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Senna siamea Irwin & Barnaby, yellow cassia, or minjri, is an evergreen tree of medium size with an irregular, spreading crown (fig. 1) bearing large clusters of bright-yellow flowers and long, narrow, dark pods throughout the year. Yellow cassia has been extensively planted in tropical to warm temperate regions as an ornamental tree, for production of small timber and fuelwood, as a shade tree for coffee and cacao, and for reforestation of degraded lands (35, 42, 45, 55).

HABITAT

Native Range

Yellow cassia is native to Southeast Asia (between latitudes 1° and 20° N. (58, fig. 2) from southern India and Sri Lanka to Burma, Thailand, and Malaysia. It has been widely introduced and naturalized in many parts of tropical Asia, Africa, the Caribbean, Central America, and subtropical North America (15, 46, 55), becoming abundant locally on roadsides and wastelands. During the first quarter of the century, yellow cassia was among the most widely used plantation species in seasonally dry and semiarid regions of Africa, particularly in Ghana, western Nigeria, Tanzania, and Uganda (42).

In the Caribbean, it was introduced to Jamaica before 1837 and planted in Guadeloupe as a shade tree for coffee and cacao (36). Elsewhere in the region, it is planted for ornamental purposes, shade, windbreaks, fuelwood, and small timber (36). It is common throughout the West Indies and occurs less commonly in southern Florida and from Guatemala to northern South America.

Climate

Yellow cassia grows well in humid, subhumid, semiarid seasonal, or monsoonal tropical climates. Mean annual rainfall requirements are 500 to 1500 mm or more in areas with a dry season lasting from 4 to 8 months (35, 58). Best growth is reported in areas with more than 1000 mm annual precipitation and a dry season of 4 to 5 months (12). It is reported to be drought hardy and tolerant of salt spray and light frosts (55, 58). In dry areas, growth is generally very

slow after 2 years unless roots have access to deep soil moisture (15, 42). Mean annual temperatures of 21 to 28 °C are characteristic of the species' native and introduced ranges, with mean maximum temperatures of 23 to 35 °C during the hottest months and mean minimum temperatures of 13 to 24 °C during the coldest months (58).

Soils and Topography

Yellow cassia grows well in sandy- and medium-textured soils that are slightly acid to alkaline (30, 43, 58). Deep, well-drained, relatively rich soils are required for best growth (15, 35). Saline and calcareous soils are tolerated, while waterlogged conditions, poorly drained soils, and low fertility sands are not (12, 15, 18). Its tolerance of relatively poor site conditions has led to its use in South Asia and Africa in reclamation of degraded lands, including lateritic sites (4, 40). However, in reforestation trials conducted in Maharashtra (India) at a site characterized by degraded vertisols, yellow cassia survival and growth were relatively poor in comparison with *Leucaena leucocephala* (Lam.) de Wit and *Azadirachta indica* A. Juss. (44). The tree grows naturally at altitudes ranging from sea level to 600 m and occasionally is found growing at 900 m (14, 35).

Associated Forest Cover

In its native range, yellow cassia is common in the forests of southern India, in mixed deciduous and dry forests of western Myanmar (formerly Burma), and in Sri Lanka



Figure 1.—Yellow cassia trees (*Senna siamea*) growing in Puerto Rico.

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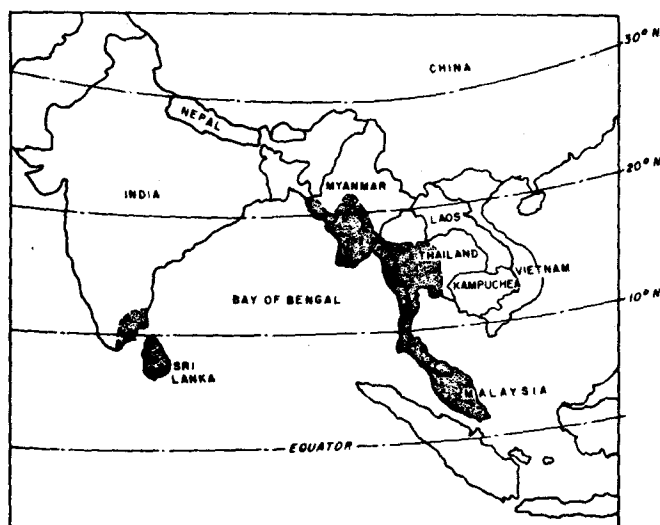


Figure 2.—Native range of yellow cassia (*Senna siamea*).

growing at elevations of up to 600 m (17). In western Thailand, it is commonly found in semievergreen forests in association with *Azelia xylocarpa* (Kurz) Craib, *Alangium salvifolium* Wang., *Cassia garrettiana* Craib, *Chukrasia velutina* Wight & Arn., *Dalbergia cultrata* Grah., *Dillenia* spp., *Dipterocarpus tuberculatus* Roxb., *Erythrophloeum teysmannii* (Kurz) Craib, *Garuga pinnata* Roxb., *Hopea odorata* Roxb., *Lagerstroemia flos-regina* Retz., *Michelia champaca* Linn., *Pterocarpus macrocarpus* Kurz, *Terminalia tomentosa* Bedd., and *Vitex pubescens* Vahl. (61).

In some areas where yellow cassia has been introduced as an ornamental or plantation species, it has become naturalized, as on the Accra plains of Ghana (42). In Puerto Rico, naturally regenerated, mixed stands composed of yellow cassia in association with such species as *Spathodea campanulata* Beauv., *Delonix regia* (Bojer ex Hook.) Raf., *Syzygium jambos* (L.) Alst., *Albizia procera* (Roxb.) Benth. (48), *Terminalia catappa* L., *Andira inermis* (W. Wright) H.B.K., *Casuarina equisetifolia* L., *Guarea guidonia* (L.) Sleumer, and *Didimopanax morototoni* (Aubl.) Decne. & Planch. are commonly found at lower elevations in the vicinity of roadside plantings.

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—In its native range, yellow cassia flowers between June and January (7). Due to the variety of environments in which it grows in Latin America, the species can be found flowering and fruiting at almost any time of the year (36). However, in each environmental area, especially the drier ones, yellow cassia is generally synchronized in its blooming and fruiting. Numerous bright-yellow flowers are borne on large pyramidal axillary panicles 20 to 30 cm long and 13 cm broad at the ends of

twigs (fig. 3), (36). Individual flowers, measuring approximately 3 cm across, occur on slender stalks 2 to 2.5 cm long. The flowers are almost regular and are composed of five concave, pointed, greenish-yellow, finely hairy sepals 8 mm long and five short-stalked, spreading, nearly equal, rounded yellow petals 15 to 20 mm long. The flowers have seven stamens of different lengths; three smaller sterile stamenodes; and a pistil with a pale green, finely hairy, one-celled ovary and a curved style (35).

The fruits, generally produced in abundance from about 5 years of age, are flat, thin pods, dark brown in color when ripe, 5 to 25 cm long, and 12 to 20 mm wide. A pod contains as many as 25 seeds (35, 62).

Seed Production and Dissemination.—Yellow cassia seeds are small, flat, bean-shaped (8 mm long), shiny, and dark brown in color, with a thin but fairly durable seedcoat. There are approximately 30,000 to 45,000 seeds per kilogram (30, 35). Seeds are released from the dehiscent pods while still on the tree (36). Ripened, unopened pods may be collected from branches, air-dried, crushed, and winnowed to separate seeds (59).

Seedling Development.—Germination in yellow cassia is epigeous. Seeds may be sown without pretreatment, although scarification by any of the following methods is reported to facilitate more rapid and uniform germination: soaking in concentrated sulfuric acid for 5 to 10 minutes,

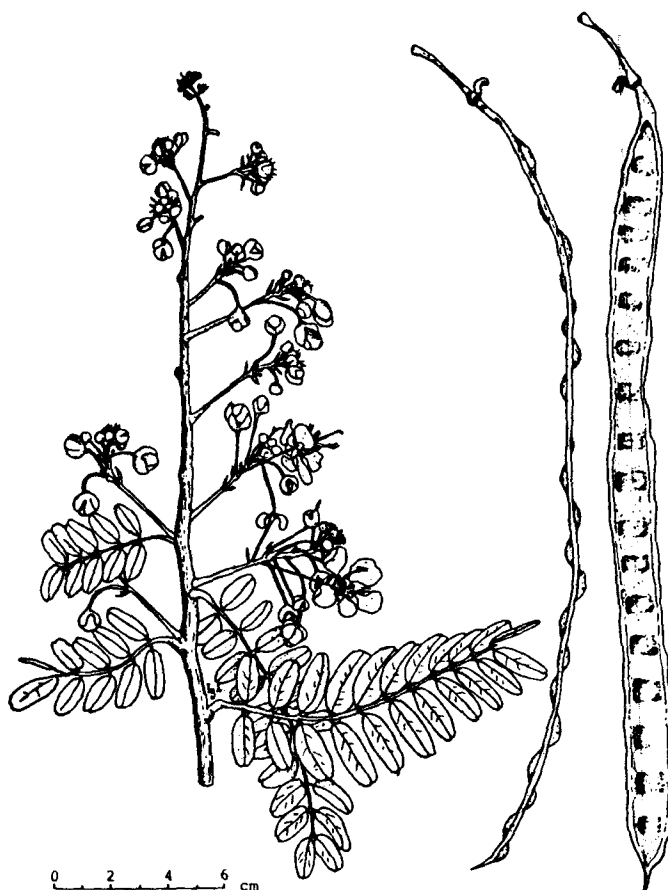


Figure 3.—Foliage and fruit of yellow cassia (*Senna siamea*) (reprinted from 36).

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soaking in cold or tepid water for 6 hours, or immersion in boiling water followed by cooling (13, 21, 30, 57).

Seed germination is commonly between 50 and 90 percent for fresh seeds, and generally occurs between 4 days and 6 weeks of sowing (30, 58). Seeds remain viable for several years when stored under dry conditions at ambient temperature (58).

The natural regeneration of yellow cassia is generally good beneath its own canopy or in mixed stands, provided there is sufficient light in the understory. In thick swards, however, natural regeneration is usually poor.

For nursery production, seeds may be sown directly into seedling containers or in open beds and transplanted to containers when seedlings are 7 to 10 cm in height (10). Seedlings are very sensitive to irrigation with saline water (0.6-9.0 mmhos) during the first 9 months (41), although plantations have been successfully raised in India using brackish water for irrigation (12). Seedlings generally reach plantable size from 6 months onward (10). Containerized seedlings raised in Nepal reached plantable size (average height: 25 cm; average root collar diameter: 2.6 mm) 12 weeks after sowing (60).

Plantations may be established by direct sowing, with containerized seedlings or stumped seedlings (seedlings whose tops have been clipped to 10 cm and roots to 20 cm) (10, 59). In seasonally dry locales, it is recommended that planting closely follow the onset of the rainy season. In parts of Africa and South Asia, where direct sowing has been used extensively, the recommended practice is to sow three to five seeds per tilled planting spot at a depth of 0.5 cm and at an initial spacing of 1.5 by 1.5 m (2, 16, 27, 55, 58). Plantations established by direct sowing are normally thinned during the second year to a density of 1,500 to 3,000 stems per hectare (55). In arid regions or on sites where rates of postgermination mortality are potentially high, the use of containerized seedlings is recommended over direct sowing (33).

Growth during the first year varies greatly among sites. Average seedling heights of 0.5 to 3.0 m are commonly reported in 1-year-old plantations in Central America, the Dominican Republic, and India (9, 11, 30).

Vegetative Reproduction.—After felling, yellow cassia coppices well for four or five rotations, producing two to five shoots per stump (12, 47, 64). Higher coppice yields are reportedly obtained when trees are felled at the end of the dry season (10). The tree also produces root suckers when damaged (58). Application of the growth regulators indolebutyric acid, naphthalene acetic acid, and indoleacetic acid reportedly enhance rooting and callus formation in cuttings (49). Anther tissue cultures have reportedly produced callus (19). The tree may be propagated by cuttings in the nursery, although survival tends to be low following outplanting (30).

Sapling and Pole Stage to Maturity

Growth and Yield.—Growth of yellow cassia is rapid. Mature trees are characterized by a straight trunk up to 30 cm in diameter at breast height (d.b.h.), smooth gray bark, and a rounded, irregular spreading crown of dense foliage. The lower trunks on older trees tend to be fluted. Average heights at maturity are approximately 18 m. Leaves are alternate, pinnately compound, 23 to 33 cm long, with slender

green and reddish-tinged axes. Each pinna is composed of 6 to 12 pairs of thin leaflets 3 to 7 cm long and 12 to 20 mm wide. The smoothed-edged leaflets are rounded at both ends with tiny bristle tips, shiny green and almost hairless upper surfaces, and gray-green lower surfaces covered with fine hairs. (35).

When managed as a fuelwood or pole crop, plantations are commonly established at spacings corresponding to between 1,000 and 3,000 stems per hectare (36, 55), although higher density plantings have been reported (11, 31). Plantations established for fuelwood production are usually harvested on rotations of between 5 and 10 years, depending on site conditions (26, 42).

Yellow cassia, planted in a mixture with Dominican mahogany (*Swietenia mahagoni* Jacq.) in the Luquillo Experimental Forest (Caribbean National Forest) of Puerto Rico on a site characterized by clay soils and an annual rainfall of 2250 mm, attained an average height of 9.2 m at 8 years.¹ Trees planted in nearby open, weedy slopes averaged 2.5 to 5.0 cm in d.b.h. and 4.6 to 6.2 m in height at 2 to 3 years. In two naturally regenerated yellow cassia stands in Puerto Rico, basal areas of 55.0 and 23.7 m²/ha were recorded for stands 12 years old and 25 to 30 years old, respectively. In the former stand, mean d.b.h. and mean height were recorded as 19.5 cm and 20.0 m; in the latter stand mean d.b.h. and mean height were 16.3 cm and 12.9 m. Mean d.b.h. and height data for selected plantations are presented in table 1.

A stem volume yield of 19.5 m³/ha per year was reported for a small-scale, 3-year-old planting at a site in the tropical dry forest zone of Colombia characterized by a mean annual precipitation of 1200 mm, an elevation of 1,030 m, and agricultural soils with a pH of 7.8 (43). Poorer yields of less than 2 m³/ha per year were reported in Burkina Faso for 7-year-old plantations established on a site receiving between 600 and 1000 mm of annual rainfall (54).

In a plantation established in Nigeria on a site characterized by shallow, gravelly sand loams, a mean annual rainfall of 1230 mm, and mean annual maximum and minimum temperatures of 31.4 and 21.4 °C, third rotation coppice yields (harvested 10 years after a previous cutting) were reported to be 85 t/ha, of which 71 percent was stemwood and 22 percent was branches (47). In West Bengal (India), aboveground biomass yields in 2.5-year-old, high-density (10,000 to 110,000 trees per hectare) fuelwood plantation trials reportedly ranged from 17 to 32 t/ha per year oven-dry weight (31). Average yields in similar trials, also conducted in West Bengal, reportedly ranged from 3 to 51 t/ha at 1.3 years (11). Elsewhere in India, total wood yields were reported as 7.2, 30.1, and 63.7 t/ha air-dry weight at 1, 2, and 3 years, respectively, in plantations established at a 1.4- by 2.7-m spacing (38). Weight tables using basal diameter as a predictor variable for both total aboveground biomass and total wood biomass have been reported (26).

Rooting Habit.—Yellow cassia produces a shallow, extensive lateral root system, and usually produces a deep taproot where local conditions permit (30). Like most members of the *Cassia* subgenus *Fistula* to which it belongs,

¹Data on file at the Institute of Tropical Forestry, Southern Forest Experiment Station, Rio Piedras, PR.

Table 1.—Growth of *Senna siamea* in selected plantations

Location	Rainfall mm/year	Soils	Tree spacing	Age Years	Mean tree height m	Mean d.b.h. cm	Reference
Central America* (12 sites)	600–1800	Well drained	2 by 2 m	2 3	1.5–5.5 3.0–8.0	..... † .....	(9)
Dominican Republic	740	Dry, compact, pH 6.8	2 by 2 m	2	5.0–5.5	.....	(30)
	1400	Rocky	2 by 2 m	2	5.0	.....
	2000	Compact	2 by 2 m	2	4.5	.....
	1900	pH 5.9	2 by 2 m	2	3.8	.....
	950–1000	Deep clay, pH 7.0–7.7	2 by 2 m	2	2.6–3.0	.....
	1200–2000	Shallow, eroded, infertile, pH 4.5–6.1	2 by 2 m	2	0.4–0.5	.....
Colombia	1200	pH 7.8	3 by 3 m	3	7.5	9.0	(42)
Fiji	.....	Deep, fertile	.....	3	4.6–6.2	.....	(42)
Tanzania	870	Sandy loams, poor in nitrogen and organic carbon	.....	2	4.6	6.5	(28)
Nigeria	.....	.....	1.8 by 1.8 m	10–12	≤15.0	10.0–12.0	(53)
West Bengal, India	.....	.....	0.3 by 0.3 to 1 by 1 m	1.3	1.1–4.3	.....	(11)

*Sites located in subtropical dry, subtropical moist, and tropical moist life zones of Costa Rica, Guatemala, Honduras, and Nicaragua. There were no consistent trends in growth rates among sites.

†... Data not available.

yellow cassia is reported to be a non-nodulating species and therefore does not form a symbiotic association with the nitrogen-fixing *Rhizobium* bacteria (1, 3, 34).

In 2-year-old plantation stands in Tanzania, characterized by a mean d.b.h. of 6.5 cm, a mean height of 4.6 m, and a density of 1,800 stems per hectare, fine root (<2 mm diameter) biomass to a depth of 100 cm was estimated to be 780 kg/ha oven-dry weight (28). The abundance of fine roots was greatest in the upper 20 cm of the soil profile and declined gradually with depth.

Root biomass was reported to comprise, on an average, 16 percent of the total biomass in 1.3-year-old plantations in India established at spacings ranging from 0.3 by 0.3 m to 1 by 1 m (11). Large lateral root (>5 cm diameter) and taproot biomass were estimated to be 35.8 and 15.2 t/ha, respectively, in 10-year-old third rotation coppice stands established at an initial spacing of 1.8 by 1.8 m. Total above-ground biomass in these stands was estimated to be 83.2 t/ha (47).

Reaction to Competition.—Yellow cassia is intolerant of shade and requires weeding during the first 1 or 2 years under plantation conditions (28, 55, 58). On shallow soils, it suffers greatly from competition with grasses, particularly *Imperata* and *Digitaria* spp. (55).

Although yellow cassia is often planted at densities as high as 100,000 trees per hectare in biomass plantations (11, 16, 31, 38), individual tree growth is greatly reduced under high-density conditions. It is therefore recommended that plantations for fuelwood and small timber production be established at densities between 1,000 and 3,000 stems per hectare (36, 55). In the savanna woodland zone of Nigeria, 4-year basal area growth of yellow cassia planted on a clear-felled area cultivated twice a year was greater for stands at 120 trees per hectare than for those at 240 trees per hectare (29), suggesting considerable root competition under moisture-limiting conditions.

Damaging Agents.—A number of insect pests have been reported to feed on the leaves, branches, and bark of yellow cassia in Puerto Rico, including the homopterans *Asterolecanium pustulans* Cockerell and *Saisetia oleae* Olivier, the isopteran *Nasutitermes costalis* Holmgren, and the lepidopteran *Megalopyge krugii* Dewitz (37). In Sri Lanka, extensive damage by the defoliating larvae of *Eurema blanda* Boisduval (Pieridae) has been reported (5). *Catopsilla pomona* Fabricius has been reported to cause some damage in China (22). Trees are reported to be generally resistant to termite attack (16, 55), although *Macrotermes* sp. and *Odontotermes* sp. have been cited as causing damage in parts of West Africa (51).

A large number of leaf pathogens have been reported (20, 40), although few are known to cause serious damage. *Cercospora cassiae-siameae* Chiddarwar and *Cochliobolus nodulosus* Luttrell have been reported to cause leaf-spot in India (40). *Oidium* sp., a powdery mildew, has been reported on yellow cassia in India (40). *Corticium salmonicolor* Berk. & Br., the cause of "pink disease," has been reported in Mauritius and Tanzania, and *Botrydiplodia theobromae* Pat. has been associated with bark necrosis of yellow cassia in Kenya, Uganda, and Tanzania (20). *Nectria haematococca* Berk. & Br. and other species of this genus have been reported to be associated with cankers and dieback in West Africa (20). Root pathogens reported to cause serious damage to yellow cassia plantations include *Armillariella mellea* (Fr.) Karst. in Uganda (20); *Ganoderma lucidum* (Leyss.) Karst. in India, Java, and Taiwan (20, 40, 66); *Polyporus baudoni* Pat. in Ghana and Tanzania (20); and *Phellinus noxius* (Corner) G.H.Cunn. in Ghana (20). Yellow cassia is reported to be susceptible to a vascular wilt caused by *Fusarium solani* (Mart.) Sacc. (53).

A number of rot fungi have been recorded from yellow cassia in Sierra Leone, including *Flavodon flavus* (Kl.) Ryv., *Nothopanus hygrophanus* (Mont.) Singer, *Trametes cotonea* (Har. & Pat.) Ryv., *Schizopora paradoxa* (Schröd. ex Fr.) Donk, and *Trametes meyenii* (Kl.) Lloyd (20). *Phaeolus manihotis* Heim. is reported as the cause of a serious root rot in yellow cassia in Ghana (46).

Parasitic plants reported on *S. siamea* in India and Sri Lanka include *Cuscuta reflexa* Roxb., *Dendrophthoe falcata* (L. f.) Ettingsh., and a *Tapinanthus* sp. (aff. *T. globifer* (Rich.) v. Tiegh) (20).

Young trees are occasionally subject to browsing by livestock and wildlife (35). Branches of mature trees are occasionally damaged in heavy winds, and the shallow lateral rooting habit makes the tree susceptible to windthrow (55).

SPECIAL USES

Yellow cassia is cultivated extensively as an ornamental and shade tree for crops such as coffee and cacao. It has also been grown in agroforestry systems in Nigeria and Tanzania as an alley crop with maize (28, 63) and as a fuelwood crop, interplanted with African millet (*Eleusine coracana* (L.) Gaertn.), castor bean (*Ricinus communis* L.), and cotton (*Gossypium* spp.) in India and West Africa (2). It is widely grown for hedgerows and windbreaks in arid regions (24, 25) and is used in India as a host for sandalwood (*Santalum album* L.), a parasitic tree (8, 12, 35). It is a useful species for reforestation of denuded hills and other degraded sites; it has been used successfully in northern Nigeria to reclaim abandoned tin mining sites (42).

The sapwood is light brown or whitish and rather thick. The heartwood is dark brown to nearly black, with dark and light streaks, hard, durable, and heavy with a specific gravity of 0.6 to 0.8 g/cm³ (12, 17, 35). The wood is used for posts, construction, mine props, furniture, and turnery (35). It is reportedly susceptible to attack by dry-wood termites in many localities (35, 36).

The wood makes an excellent but smoky fuel, with a relatively high caloric value of 5.8 kcal/g (12). Tannin has been extracted from the bark (35). Pulps prepared from yellow

cassia are reported to be either marginally suitable or unsuitable for paper production (23, 50, 65).

Yellow cassia is a major honey source in Venezuela (15). Flowers are sometimes an ingredient of curries (7). Foliage and fruits, while highly toxic to hogs (36), are reportedly a suitable source of fodder for sheep and cattle (35).

GENETICS

Until recently, yellow cassia was most commonly known as *Cassia siamea* Lam. Other botanical synonyms include *C. florida* Vahl., *C. sumatrana* Roxb. ex Hornem., *C. gigantea* Bert. ex DC, *Chamaefistula gigantea* (Bert. ex DC) G. Don, *Sciacassia siamea* (Lam.) Britton, and *Senna sumatrana* Roxb. (7, 32, 37, 56). The species is sometimes confused with *Cassia surattensis* Burm. f., which has shorter and sometimes obovate leaflets and a stalked gland on the rachis between the two most basal sets of leaflets (6). Related species that are currently receiving attention as sources of fuelwood and small timber are *C. marginata* Roxb., widely grown in Haiti, and *C. spectabilis* DC., a species native to Central America and northern South America (42). Both species share yellow cassia's rapid growth and vigorous coppicing characteristics. The haploid chromosome number of yellow cassia is 14 (19, 52).

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