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FOREST RESTORATION RESEARCH IN NORTHERN THAILAND, 1. THE FRUITS, SEEDS AND SEEDLINGS OF *HOVENIA DULCIS* THUNB. (RHAMNACEAE)

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ABSTRACT

Hovenia dulcis Thunb. (Rhamnaceae) is a rare native tree species recently added to Thailand's flora, found in stream valleys in primary lower montane evergreen forest 1,075–1,250 m above sea level. It is a deciduous tree, shedding its leaves from late August to February, It flowers from December to May and fruits from August to January. Seeds begin to germinate 17–77 days after sowing and continue to do so over several months. A detailed description of the seedling is presented.

Due to the rarity of this species, we recommend including it in tree planting programs for forest restoration to prevent its local extinction and to increase the diversity of regenerating forests. To produce seedlings, seeds should be collected in November–January and planted in nurseries under moderate shade (about 40% full sunlight) in forest soil with high organic matter content. The seeds and seedlings should be kept well watered and protected from animals. Under favourable conditions, seedlings should reach a size suitable for planting in less than 12 months. Stream valleys in degraded evergreen forest at 1,000–1,300 m above sea level are the most promising planting sites for this species, but experiments at other sites are recommended.

INTRODUCTION

This paper is the first in a series describing the work of the Forest Restoration Research Unit (FORRU), a joint initiative between Chiang Mai University (CMU) and Doi Suthep-Pui National Park Headquarters (under the Royal Forest Department), where the unit is located. It is generously sponsored by Riche Monde (Bangkok) Ltd. and it aims to develop appropriate techniques to accelerate natural forest regeneration on deforested sites to conserve biodiversity and maintain watersheds in protected areas in northern Thailand (ELLIOTT ET AL., 1995). The initial aims of the Unit are to gather descriptive, ecological and taxonomic information on the wide variety of tree species which grow in the region. This includes data on the seasonal cycles of flowering and fruiting, seed germination and seedling

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morphology. This information, when complete, will be published as a handbook to aid recognition of the fruits, seeds and seedlings of native forest trees and advise on the propagation of seedlings for tree planting projects. In the meantime, short papers on individual species, such as this one, will be published as results become available.

Hovenia dulcis Thunb. (Rhamnaceae) was added to the flora of Thailand as recently as 1993 (MAXWELL, 1994). Consequently, very little is known of the ecology of this tree species in Thailand.

HABIT AND HABITAT

H. dulcis is a large canopy tree, reaching a height of 20–30 m and a diameter at breast height (dbh) of 22–55 cm. In northern Thailand (the southern limit of its known distribution (MAXWELL, 1994)), it is an uncommon species, having been collected at only two sites: Doi Suthep-Pui National Park and Doi Khun Tan National Park in stream valleys in primary lower montane evergreen forest from 1,075 to 1,250 m above sea level. Voucher specimens are deposited at CMU, Biology Department Herbarium (Suriya S18b2, Maxwell 93–1554, 93–1555 & 94–625). It is also known from Japan, from where it was described, the subtropical Himalayas, China and Korea (LAWSON, 1875; SASTRI, 1959; BEAN, 1973; SEN GUPTA & SAFUI, 1984; MABBERLY, 1987). It is cultivated in some parts of eastern Asia and specimens have been grown at Kew Gardens in Britain (BEAN, 1973).

Its mature leaves (Fig. 1) are arranged spirally. The blades are thin, 11–13 cm long by 5–9 cm wide, ovate to oblong, acuminate at the apex, rounded, truncate or cuneate at the base, with toothed margins. The upper surface is hairless and dark glossy green; the lower surface is a lighter green with prominently raised veins covered in fine brown hairs. There are 5–6 secondary veins per side, the lowest paired from the base of the blade but otherwise alternate. Leaf stalks (petioles) are about 12–14 mm long and are covered in fine brown hairs. The leaf blades of a juvenile tree (Maxwell 93–1554), 16 m tall, with a dbh of 14 cm, were mostly ovate, with less conspicuously toothed margins and were more hairy, especially on the upper surface. Leaf blades of seedlings (described below) are also hairy on the upper surface, rather than hairless as in the adults. The species has very characteristic thick bark with longitudinal, broad, flat, grey or light brown ridges (with numerous narrower, short, side–ridges), separated by narrow fissures about 1 cm deep and brick–red in the center (Fig. 2.) The bark is often covered in white or white-green lichens and algae.

PHENOLOGY

Despite its habitat preference for evergreen forest, *H. dulcis* is itself deciduous. At 1,075 m above sea level on Doi Suthep, a large proportion of its leaves begin to turn yellow in late August to early September (the peak of the rainy season), when they are readily detached by the slightest breeze. By January to February the crown is completely bare or almost so, but flushes with new leaves in March (the peak of the dry season). Flowers have been observed in December and from March to May. Fruits develop slowly.

Figure 1. *H. dulcis* foliage and immature fruits *(CMU, Biology Department Herbarium, Suriya s18b2),* 29th August 1995, 1,150 m above sea level, Doi Suthep-Pui National Park, Chiang Mai (photo S. Elliott).

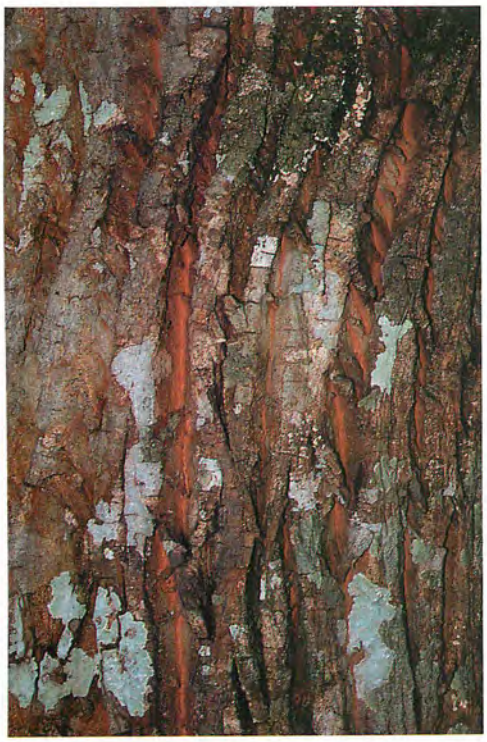

Figure 2. The distinctive bark of a mature *H. dulcis* tree about 64 cm in diameter, 29th August 1995, 1,075 m above sea level, Doi Suthep-Pui National Park, Chiang Mai (photo S. Elliott).

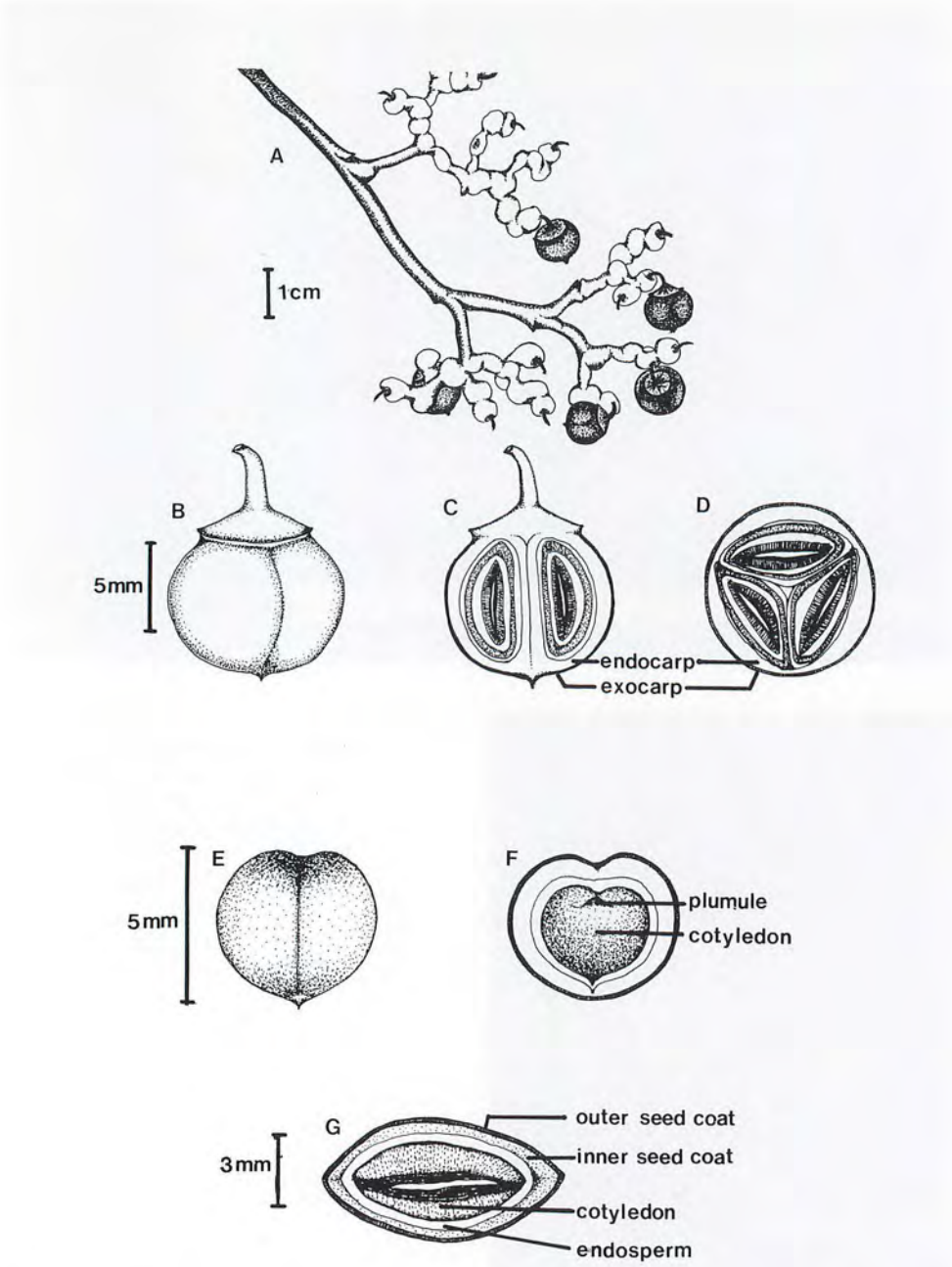

Figure 3. Fruits and seeds of *H. dulcis* (from same tree as in Figure 1): A. cyme, note the thickened fruit stalks, which are characteristic of the species and are believed to have medicinal properties; B. fruit; C. longitudinal section through fruit; D. transverse section through fruit; E. seed; F. longitudinal section through seed; G. transverse section through seed (drawings by K. Suriya and G. Pakaad).

Full-size but unripe fruits (the seed not yet developed) can be seen in July–August. Ripening occurs from August to December, when the seed grows to fill the fruit completely. By January, most of the fruits have fallen or been eaten by birds or mammals. These notes are based on opportunistic observations and unpublished data of the authors.

FRUITS AND SEEDS

The fruits are capsules, produced in cymes (a broad flat-topped inflorescence with the central flowers opening first). The fruit stalks (pedicels) are very thin and curving for 2–3 mm immediately above each fruit, but further along, together with other axes, they become swollen and fleshy (almost as wide as the fruits themselves), green when the fruits are unripe, turning red-brown or black as the fruits ripen (Figs. 1 and 3A). This part of the fruit stalk is known for its medicinal properties, particularly that of curing hangovers (MABBERLY, 1987).

The fruits (Figs. 1 & 3A–D) are roughly spherical capsules, which split open along internal walls (septicidally dehiscent), 6.9–8.5 mm long, 6.0–7.4 mm wide, and 6.0–7.7 mm thick (means ± SD's: 7.87 ± 0.39, 6.99 ± 0.34 and 6.87 ± 0.41 mm, respectively, n = 20). They are three-lobed, lime-green and moist when unripe, turning brown or black and drying out upon ripening. There is usually one seed in each lobe. Each capsule has a small cup at its base (derived from the old calyx) and a small scar at its apex (derived from the style). Both the outer and inner layers of the fruit wall (exocarp and endocarp respectively) are thin (Fig. 3C–D). At maturity, the outer layer gradually disintegrates and flakes off, exposing the white to cream–colored inner layer. The three segments (locules) of the inner layer of the fruit wall then separate and dangle on irregular threads from the fruit stalk; the fibres in the wall of each segment spread apart slightly, becoming basket–like. It is unclear whether the seeds fall out of each segment or must be removed by seed dispersers.

Seeds (Fig. 3E–G) are smooth, glossy, turning from light brown to dark brown and then black as the fruit ripens. Each seed is shaped like a one–third segment of a sphere, 5.0–6.0 mm long, 4.8–5.8 mm wide and 2.2–2.6 mm thick (means ± SD's: 5.57 ± 0.41, 5.37 ± 0.21 and 2.36 ± 0.24 mm, respectively, n = 20). The hilum (the scar where the seed was previously attached to the fruit) has a shallow rim around it. The embryo is composed of a small rudimentary shoot (plumule) and two large seed leaves (cotyledons). There is a thin layer of endosperm around the embryo. The seed coat is formed of two prominent layers: the outer one is clear to cream-colored, forming a hard protective covering around the seed; the inner one is softer and brown to black, giving the seed its color. Seeds dried overnight at 90 °C had a mean dry weight (± SD) of 27.8 ± 3.75 mg (n = 20) and a mean moisture content (± SD) of 19.1% ± 4.4% (n = 20).

SEED DISPERSAL AND SEED PREDATION

MAXWELL (1994) noted that fruiting trees attract many birds. However, since the capsules are dry and thin-walled, he assumed that the birds were eating the swollen fruit

stalks. Birds perching on and eating the fruit stalks might shake seeds out of the basket-like endocarp segments. If so, seeds would only be dispersed directly below the canopy until parts of the infructescence were broken off and carried to a perch in another tree for consumption. If seeds mostly fall below the canopy of the parent, evidence for secondary dispersal of the seeds away from the canopy by ants or small rodents should be investigated.

There is considerable pre-dispersal seed predation. On Doi Suthep in August 1995, large numbers of infructescences with green but full-size fruits were observed on the ground beneath three *H. dulcis* trees. Some had blown off in the wind; others had been severed by animals. Many capsules on the ground had been chewed and the seeds removed, but the capsule walls remained largely uneaten. Capsules still attached to the tree were largely intact. This suggests that arboreal animals, probably birds, were consuming only the fleshy fruit stalks in the canopy and dropping the capsules to the ground, where terrestrial rodents removed the seeds. In addition, there is a substantial amount of pre-dispersal predation by insects: about 20% of the seeds collected for germination (see below) had been damaged by insects.

Post-dispersal seed predation is also high. In March, seeds of *H. dulcis* were planted in a large grassy clearing 1,500 m above sea level within and without cages to protect the seeds from predation by small mammals and birds. There were 100 seeds in each treatment, in two replicates of 50. Protection from predation significantly increased the rate of germination and survival from 5% (± SD 7.1) for exposed seeds to 29% (± SD 24.0) for protected ones ($p<0.001$, chi–square test). At the FORRU nursery, seeds left on a bench were also attacked by rats in September. They devoured the seed contents but discarded the seed coat.

SEED GERMINATION

Two preliminary seed germination trials were carried out, one at the FORRU nursery and one at Doi Pui nursery.

Trial 1. Ripe fruits were collected from the ground below a single tree, ca. 25 m tall with a dbh of 64 cm near Rusee Cave, 1,075 m above sea level in Doi Suthep-Pui National park on 20th December 1994. Seeds were removed from the fruits and planted on 24th December at the FORRU nursery, 1,050 m above sea level, under two shade treatments: partial shade, (about 40% of full sunlight, similar to conditions in partially regenerating gaps) and deep shade, (less than 1% full sunlight, similar to conditions under an evergreen forest canopy). For the partial shade treatment, seed trays were placed on top of concrete benches, under a transparent plastic roof; for the deep shade treatment, trays were placed underneath the benches, screened around the sides with black plastic shade netting. For each of the two shade treatments, 72 seeds were divided into three replicate batches of 24, which were randomly assigned to different benches and watered daily. Each replicate consisted of 24 adjacent compartments (3.5 x 3 x 7 cm) in one seed tray containing forest soil.

The first seed germinated 17 days after planting in partial shade and after 24 days in deep shade. Seeds continued germinating until up to 115 days from the planting date (Fig. 4). The final germination percentage was significantly higher ($p<0.05$, chi-square test) in

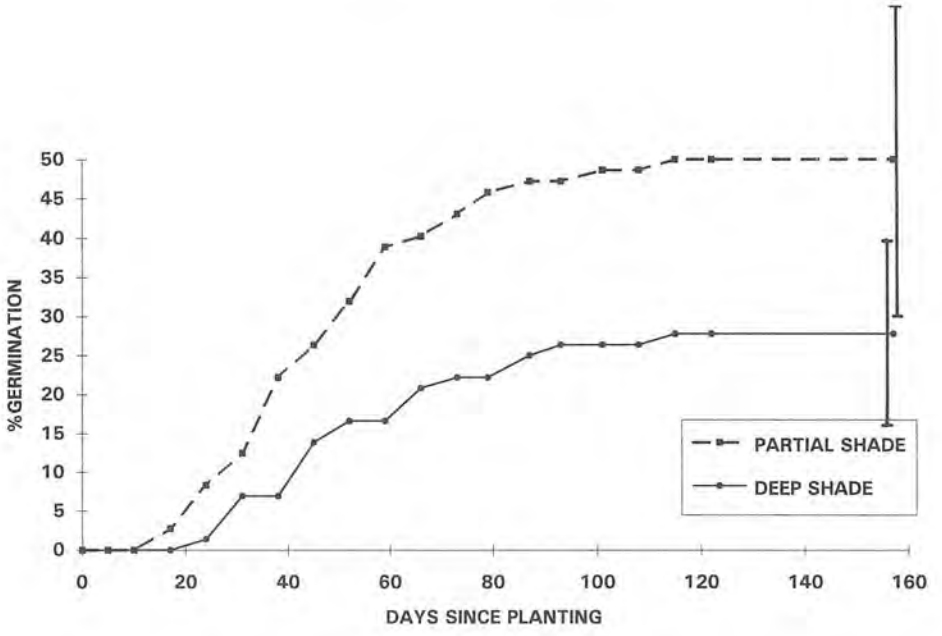

Figure 4. Germination curves of *H. dulcis* seeds in partial and deep shade at the FORRU nursery, Doi Suthep-Pui National Park 1,050 m above sea level. Bars indicate standard error of the final germination percentages (n = 3).

Table 1. Final percent germination of *H. dulcis* seeds sown at three levels of shading, with and without supplementary watering during the dry season. Values are means ±SD.

	100% full sunlight	8% full sunlight	1% full sunlight
Watered	18% (± 8.5)	39% (± 35.4)	37% (± 29.7)
Not watered	2% (± 0.0)	27% (± 9.9)	13% (± 1.4)

partial shade (50% ± SD 21.2%) than in deep shade (28% ± SD 12.2%). In addition, for those seeds that germinated, the number of days between sowing and germination did not differ significantly between treatments (p = 0.69, Kolmogorov–Smirnoff 2–sample test, SOKAL & ROHLF, 1981). Fifty per cent of all seeds that germinated had done so 45 days after sowing in both treatments.

Trial 2. Ripe fruits were collected on 25th February 1994 from the ground beneath a different tree growing close to that used in trial 1. In contrast to trial 1, cleaned seeds which were visibly damaged were discarded. Seeds were then planted at Doi Pui nursery, 1,450 m above sea level, under three levels of shading, with and without supplementary

watering during the remainder of the dry season. Seeds were planted in individual bags (6 cm diameter), containing forest top soil, which were randomly assigned to different treatments. For each treatment, 100 seeds were divided into two replicate batches of 50 bags. The three levels of shading were: full sunlight in the nursery area with no shade cloth (100% full sunlight); partial shade in a shade house entirely covered by 50% density shade cloth (about 8% full sunlight) and full shade (about 1% full sunlight) in a shade house entirely covered by 90% density shade cloth.

With supplementary watering, the first seeds germinated 42–49 days after planting in all three shade treatments. Without supplementary watering, the first seeds germinated 56 days after planting in partial and full shade, but only after 77 days in full sun. The last seeds in all treatments germinated after 84–112 days. With watering there was no significant difference in final germination between the two shaded treatments (i.e. 8% and 1% full sunlight). However germination under both shade levels was significantly higher than under full sunlight ($p<0.05$, chi-square test). Watering increased germination of all treatments, significantly so in full sunlight and deep shade ($p<0.05$, chi-square test), but not significantly in partial shade.

The two trials were conducted independently and many parameters varied, such as the collection date, storage time, light levels and other environmental conditions in which the seeds were germinated. However, both trials demonstrated that freshly harvested seed of *H. dulcis* can be successfully germinated in a nursery with a germination percentage of up to 50% and that a moderate level of shade (8–40% of full sunlight) produces the best results. Very deep shade and full sunlight appear to be less favourable for germination. In the only other study of seed germination of *H. dulcis* currently known to the authors, RILEY (1981) recommended scarifying seeds with sharp sand and pre-chilling at 1–5 °C for 30–60 days to increase the germination rate. Further trials are being carried out at the FORRU nursery to assess more critically the effect of different propagation treatments, to provide an unequivocal recommendation for the propagation of this species.

SEEDLINGS

Seedlings were raised from seed collected from one parent tree. They were initially grown in partial and deep shade (as described above), then transferred to a shaded nursery bed (15–20% full sunlight) and grown to larger sizes. Descriptions are based on about 40 unbranched seedlings less than 60 cm tall and one branched seedling about 80 cm tall. Herbarium specimens of seven seedlings of various sizes (Suriya s18b1 h1–h2) are deposited at the CMU Biology Department Herbarium. Various stages of development are illustrated in Figures 5–6.

Seedlings: cotyledons are held above the soil (epigeal) and are free of the seed coat (phanerocotylar).

Roots: Primary root slender, fibrous, white to light brown, developing into a thick tap root. **Secondary roots** few, slender, sparsely branching, cream–coloured.

Stems: Hypocotyl (the part of the stem immediately below the cotyledons) 3–6 cm long, light green with orange–brown longitudinal striations; densely covered with minute white hairs. **Epicotyl** (the part of the stem immediately above the cotyledons) 8–12 cm

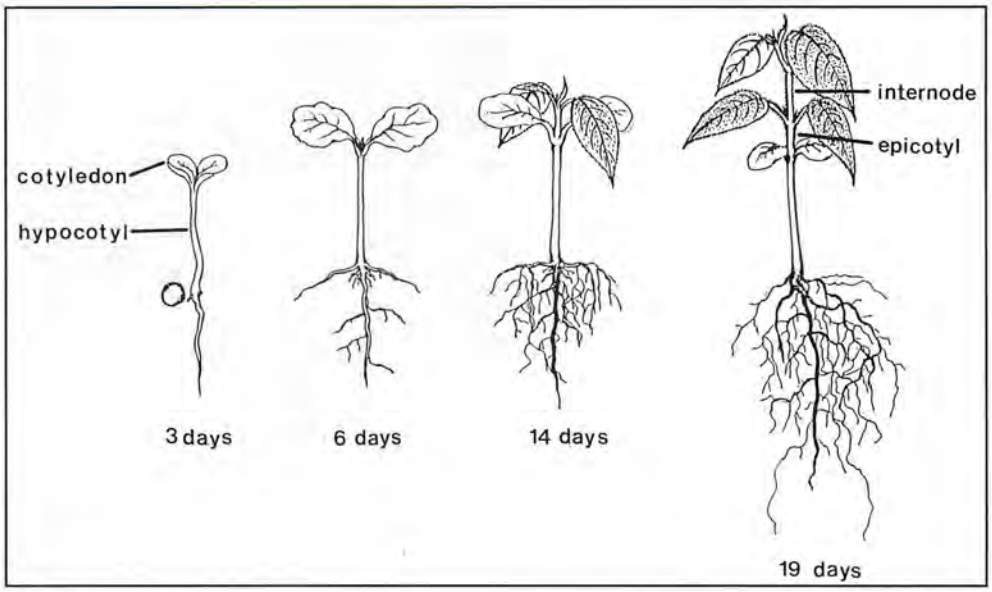

Figure 5. Seedlings of *H. dulcis* aged 3–19 days *(CMU Biology Department Herbarium, Suriya s18b1 h1)* (drawing by K. Suriya).

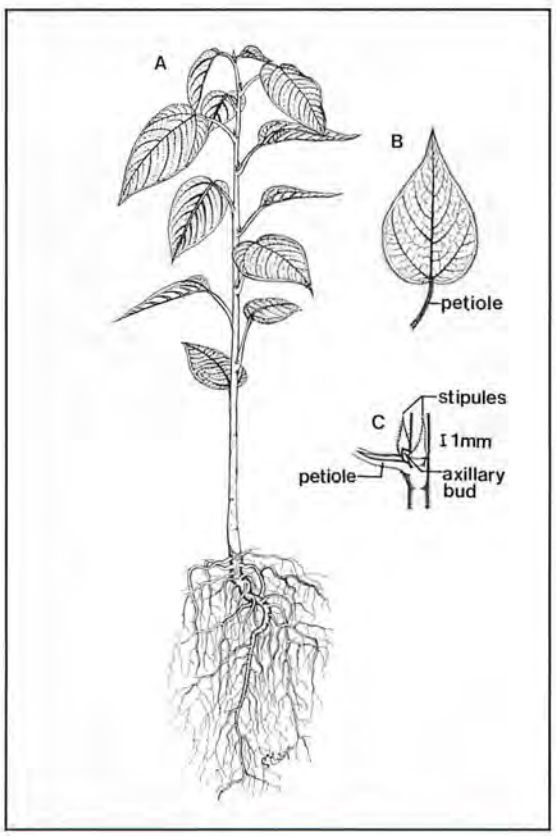

Figure 6. A. seedling of *H. dulcis* aged 183 days; B. leaf venation and C. stipules and axillary bud. *(CMU Biology Department Herbarium, Suriya s18b1 h2)* (drawing by K. Suriya).

Figure 7. The *H. dulcis* seedling from Fig. 6 aged 14.5 months.

Figure 8. The *H. dulcis* seedling from Figs. 6–7 aged 19 months.

long, light green, covered in white hairs. **Internodes:** first internode 6–11 mm long, later internodes up to 42 mm long; youngest parts light green, covered in white or light brown hairs; older parts a darker shade of green–brown, with prominent pores (lenticels), especially on the lower part. **Stems** of larger seedlings erect, slender. **Axillary buds** (on the stem above the petiole) minute, green with brown apex, conical, hairy, about 1 mm in diameter.

Cotyledons (seed leaves) two, opposite, hairless, persistent until about the 11th leaf expands. Blades green, thin, orbicular, with entire margins, rounded to somewhat truncate at apex, rounded at base; 13–14 mm in diameter (when mature). **Venation** pinnate, obscure, with two basal veins. **Petioles** (cotyledon stalks) 3–4 mm long, covered in fine white hairs.

Leaves opposite at first node, spiral at later nodes. Blades at first node thin, darker green above than below, ovate, acuminate at apex, truncate at base, finely toothed along margins, 22–35 mm long x 14–17 mm wide; simple, fine, white hairs sparse on blades above, absent on blades below, dense on midrib above and below and somewhat dense on other veins below. Blades at later nodes ovate, but somewhat broader at higher nodes than at lower nodes, up to 122 mm long x 85 mm wide, otherwise similar to blades at first node. **Venation** pinnate; primary and secondary veins below lighter green than the blade, prominently raised; primary basal veins two, opposite; secondary veins 4–6 on each side of midnerve, alternate; all lateral veins curved, mostly free–ending, sometimes weakly looped. **Petioles** (leaf stalks) very hairy; 6–8 mm long and 0.2–0.4 mm thick at first node, up to 50 mm long and 2 mm thick at later nodes; green with light brown hairs. **Stipules** thin, ovate–lanceolate, acuminate at the apex; about 1 mm long at first node, to 4 mm long at later nodes; densely covered in fine white hairs; sometimes persisting after leaves are shed at early nodes, but usually falling soon after leaves mature at later nodes, leaving tiny scars.

Branches not formed on seedlings less than 60 cm tall; first produced at 68 cm above ground level (about node 24), then in each of the next four consecutive leaf axils; spiral around stem; extending soon after the subtending leaf matures.

Odour and **sap** not distinctive.

CONCLUSIONS

H. dulcis is a rare species in northern Thailand, currently known from only two sites. We strongly recommend that it is planted in forest restoration projects to protect it from local extinction. Planting *H. dulcis* in degraded forest would have the advantage of introducing a primary forest tree species into gaps at an earlier stage of forest regeneration than would occur naturally. In addition, because this species is attractive to many animal seed dispersers, it should attract many primary forest animal species into the gaps, which should increase the seed rain of primary forest trees and hasten recovery of the forest.

To produce seedlings of this species for forest restoration projects, we recommend that seeds are collected in November–January and planted in nurseries under moderate shade (about 40% full sunlight) in forest soil with high organic matter content. The seeds and seedlings should be kept well watered and protected from animals. Under favourable conditions, seedlings should reach a size suitable for planting in less than 12 months.

More experimental work is needed to optimize the propagation methods for this species.

As *H. dulcis* is only known to grow along stream valleys in lower montane evergreen forest, we suggest that it is first planted in degraded evergreen forests along permanent streams. If it successfully establishes in this habitat, it should be tested in a wider range of degraded forest types to determine whether its local rarity is caused by very particular site preferences or other factors. In view of the high rate of post-dispersal seed predation, we recommend the planting of seedlings, rather than direct sowing of seeds.

ACKNOWLEDGMENTS

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Notes added in proof: H. dulcis can grow very fast. The seedling in Fig. 6 was planted near the FORRU nursery (1,050 m above sea level) in an east-facing open area where the ground vegetation was cut back. It reached a height of 2.20 m, 19 months after seed sowing. Its high growth rate and spreading canopy could shade out competing ground vegetation and create conditions suitable for establishment of other naturally-dispersed woody species. Young seedlings (about 10 cm tall) can be collected near parent trees in July–August. These could be transferred to nurseries for planting out at the beginning of the next rainy season.