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*Moringa oleifera* Lam., commonly known as resedá, horseradish tree, drumstick tree, ángela, árbol de los aspáragos, árbol de las perlas, ben tree, and by several other names (32, 37), is a small, fast-growing evergreen or deciduous tree that usually grows up to 10 or 12 m in height. It has a spreading, open crown of drooping, fragile branches, feathery foliage of tripinnate leaves, and thick, corky, whitish bark (fig. 1). It is valued mainly for its edible fruits, leaves, flowers, roots, and seed oil and is used extensively in traditional medicine throughout its native and introduced ranges (7, 23, 37, 41).

## HABITAT

### Native and Introduced Ranges

Resedá is indigenous to south Asia, where it grows in the Himalayan foothills from northeastern Pakistan to northern West Bengal (India) (39, 47, 55) (fig. 2). It has been introduced and become naturalized in other parts of India, Pakistan, Afghanistan, Bangladesh, Sri Lanka, Southeast Asia, west Asia, the Arabian peninsula, east and west Africa, southern Florida, throughout the West Indies, and from Mexico to Peru, Paraguay, and Brazil (23, 31, 32, 47, 60). In Puerto Rico, it is grown chiefly as an ornamental and in fencerows and hedges and has become naturalized along roadsides on the coastal plains and lower foothills.

### Climate

In its native habitat, annual temperature fluctuations tend to be very large, with minimum and maximum shade temperatures ranging from -1 to 3 °C and from 38 to 48 °C during the coldest and warmest months, respectively (55). In this region annual rainfall ranges from 750 to 2200 mm (41, 55). Resedá is highly drought tolerant and is cultivated in semiarid and arid regions of India, Pakistan, Afghanistan, Saudi Arabia, and east Africa, receiving an annual rainfall as low as 300 mm (7, 47), although such sites are probably irrigated or are characterized by a high water table. In Puerto Rico, resedá has become naturalized to a limited extent on sites with an annual rainfall between 1000 and 1800 mm (18).

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## Soils and Topography

Resedá grows at elevations up to approximately 1,400 m along the larger rivers of its native range on sandy or gravelly alluvium (7, 55). These soils are generally well drained and often low in organic matter. While surface soils may be very dry for several months of the year, the water table is usually located within the maximum rooting depth of trees (9). Where it has been introduced, resedá grows well from sea level to a 1,200-m elevation (23) in most light- to medium-textured soils, but best growth occurs on sandy loams (47). In Puerto Rico, resedá grows at low elevations in excessively drained and moist, well-drained soils of medium fertility with a pH between 5.5 and 7.5 (18). Poor performance was reported on semiarid Alfisols at an elevation of 1,560 m in Kenya (25).

## Associated Forest Cover

In its native range, resedá grows in secondary dry tropical deciduous forests in association with *Albizia procera* (Roxb.) Benth., *Bombax malabaricum* DC., *Dalbergia sissoo* Roxb., *Ficus glomerata* Roxb., *Gmelina arborea* Linn., *Kydia calycina* Roxb., and *Lagerstroemia parviflora* Roxb. (2, 9). In secondary forests on the south coastal plain of Puerto Rico, resedá is associated with *A. lebbek* (L.) Benth., *Bucida buceras* L., *Leucaena leucocephala* (Lam.) de Wit, *Pithecellobium dulce* (Roxb.) Benth., *Prosopis pallida* (H. & B.) ex Willd., *Tabebuia heterophylla* (DC.) Britton, and *Tamarindus indica* L. (author, personal observation).



Figure 1: — *Resedá* (*Moringa oleifera*) in Puerto Rico.

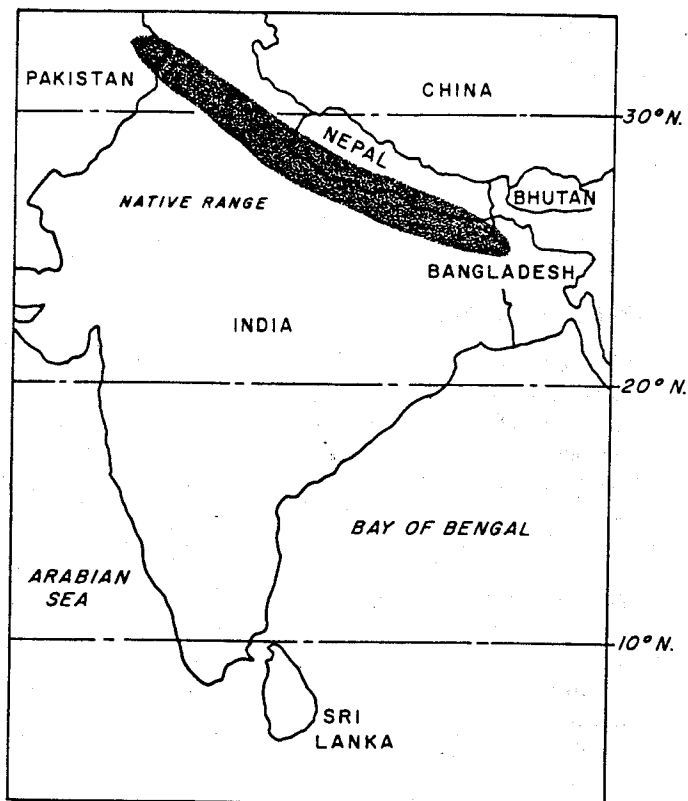


Figure 2. — Native range of *resedá* as indicated by shaded area (*Moringa oleifera*).

## LIFE HISTORY

### Reproduction and Early Growth

**Flowering and Fruiting.**—Flowering phenology varies widely among varieties and with location. Trees may flower only once, between the months of April and June in seasonally cool regions such as north India, twice a year in south India, or year-round in locales with more constant seasonal temperature and rainfall regimes, as in Puerto Rico and elsewhere in the Caribbean (32, 47). Flowering generally begins at an early age, often within the first 6 months after planting and usually within the first year. The fragrant, bisexual, yellowish-white flowers are borne on slender, hairy stalks in spreading or drooping lateral flower clusters 10 to 25 cm long (fig. 3). Individual flowers are approximately 0.7 to 1 cm long and 2 cm broad with five unequal yellowish-white, thinly veined petals (32, 47). Bees and other insects, as well as birds, are the principal pollinators (26, 37).

The fruits are pendulous, linear, three-sided brown capsules with longitudinal ridges, usually 20 to 45 cm long, sometimes up to 120 cm long, and 2 to 2.5 cm broad (32). The fruits reach maturity approximately 3 months after flowering (43). Twenty-four seed pods from Puerto Rico contained an average of  $15.8 \pm 1.4$  seeds and ranged from 2 to 26 seeds per seed pod (author, personal observation).

**Seed Production and Dissemination.**—*Resedá* seeds are dark brown, globular, and about 1 cm in diameter, with

three whitish papery wings (47). Seed weights apparently differ among varieties, ranging from 3,000 to 9,000 seeds per kilogram (41). Two samples of 100 cleaned seeds from Puerto Rico averaged  $0.325 \pm 0.005$  and  $0.310 \pm 0.006$  g per seed, or between 3,080 and 3,230 seeds per kilogram (author, personal observation). The mature seed pods remain on the tree for several months before splitting open and releasing the seeds, which are dispersed by wind, water, and probably animals.

**Seedling Development.**—Germination in *resedá* is epigeal. Seeds should be sown without pretreatment as scarification does not positively affect germination rates (48). The optimal sowing depth for *resedá* seeds is 1 to 2 cm (48, 58).

Germination is commonly between 60 and 90 percent for fresh seeds (23, 41, 48, author, personal observation) and occurs between 7 and 30 days after sowing (48, author, personal observation). Seeds do not retain their viability in storage for longer than 2 months (48, 58). In India, germination percentages of 60.0, 48.0, and 7.5 percent were reported for seeds sown 1, 2, and 3 months, respectively, after collection (48). Other studies have reported germination rates ranging from 10 to 60 percent for seeds after 1 month of storage (37). Both germination and early seedling development are favored by partially shaded conditions (23).

Seedling growth in *resedá* is rapid. Seedlings grown in pots in Puerto Rico were 20 to 30 cm in height 6 weeks after sowing, and seedlings reach plantable size (30 to 50 cm) 2 to 3 months after sowing (author, personal observation). Seedlings occasionally grow to 2.5 m in height 3 months after sowing and between 1.8 and 3.6 m 5 months after sowing (37). In India, where *resedá* is widely cultivated, plantations are established using both nursery-grown seedlings and cuttings (47).

The natural regeneration of *resedá* is fair on disturbed sites such as roadsides and field borders where competition for light and soil moisture is not severe.

**Vegetative Reproduction.**—*Resedá* is easily propagated by cuttings but is difficult to propagate by air layering (48). Large limb cuttings of 1 to 1.4 m in length and 4 to 5 cm in diameter are typically planted during the summer rainy season in south India (47). Plants raised from seeds reportedly produce fruit of inferior quality and are slower to produce fruit (47). Large branch or stem cuttings, planted in moist soil, root readily and grow to sizeable trees within a few months (47). However, some studies suggest that trees grown from seeds produce longer roots than those grown from cuttings and may be preferable for plantations established in semiarid and arid regions where unstable soils and water table depth potentially limit growth (23). In northern India, rooting success of branch cuttings was better during the spring months than during either the summer rainy season or the cooler winter months (48). In these studies, 2-year-old stem cuttings 30 cm in length and 0.75 to 2.0 cm in diameter rooted more readily than 1-year-old stem cuttings. Rooting percentages were optimized by treatment with the plant growth regulator indole-butyric acid (IBA) at concentrations of 50 ppm for 24 hours prior to planting. Large branch cuttings 1 to 2 m in length are often used with good success, provided they are planted to a depth of 50 cm (41).

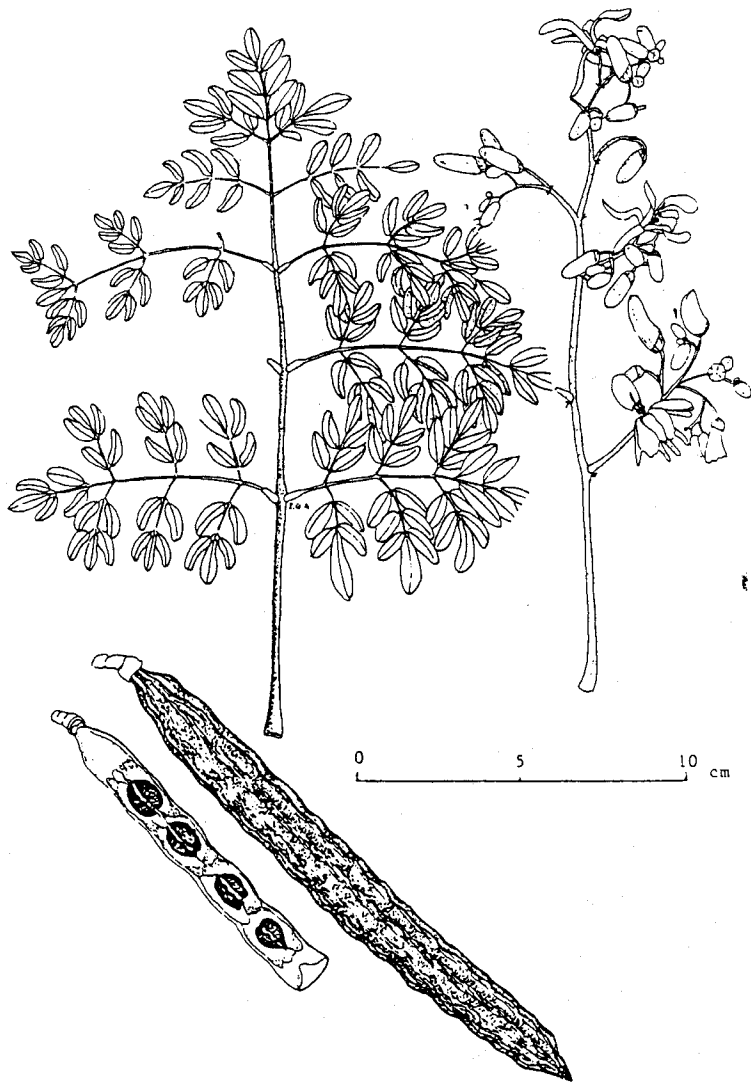


Figure 3. — Foliage and fruit of resedá (*Moringa oleifera*) (28).

Resedá resprouts vigorously after cutting, producing four to eight shoots per stump (41). Trees grown for fruit and fodder production are commonly pollarded to restrict crown spread and promote new branch growth (47).

#### Sapling and Pole Stage to Maturity

**Growth and Yield.**—Resedá grows rapidly on favorable sites, with height increments of 1 to 2 m per year during the first 3 to 4 years. While trees rarely grow taller than 10 to 12 m, they occasionally attain heights of 15 to 16 m with diameters at breast height (d.b.h.'s) up to 75 cm (29). Fruit production in resedá begins at an early age, as early as 6 to 8 months after planting in the case of trees raised from cuttings (47). Fruit yield is generally low during the first 2 years, but from the third year onward, a single tree can yield 600 to 1,600 or more fruits per year (7, 37, 47).

**Rooting Habit.**—Resedá seedlings develop a swollen, tuberous white taproot with a characteristic pungent odor, and very sparse lateral roots. Trees grown from seeds form

a deep, stout taproot and a wide-spreading system of thick tuberous lateral roots. Taproots do not develop on trees propagated from cuttings (31).

**Reaction to Competition.**—Resedá is a strongly light-demanding species, and is commonly planted at spacings of 3 by 3 m to 5 by 5 m in block plantations and 5 m in line plantings (41, 47). "Living fences" or hedges of resedá are commonly established at spacings of 1 m or less and managed for foliage production through frequent cuttings (37). Seedlings are susceptible to drought and to competition with grasses. Once established, saplings and poles are very hardy and can survive both drought and root competition.

**Damaging Agents.**—In India, resedá has several insect pests. These include the bark-eating caterpillar, *Indarbela quadrinotata* Wlk.; the hairy caterpillar, *Eupterote molifera* Wlk.; the green leaf caterpillar, *Noorda blitealis* Wlk.; and the budworm, *N. moringae* Tams, which can cause serious defoliation; the larvae of *Tetragonia siva*; *Metanastia hyrtaca*; *Heliothis armigera*; and *Helopeltis antonii* Sign. (Lepidoptera); an aphid, *Aphis caraccivora*; the scale insects, *Ceroplastodes cajani* and *Diaspidotus* sp.; the stem borers, *Indarbela tetraonis* (Moore) and *Diaxenopsis apomecynoides*; and a fruitfly, *Gitonia* sp. (8, 27, 37, 45, 47, 57). Several other insect pests causing minor or only occasionally serious damage have been reported (41). In Puerto Rico, resedá is reportedly very susceptible to attack by termites (36). Seed predation by an unidentified insect is often heavy (author, personal observation).

Resedá is not affected by any serious diseases in its native or introduced ranges. Several diseases are reported to cause minor damage to trees in south India, including a root rot caused by *Diplodia* sp. (47) and fruit rot caused by *Cochliobolus hawaiiensis* (30). Resedá is a collateral host of *Leveillula taurica*, a powdery mildew that causes serious damage in papaya (*Carica papaya* L.) nurseries in south India (56). Resedá is highly susceptible to wind damage.

#### SPECIAL USES

The soft wood of resedá is little used outside of its native or introduced south Asian range except as a fuelwood (17, 32). In India, it is used to a limited extent in the textile industry for shuttles and picking-sticks and is suitable for pulp production for newsprint (20, 49), cellophane, and textiles (35, 41).

The tree is mainly valued for its edible, tender pods, which have a taste very similar to asparagus. These are eaten as a nutritious vegetable, either cooked or pickled. The tender leaves taste like watercress and, along with the flowers, are consumed cooked or raw. They are rich in protein, minerals, beta-carotene, thiamin, riboflavin, and other vitamins, particularly vitamins A and C (6, 11, 17, 21, 40, 41, 44, 47, 50, 51, 59). The ascorbic acid (vitamin C) content of the green pods ranges from 92 to 126 mg per 100 g of pulp (15). The young fruit, flowers, and leaves contain 5 to 10 percent protein (54).

The immature seeds, which taste like peanuts after frying, are also consumed raw or cooked (13, 47, 54). The roots, which have the pungent taste of horseradish (*Armoracia rusticana* Gaertn.), are used as a condiment or gar-

nish after peeling, drying, and mixing with vinegar (36). The root bark must be completely removed as it is rich in alkaloids, notably moringine, a toxic compound allied to ephedrine (37).

Resedá seeds contain between 19 and 47 percent oil (3, 22, 28, 54). This oil is similar to olive oil and is rich in palmitic, stearic, behmic, and oleic acids (41, 59). Known commercially as "ben oil," it is used for human consumption, illumination, and in cosmetics and soaps (13, 14, 47, 54). This oil is highly valued by perfumers for its power of absorbing and retaining odors, and by watchmakers as a lubricant (47). The oil cake is used as a fertilizer (13).

The crushed seeds have been used as an effective and low-cost method for removing turbidity and reducing bacterial contamination from drinking water in rural communities in the Sudan, Malawi, and Indonesia (23, 52). Leaf extracts have been found to increase root nodulation, nodule weight, and *Rhizobium* nitrogenase activity in mung bean, *Vigna mungo* (L.) Hepper, when applied to seeds or as a root dressing (4).

The corky bark yields a coarse fiber, which is utilized in making mats, paper, and cordage. The stem exudes a mucilaginous gum that is used in leather tanning and calico printing (5, 41, 47). In many parts of its range, the leaves and twigs are used as fodder for cattle, sheep, goats, and camels (34, 42). The flowers are a good source of pollen for honeybees (7, 32, 46).

Resedá has numerous medicinal uses that have been appreciated for centuries in many parts of its native and introduced ranges (7, 38, 47). The uses of its roots, root bark, stem bark, stem exudates, leaves, flowers, and seeds in the treatment of a wide variety of ailments have been discussed in ancient Sanskrit texts on medicine (47), and the tree continues to have an important role, particularly as a counter-irritant, in indigenous medicine in Asia and west Africa (6, 7, 10, 12, 24, 37, 41, 54). The juice extracted from the leaves has strong antibacterial and antimalarial properties (10, 13, 16, 19). The flowers and roots contain pterygospermin, an antibiotic that is highly effective in the treatment of cholera (33). Several compounds of proven medicinal value have been isolated from the roots, root bark, stem bark, and seeds (7). Ben oil is commonly used in the treatment of gout and acute rheumatism (49).

## GENETICS

Resedá exhibits considerable phenotypic variation within its range (47, 53). While wild trees usually bear small fruits, cultivated varieties grown in south India, known as "Jaffna" and "Chavakacheri murunga," bear fruits ranging in length from 60 to 90 cm and 90 to 120 cm, respectively. A variety with red-tipped fruits, "Chemmurunga," is said to flower year-round and to yield heavy crops. Other well-known varieties cultivated in the south Indian state of Tamil Nadu include "Palmurungai," which has a thick pulp and bitter taste; "Punamurungai," and "Kodikalmurungai," which produces very short fruits (15 to 23 cm in length). In the

West Indies, several varieties are cultivated; some produce an abundance of fruit while others rarely flower and are principally grown for their foliage (47).

*Moringa* (a vernacular name from south India) is the sole genus in the family Moringaceae, with 10 to 12 species native from North Africa to Southeast Asia (1). In addition to *M. oleifera*, several other species have proven to be useful sources of food, fiber, medicinals, and other products. These include *M. concanensis* Nimmo, *M. drouhardii* Jumelle, *M. longituba* Engl., *M. ovalifolia* Dinter & A. Berger, *M. peregrina* (Forsk.) Fiori, and *M. stenopetala* Cuford (23, 37).

Botanical synonyms include *M. moringa* (L.) Millsp., *M. pterygosperma* Gaertn., *M. nux-ben* Perr., *Hyperanthera moringa* Willd., and *Guilandina moringa* Lam. (37). Resedá is a diploid species with 28 chromosomes (47).

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