the growth.

Particularly for *Z. acanthopodium* that were planted alongside other crops or trees, several cultivation systems are observed in this study. These are the following:

***Zanthoxylum acanthopodium* is planted interspersed with annual crops such as corn, chili, and tomatoes.** Using this planting pattern has many advantages, namely that farmers continue farming crop activities and can continue to harvest the other alternately according to the commodities planted (Figure 4.E). When the price of one commodity decreases, they can rely on other commodities whose prices are stable or even increased.

Using an agroforestry system planted alongside coffee plants. North Sumatra is one of Indonesia's largest Arabica coffee production regions and Arabica coffee is one of the Indonesian main export commodities. *Z. acanthopodium* is usually planted between coffee plants or on the side of coffee plants (Figure 4.F). This is often used as a border plant in the garden to protect coffee plants from

pests such as bats, mongooses, and civets. The thorns on the stem become a barrier from these pests attacking.

***Zanthoxylum acanthopodium* is planted next to other crops such as corn fields, upland rice plants, and vegetable fields.** After planting annual crops, some farmers burn the land before starting farming activities again, and *Z. acanthopodium* will grow within one to two months (Figure 4.G). They were then allowed to grow, nurtured, and moved to adjust the planting distance. Therefore, an *Z. acanthopodium* field is formed. The location of this field is usually next to a field that has been planted with annual crops.

***Zanthoxylum acanthopodium* is planted on land not used to cultivate crops in an empty area.** Farmers use land that is still empty for *Z. acanthopodium* planting areas, and they burn the land before starting farming activities and it will grow within one to two months (Figure 4.H). *Z. acanthopodium* is allowed to grow, then nurtured and sorted to adjust the planting distance.



Figure 4. *Zanthoxylum acanthopodium* growth and cultivation. A. Grows wild in the forest. B. Planted under pine trees. C. On areas with fairly steep slopes. D. Valley area as a location for planting. E. Planted with chilies, tomatoes, and sweet corn. F. Using an agroforestry system planted alongside coffee plants. G. *Andaliman* is planted next to other crops, such as corn fields. H. *Andaliman* is planted on land that is not used for cultivation of other crops in the form of an empty area. I. *Andaliman* planted in the field by planting *Andaliman* only

***Zanthoxylum acanthopodium* planted in the field by planting this one only.** Some farmers have consistently only planted *Z. acanthopodium* in one large land expanse. Generally, this type of planting is done by farmers with a large land area of 5 to 10 hectares (Figure 4.I). The planted *Z. acanthopodium* can reach 500 and even thousands of stems. Some *Z. acanthopodium* are planted regularly with consistent spacing, and some are irregular. With so many *Z. acanthopodium* planted, farmers can alternately and sustainably harvest fruit. If the price is high, it can be very profitable. Due to the large number of *Andaliman* planted in one large area, many seedlings are also growing around it.

Cultivation of *Z. acanthopodium*

There have been many studies related to the germination of *Z. acanthopodium* seeds. The problem faced in efforts to propagate them generatively is the low germination rate of the seeds. The seeds without treatment had a germination percentage of 30% at 100 days after planting. The hard seed coat structure causes low germination and a relatively long germination age because the hard structure can cause barriers in the water imbibition and gas exchange process. Several studies revealed these low germination and varying germination ages. Shofyani and Sujarwati (2020) scarified *Z. acanthopodium* seeds in H₂SO₄ soaking at concentrations of 0%, 25%, 75%, and 100% with soaking times of 15 minutes, 30 minutes, 45 minutes, and 60 minutes, resulting in a germination percentage of 6.67% at 7th day. Pardosi (2021) also soaked *Z. acanthopodium* seeds with coconut water at concentrations of 0%, 25%, 75%, and 100% with a soaking time of 6 hours, 12 hours, and 60 minutes. Soaking time of 6 hours, 12 hours, 18 hours, 24 hours, and 30 hours resulted in a germination percentage of 0.16% on the 16th day.

Pasaribu (2021) and Pardosi (2021) observed the splitting of the seeds to confirm the presence or absence of endosperm and embryo in the seeds. Based on the observations of Pasaribu (2021), some of the seeds used did not have endosperm and embryos, with a percentage of seeds of 58%, and the results of Pardosi (2021) showed some *Z. acanthopodium* seeds did not have endosperm and embryos with a percentage of seeds 59%. Seeds that do not contain endosperm and embryos are obtained from physiologically mature fruits and have passed seed selection by water immersion due to the thick skin of seeds. These results indicate that seed selection by water immersion is unsuitable for the seeds. Other methods are needed to distinguish seeds that contain endosperm and embryos from those that do not contain endosperm and embryos. Fransiska and Sujarwati (2023) also studied by treatment of seed wounding and soaking with coconut water, revealed the method cannot break the dormancy of seeds; no seeds germinated until the 45th day; the study results on the condition of the seeds on 45th was 76-88% intact, 4-16% slimy, and 4-16% moldy. In addition, seeds are harvested in large quantities when the seed coat is still green; this stage is the best, widely used as a spice.

Therefore, the low seed germination potential is largely due to the high number of immature seeds in the panicles and seed fertility due to inadequate pollination caused by excessive humidity and temperature during flowering (Jacob et al. 2023). Based on the results of field surveys and interviews with respondents, it was found that *Z. acanthopodium* is generally planted by maintaining wild plants because the seeds are difficult to germinate (Figure 5.A). Farmers also still use wild seeds taken from their gardens or by asking from other gardeners. Some farmers germinate by burning the area to be planted with *Z. acanthopodium*. Some farmers have planted *Z. acanthopodium* by collecting dead or old ones on the edge of the field by piling them up. After the pile is already high, the pile is burned before the rainy season, and then within one to two months, it will grow. The plant is allowed to grow, then maintained and sorted to adjust the planting distance.

Some farmers germinate by collecting old *Z. acanthopodium* seeds as material to be germinated. Farmers make a 1 x 1 m area of land. The land is dug approximately 2 cm deep. When it has rained 2 to 3 times, the seeds are sown into the excavated soil, and the seeds are sprinkled until the seeds are not visible about 1 cm. Next, apply litter in the form of dry leaves on top, and then burn it. Wait until one to two months for the seedlings to grow. After the seedlings have grown 2 leaves, they can be transferred to polybags. Finally, after about 1 month in the polybag, the seedlings are ready to be planted in the field (Figure 5.D-G).

The interview revealed that this plant does not require fertilization. Farmers only rely on forest litter or apply some litter near the roots; the falling and decomposed litter are important factors contributing to soil quality. Nutrient inputs from litter play an important role in maintaining soil fertility.

The *Z. acanthopodium* farmers have their way, which is the local wisdom of the locals in cultivating them. Their intervention, as well as their skills, are crucial to maintain their farm most sustainably. The farmers often cultivated *Z. acanthopodium* in the agroforestry farm by utilizing land previously overgrown with other plants, such as frankincense, coffee, and other annual crops. The cultivation system was not carried out by cultivating the land areas by regular spacing as in conventional farming, but they planted the seeds found in the forest or around the plants in vacant areas on their agroforestry land, irregularly.

Just before the rainy season, the farmers collect the remaining *Z. acanthopodium* plants and prune the old plants, which are then piled on the edge of the farmland to be burned. After the farmland is exposed to rain for 2 to 4 weeks, the seedlings usually grow and may reach 20 cm before being planted on the dedicated land (Figure 5.B). Techniques for propagating them are done by soaking seeds in hot water for 30 minutes. Next, the seeds are spread on the ground, covered with thin litter, and burned. After that, the seeds are left until they grow into seedlings naturally.



Figure 5. 14. Cultivation of *Z. Acanthopodium*. A. Wild seedlings in the *Andaliman* planting area. B. Symptoms of stem borer attack. C. Seedlings that have reached a height of 20 cm are ready to be planted. D. Making a place for *Andaliman* nursery, E. One to two months later, seedlings will grow, F. After the *Andaliman* seedlings have grown 2 leaves, they can be transferred to polybags, G. After about 1 month in the polybag, the seedlings are ready to be planted in the field

Based on the farmer's information, seed propagation is done by breaking the seeds' dormancy with high-temperature treatment (soaking in hot water and burning). *Z. acanthopodium* seedlings are then put in planting holes and covered with soil and organic litter around the roots to maintain the soil moisture. Then, the seedlings are covered with large leaves in the soil and to cover the seedlings from direct sunlight exposure. The planting is usually carried out during the rainy season to reduce the mortality rate of the planted seedlings. Local farmers usually use bamboo to mark the planting spot for *Z. acanthopodium* seedlings. The activity of planting the seedlings is not conducted simultaneously but depends on the situation and condition of the land and the age of existing trees. If the farmers have a lot of spare land, the farmers usually multiply planting. Also, if many trees are old and considered unproductive, the plants will be replaced, and planting will be carried out again.

Based on the results of surveys in *Z. acanthopodium* planting locations such as in Simalungun and Dairi, it shows that some *Z. acanthopodium* plants are attacked by stem borers. The symptoms of the attack are that the tip of

the twig dries up and there are burrow holes, the larvae burrow into the stem under the skin layer with a burrow diameter of 0.5-1 cm, on the surface of the burrow hole there is sawdust, the larvae burrow into the stem, the depth of the burrow is 1.5-2 cm and the length is 5-15 cm, the affected stem will rot so that it accelerates the death of the plant, and finally the upper end of the branch will die (Figure 5.C).

Traditional utilization

The interview revealed, generally, *Z. acanthopodium* fruit is widely used as a seasoning for traditional Batak dishes, such as in *arsik* carp (carp curry without coconut milk) (Figure 6.A), *natinombur* (grilled fish with *Z. acanthopodium* chili sauce), *saksang* (meat cooked with *Z. acanthopodium* spices), *manuk napinadar* (chicken roasted and mixed with chicken blood) (Figure 6.B), *dengke mas na niura* (raw fish fermented with spices), *gota* chicken (Figure 6.C), *gomak* noodles (Figure 6.D), *tanggo tanggo*, and *Z. acanthopodium* chili sauce (Figure 6.E).

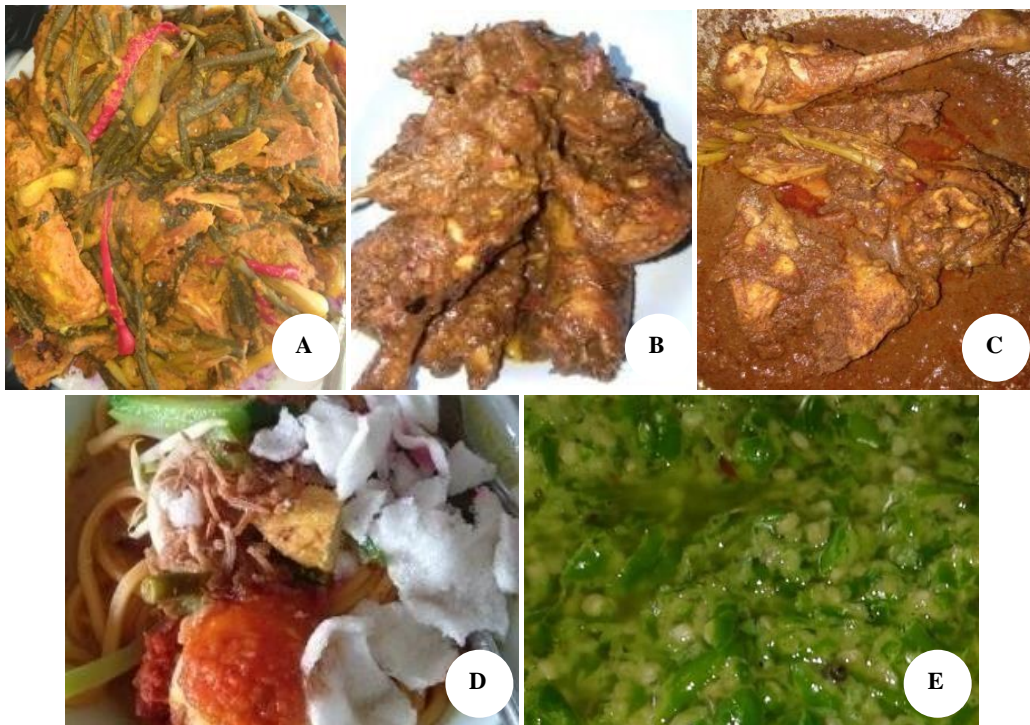


Figure 6. A. *Arsik* carp. B. *Manuk napinadar*. C. *Gota* chicken. D. *Gomak* noodles. E. Chili sauce

The *Z. acanthopodium* fruit as a spice is favored for its distinctive flavor with a citrus, spicy, and bitter aroma, making it flavorful. Apart from being processed with fish or meat, this spice is also consumed as a chili sauce, especially as a complement to food processed by grilling or frying. In processed fish or meat, *Z. acanthopodium* serves as a fishy odor reducer. Since ancient times, the fruit has also been mixed in processed foods for preservation. This is done considering that the technique of extending the expiration time of processed foods by salting is limited due to the lack of salt sources in the highland areas of North Sumatra. Apart from being a spice, various *Z. acanthopodium*-derived products have also been developed in North Sumatra, such as powder, *bandrek*, tea, flavored chips, flavored candy, instant *arsik* seasoning, noodles, meatballs, and pizza.

Zanthoxylum acanthopodium fruits have been one of the main ingredients of various typical cuisines of Bataknes communities in Lake Toba for centuries. This herb is preferred considering the distinctive taste with citrus aroma, bitter spicy and flavorful taste. In these local people, besides being processed with fish or meat, the fruit is also consumed as pickles or chili sauce, especially as a complement to processed foods by grilling or frying. In the past, mixing the fruits in processed food was also applied as a food preservative.

***Zanthoxylum acanthopodium* conservation**

The *Z. acanthopodium* conservation in North Sumatra is based on local communities' traditional agricultural and ecological management. People love and respect them as a plant that can only grow well in their ancestral lands; the

existence of *Z. acanthopodium* brings blessings to the people of North Sumatra. There are so many advantages and benefits derived from the existence of *Z. acanthopodium*. Tradition is local wisdom in the form of culture from generation to generation. Based on years of farming experience, farmers state that forests are very suitable for planting locations. The community believes that the forest provides life for the surrounding community economically and spiritually. As part of the environment, the forest must be well preserved. The community manages the forest to protect and fulfill life needs, social integration, education, belief, and self-actualization. Forest resource management based on traditional ecological knowledge encourages the creation of sustainable forest resources. Local knowledge of management and cultivation can contribute to developing cultivation practices that will support farmers' economic growth due to the commercialization as a spice commodity for domestic and export needs. However, the commercialization of *Z. acanthopodium* must still pay attention to environmental sustainability. Due to their distinctiveness and many benefits obtained from *Z. acanthopodium*, people increasingly believe that this plant must be preserved.

Discussion

Moreover, most *Zanthoxylum* species' isolated geographical environments and different climates usually lead to consolidated differences between taxa. *Z. acanthopodium* was classified as a *Zanthoxylum* species and mostly exhibits apomixis, where differences between cultivars may be negligible. Therefore, we hypothesized that the genetic diversity of *Zanthoxylum* species is low on

the cultivar level because of their apomixis and stable genotypes, although they have many different names and are distributed in several different areas (Fei et al. 2021a, b). Unfortunately, the published literature on the genetic diversity of *Zanthoxylum* species and the relationship between their morphological traits and genetic diversity is lacking (Deng et al. 2023).

Aside from the common method of *Z. acanthopodium* farming in farmland, local communities also cultivate this plant as part of the agroforestry system planted under pine trees in Samosir Forest. The farmers planted the seedlings under the shade of large trees such as pine (*Pinus merkusii*), kayu putih (*Melaleuca* spp.), attarasa (*Litsea cubeba*), and other large trees. *Z. acanthopodium* is usually planted in the forest or on the edge of the forest with a specific habitat profile, namely areas with a steep slope and slightly shaded (Nurlaeni et al. 2021).

Field surveys in these sites show that *Z. acanthopodium* distributed around the Lake Toba Districts, such as in Simalungun, Dairi, Humbang Hasudutan, Samosir, Toba Samosir, Karo, North Tapanuli, and South Tapanuli. The data obtained from field explorations shows 169 distribution points across 8 districts, following Suriani et al. (2019) stated that *Z. acanthopodium* is widely distributed in the Lake Toba region. Habitat characteristics of *Z. acanthopodium* are at an elevation of 854-2,676 masl with rainfall of 1,500-4,000 mm/annual, suitable on 7 land cover types (dryland, agriculture, rice fields, secondary dryland forests, shrubs, industrial plantations, and settlements), 4 soil types (Humic Acrisols, Orthic Acrisols, Humic Cambisols, and Orthic Ferralsols), and 4 critical land types (critical, rather critical, critical potential, and very critical). Environmental variable data used in the analysis. Soil Type, Land Soil type data, FAO, 1979. Soil Map of the World. Rainfall, Sumatra Island rainfall data, ESRI shape rain observation station source files (BMKG, PU, Private) 1970-2004 with a 0.01 degree resolution or 1.11 km. Critical Land, Sumatran Island critical land data, Directorate General of Forestry Planning, Ministry of Forestry Indonesian Republic of Indonesia, KML format. Elevation, Sumatera island elevation data, DIVA-GIS shapefile source SRTM30 data set, CGIAR-SRTM data with resolution of 30 arc sec. Land Cover, Land Cover map data, Directorate General of Forestry Planning, Ministry of Forestry Indonesian Republic of Indonesia, KML format.

Research conducted by Junaedi (2019) on the ecology of *Z. acanthopodium* showed that land slope is an important factor in *Z. acanthopodium* abiotic habitat preferences. The SLA measurements showed values that varied between 29.38-88.55 mm²/mg with a mean SLA value of 54.05 mm²/mg. Statistical analyses to compare the SLA data of *Z. acanthopodium* differentiated by habitat land use (i.e., natural area versus cultivated area) and habitat slope (high slope versus low slope) showed that they were not statistically different. This was indicated by the p-value of the t-test statistic of 0.073 for different habitat land uses and 0.075 for different habitat slopes. The SLA value between cultivated and growing wild of *Z. acanthopodium* in the forest is not significantly different. In contrast, the SLA value between *Z. acanthopodium* on

low and high slopes is relatively different. SLA can capture differences in the habitat conditions. *Z. acanthopodium* that grows naturally requires shade to support its life. The results of this study indicate that fully open habitats with full sun exposure during the day are not suitable for *Z. acanthopodium*. Therefore, to cultivate *Z. acanthopodium*, shade plants are required to a limited extent (especially when it is still a seedling) until it can grow stably. Thus, it can be grown inter-cropped with tall trees that shade the cultivation area.

In this traditional farming, *Z. acanthopodium* growth depends on soil fertility and sufficient rainfall (Nurlaeni and Junaedi 2018; Nurlaeni et al. 2021). Farmers also do not carry out regular maintenance to control weeds and irrigation; watering only relies on rainfall. Furthermore, pesticides for pests and diseases are never used because, according to farmers, the plants are rarely attacked by pests and diseases; for example, the common pests include leaf caterpillars, stem borers, and ants. Generally, farmers collect pests manually because the number of pests can still be controlled without pesticides. *Z. acanthopodium* cultivation growth did not use chemical fertilizers or fungicides, and the control treatment was carried out by clearing the land around the plants (Pane et al. 2022). However, a common disease is root rot, making the plant wither over time, dry up, and die. Usually, farmers will immediately remove the affected part of the plant and then burn it. Local varieties of cultivated crops originate from ancient times, have unique characteristics and have not undergone changes, usually have high genetic diversity, are more adaptable to the local environment, and are closely related to the traditions and cultivation systems that exist in local communities (Feng et al. 2020; Yan et al. 2023).

Some *Zanthoxylum* species are traditional dual-use plants as medicine (Yan et al. 2023). Apart from being a source of healthy nutrition, this spice is also processed and applied in traditional medicine. Ripe fruit can be eaten separately or mixed with other foodstuffs to treat dyspepsia, such as nausea, fullness-feeling (bloating), ulcers, and other stomachache symptoms. Both dried and fresh fruits are crushed into a paste and then rubbed on the gums to reduce the pain of tooth inflammation. In cold weather conditions, especially in higher and mountainous regions, *Z. acanthopodium* fruit is often chewed to warm the body and overcome colds. The roots are also boiled to cure toothache. For topical application, the fruit is crushed into a lotion to treat scabies, and the bark is boiled and used to cure fever, colds, and worm medicine. The essential oil derived from dried and fresh fruit is used for the inflammation of toothaches and to warm the body (Kholibrina and Aswandi 2021). The *Zanthoxylum* genus has become very valuable for discovering and utilizing medicinal and agrochemical natural products (Chen et al. 2022).

Zanthoxylum acanthopodium is also an analgesic that can reduce or eliminate pain. The high iron content in the fruit helps the formation of hemoglobin, a protein in red blood cells responsible for carrying oxygen to all organs and tissues. This condition will facilitate the circulatory system in the body (Natasutedja et al. 2020; Susanti et al.

2020). In addition to the Batak people in the Lake Toba highlands, the people of the Himalayas, Tibet, and the surrounding areas also use them as an aromatic, tonic, appetite generator, and stomach pain medicine (Yonzon et al. 2012; Yonzon and Rai 2016). The successful experience of traditional utilization shows that *Z. acanthopodium* has great prospects as an herbal medicinal ingredient (Bhatt et al. 2018; Muzafri 2019).

Therefore, many steps are needed to protect *Zanthoxylum* biodiversity, including ex-situ conservation. In addition, efforts are needed to strengthen the management of local commodity protection in an area and reduce the disturbance of excessive human activities and exploitation. Genetic diversity and wild *Zanthoxylum* germplasm must be protected immediately, and the community's local wisdom to preserve the environment must be maintained. *Z. acanthopodium*, a typical spice plant that only exists in North Sumatra and part of Aceh, characterizes itself, and we must preserve its existence. Hopefully this article will be a useful reference material as an effort to introduce and preserve it.

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