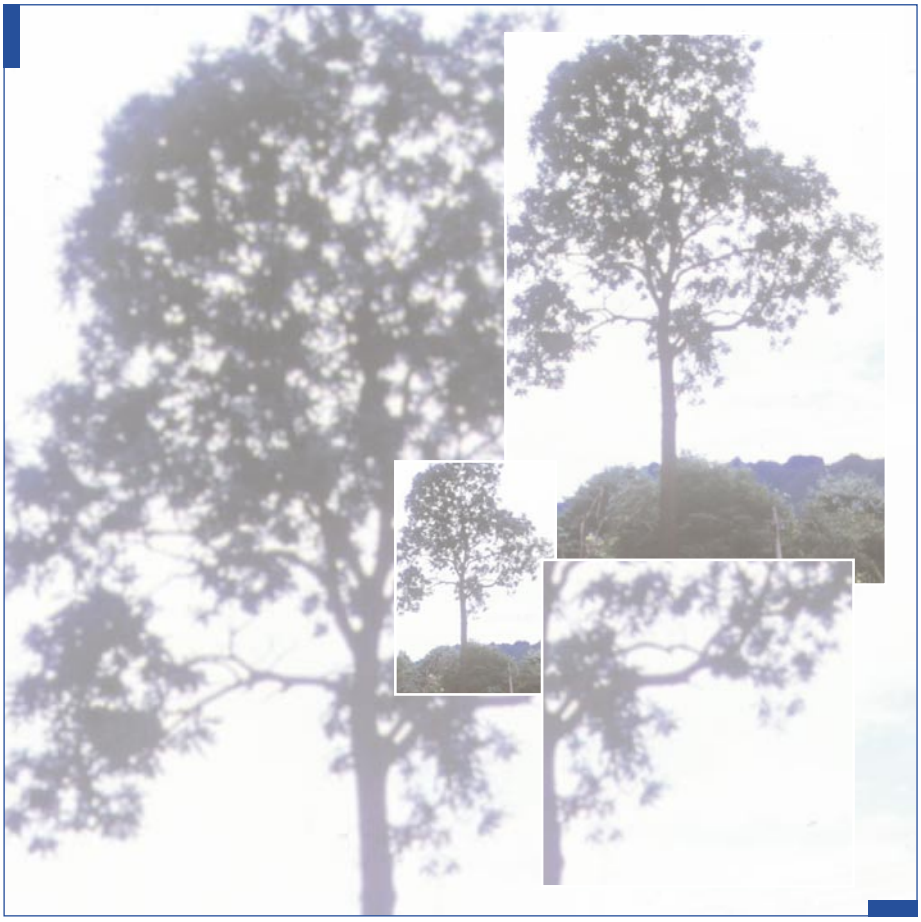
Chukrasia: Biology, Cultivation and Utilisation



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Chukrasia: Biology, Cultivation and Utilisation

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Contents

Preface

This technical report on *Chukrasia* has been prepared as part of ACIAR forestry project FST/1996/005, 'Development of domestication strategies for commercially important species of Meliaceae'. The information is derived from existing literature and personal communications, as well as observation by the authors.

Many individuals and institutions have generously assisted in its preparation. We particularly thank to the following:

In Vietnam, Prof. Dr Le Dinh Kha and Dr Nguyen Ba Chat of the Forest Science Institute who provided information on natural distribution and utilisation aspects. Dr Ha Huy Thinh and Mr Phi Quang Dien translated a major publication from Vietnamese to English.

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1. Introduction

Chukrasia A. Juss. is a valuable multipurpose tree genus, distributed mainly in South and Southeast Asia. The timber is highly prized for high-grade cabinet work, decorative panelling, furniture, musical instruments, interior joinery such as doors, windows and light flooring, sporting goods and for carving. It is also used for railway sleepers, ship and boat building, packing boxes and general construction. Flowers contain a red and yellow dye, bark and leaves contain commercial gums and tannins and the astringent bark has medicinal uses. It has many trade names: bastard cedar, Burma almondwood, chicrassy, Chittagong wood, East Indian mahogany, Indian red wood, white cedar, yinma, yomhin and surian batu (Ho and Noshiro 1995; Mabberley and Pannell 1995).

Chukrasia is a priority tree for plantation forestry and genetic conservation in many tropical countries including China, Laos, Malaysia, Myanmar, Thailand and Vietnam. It is relatively fast growing and easily propagated. It has been tried successfully in plantations in Australia, China, India, Myanmar, South Africa, Sri Lanka and Vietnam. It has been planted as a shade tree for coffee plantations in India (Rai 1985), and is being domesticated as an agroforestry tree in China, Sri Lanka and Vietnam (Nguyen Hoang Nghia 1996; Bandara 1999; Zeng 1999a).

Information available on *Chukrasia* is mainly on taxonomy, wood properties and uses, with less on silviculture and genetic improvement, although Nguyen Ba Chat (1996) recently reported results of his research on the silviculture of *Chukrasia tabularis* A. Juss. in Vietnam. The existing literature is published in various languages, especially Chinese, English, French and Vietnamese. In addition, there is a considerable number of unpublished reports. These publications are often scattered and difficult to locate. This review brings together available information and identifies research needed for sustainable use of the genus.

This monograph is one of several joint research activities on *Chukrasia* in a collaborative project, ‘Development of domestication strategies for commercially important species of Meliaceae’, partially funded by the Australian Centre for International Agricultural Research (ACIAR). Other collaborative activities currently underway include surveys of natural occurrence, seed collection, studies on reproductive biology and investigation of genetic variation in seedling morphology and isozymes, and field provenance trials in Laos, Malaysia, Thailand and Vietnam.

2. Biology

Nomenclature

The genus *Chukrasia* belongs to the Meliaceae family. It is a member of the subfamily Swietenioideae within the tribe Swietenieae Benth. & Hook., which includes other important genera such as *Entandrophragma*, *Khaya*, *Lovoa* and *Swietenia* (Pennington and Styles 1975; Mabberley and Pannell 1995). The name of the genus is adapted from the Bengali name, chikrassee (Mabberley and Pannell 1989).

Chukrasia A. Juss. is a distinctive genus comprising one or possibly two species: *C. tabularis* A. Juss. and *C. velutina* (M. Roemer) C. DC. (de Candolle 1878; Brandis 1921; Pennington and Styles 1975; Mabberley and Pannell 1995). The former name is derived from the Latin *tabularis* (flattened), in reference to the flat seeds (Mabberley and Pannell 1989). The latter name is derived from the Latin velutinus in allusion to the fine short erect hairs on the leaves. Both taxa are recognised in Sri Lanka (Bandara 1999) and Thailand (Smitinand 1980). Some botanists, however, consider *C. velutina* to be a variant of *C. tabularis* (Ho and Noshiro 1995). Mabberley and Pannell (1995) reported that ecotypes might exist in seasonal forests.

Chukrasia tabularis was first collected in India and the description by A. de Jussieu in 1830 (Anon. 1830) is given here verbatim:

> "Calyx short, 5-toothed. Petals 5, erect. Stamen-tube cylindric-oblong, 10-crenated filaments, the crenatures each bearing one terminal anther. Anthers exerted, erect. Style short, thick, scarcely distinct in appearance from the ovary. Stigma capitate, 3-lobed upwards. Ovary oblong, seated on a short disk, 3-celled, ovules numerous in each cell. Fruit…*Chukrasia tabularis*: tall tree, pinnate leaves, leaflets sub-opposite. Panicles terminal."

A more comprehensive description of *Chukrasia* species was given by de Candolle (1878) and Pellegrin (1908). On the basis of leaf structure, leaf pubescence and floral characteristics, Kurz (1873) and de Candolle (1878) treated *Chukrasia* as two separate species, namely *C. tabularis* and *C. velutina.* However, based on the same traits Pellegrin (1908) maintained one species (i.e. *C. tabularis*) with four different varieties (*attopeuensis* Pierre, *velutina* King, *microcarpa* Pierre and *dongnaiensis* Pierre). Anon. (1930) suggested that if two taxa were to be recognised, they should be known as *C. tabularis* A. Juss. and *C. nimmonii* Graham ex Wight.

Since then, there have been various descriptions of the genus with different species names. Mabberley and Pannell (1995) made the most recent revision and provided a comprehensive list of synonyms of *C. tabularis* A. Juss. (Table 1). The local names given to *Chukrasia* in its natural range are listed in Table 2. The holotype specimen is currently held by the Musée d' Histoire Naturelle de Paris, France.

Clarification

In this monograph the generic name '*Chukrasia*' is used throughout in reference to either or both species of the genus *Chukrasia*. The specific names *Chukrasia tabularis* and *Chukrasia velutina* are used where particular reference is made to the respective species.

Table 1. Synonyms of *Chukrasia tabularis* A. Juss.

Synonym	Reference
Swietenia trilocularis [Roxb. ex Buch.-Ham]	Journey Madras 1: 184. 1807
Cedrela sp. Wall.	Num. List n. 4892. 1831/2
Swietenia sotrophola Buch.-Ham. ex Wall	Num. List 214, n. 1269. 1831/2
Swietenia chikrassa Roxb.	Fl. Ind. 2: 399. 1832
Chickrassia tabularis (A. Juss.) Wight & Arn.	Prod 1: 123. 1834
Chikrassia nimmonii R. Graham ex Wight	Ind. Bot. 148. 1840
Chikrassia trilocularis (G. Don f.) M. Roemer	Fam. Natur. Monogr. 1:135. 1846
Chikrassia velutina M. Roemer	Fam. Natur. Monogr. 1:135. 1846
Sapindus multijugus Wall.	Num. List n. 8099. 1847
Chikrassia tabularis var. *b*, Thw.	Enum. Pl. Zeyl. 61. 1858
Melia tomentosa sensu Kurz	Rep. Andam. Vi. 1867
Swietenia villosa Wall. ex Kurz	J. Asiat. Soc. Bengal 42, 2: 65. 1873
Swietenia velutina Wall. ex Kurz	J. Asiat. Soc. Bengal 42, 2: 65. 1873
Chukrasia velutina (M. Roemer) C. de Candolle	In de Candolle & de Candolle, Mon. Phan. 1: 727. 1878
Chukrasia velutina var. *macrocarpa* C. de Candolle	In de Candolle & de Candolle, Mon. Phan. 1: 727. 1878
Chikrassia tabularis var. *genuina* Theob.	In Mason, Burma, ed. 3, 2: 586. 1883
Chikrassia tabularis var. *velutina* (M. Roemer) Theob.	In Mason, Burma, ed. 3, 2: 586. 1883
Plagiotaxis chickrassa [Wall. ex] Kuntze	Rev. Gen. Pl. 1: 110. 1891
Plagiotaxis velutina [Wall. ex] Kuntze	Rev. Gen. Pl. 1: 110. 1891
Chukrasia tabularis var. *attopeuensis* Pierre	Fl. For. Cochinch. 5: t. 357C. 1896
Chukrasia velutina var. *dongnaiensis* Pierre	Fl. For. Cochinch. 5: t. 357C. 1896
Chukrasia velutina var. *microcarpa* Pierre	Fl. For. Cochinch. 5: t. 357C. 1896
Chukrasia tabularis var. *velutina* (M. Roemer) Pellegrin	In Lecompte, Fl. Gén. Indochine 1: 780. 1911
Chukrasia tabularis var. *dongnaiensis* (Pierre) Pellegrin	In Lecompte, Fl. Gén. Indochine 1: 780. 1911
Chukrasia tabularis var. *microcarpa* (Pierre) Pellegrin	In Lecompte, Fl. Gén. Indochine 1: 780. 1911
Dysoxylum esquirolii Lévl	Cat. Pl. Yunnan 176: 1916
Chukrasia nimmonii (R. Graham ex Wight) Merr. & Chun	Sunyatsenia 1: 61. 1930
Chukrasia tabularis var. *quadrivalvis* Pellegrin	In Lecompte, Fl. Gén. Indochine suppl. 721. 1946
Chukrasia chickrassa (Roxb.) Schultze-Motel	Kulturpfl. Beih. 4: 209. 1966

Table 2. Local names of *Chukrasia* in countries of natural occurrence

Country	Local name	References
Cambodia	Voryong	Ho and Noshiro 1995
China	ma lian, mau ma lian, Vietnam ma lian	Wang *et al.* 1992
India	boga poma, bogipoma, chkrasi, pabba, dalmara, uruli, paruli, lal devadari, malaveppu, madagirivembum, agal, malei-veppu, agil kullimatti vedivembu, madagari vembu kindavepa, akil chuvannagil	Bourdillon 1908; Brandis 1921, Anon. 1974
Indonesia	ingol batu	P. Clegg, Raja Garuda Mas International Forest Service, Indonesia 2000 pers. comm.
Laos	mai nhom, nhom hin, nhom kok	Vidal 1962; Samountry 1999
Malaysia	surian batu, cherana puteh, repoh, suntang puteh	Desch 1954; Ng 1992; Appanah and Weinland 1993; Ho and Noshiro 1995; Rasip and Kassim 1999
Myanmar	yinma, tawyinma, kinthatputgyi	Brandis 1921; Ho and Noshiro 1995
Sri Lanka	hulan hik, hiri kita, kaloti	Mabberley and Pannell 1995; Bandara 1999
Thailand	*C. velutina:* khoyong, cha ka dao, yom khaao, yom hin, ma fueang chaang, sadao hin, ring-baong, ree, siat khaang; *C. tabularis:* fak daap, waa-raa-yong, siat kaa	Smitinand 1980; Ho and Noshiro 1995
Vietnam	lat hoa, lat da dong, lat chun	Ho and Noshiro 1995; Nguyen Ngoc Chinh et al. 1996; Le Dinh Kha and Phi Quang Dien 1999

Botanical Description

Most botanical descriptions of *Chukrasia* species appear to refer to *C. tabularis* although some may also apply to *C. velutina*. Anon. (1830), Wight and Walker-Arnott (1834), Hooker (1875), de Candolle (1878), Pellegrin (1908), Troup (1921), Pennington and Styles (1975), Ho and Noshiro (1995) and Mabberley and Pannell (1995) have all provided a botanical description of the genus. It appears that the three last publications refer to those that had been published prior to Troup (1921).

The following botanical description has been extracted from the above literature, with additional information on the bark, leaves, capsule and seed being taken from field observations on trees growing in China, Thailand and Vietnam. An intensive study in Canberra on seedlings raised from seed collected from 24 locations in nine countries has also added new information on juvenile and mature leaves.

The leaves, flowers, fruit and seeds of *C. tabularis* are illustrated in Figure 1.

Tree

Chukrasia is a medium to large tree up to 40 m tall, with a bole branchless for up to 25 m and reaching over 120 cm in diameter at breast height. The stem is generally straight with large convex buttresses to 150 cm from ground. *Chukrasia velutina* is smaller than that of *C. tabularis.*

The bark is brown to dark brown in colour, smooth in seedling becoming fissured vertically and scaling or cracking into rectangular blocks with age. The inner bark is red-brown or pinkish; sapwood straw; heartwood yellow to reddish brown.

Chukrasia trees growing naturally in Thailand show two distinctive bark types (Fig. 2). The bark of trees which occur in mixed deciduous forest is more deeply fissured and corky than that of those which occur in semi-evergreen forest. The deeply fissured bark type is known locally as *C. velutina.* The smoother bark type is similar to that generally described for *C. tabularis.*

Foliage

Chukrasia develops both pinnate and bipinnate leaves (Fig. 3). The first 7–9 leaves are pinnate with terminal spike. As the seedling grows, the leaves become either paripinnate with terminal spike, imparipinnate or bipinnate, 30–50 cm long at maturity. The paripinnate and imparipinnate forms are commonly associated with the less pronounced fissured bark characteristic (i.e. *C. tabularis* type) while the bipinnate form is associated with the more pronounced fissured bark characteristic (i.e. *C. velutina* type). Some mature trees may also develop both bipinnate and pinnate leaves (i.e. trees in Kanchanaburi province, Thailand).

Leaflets are deeply lobed to laciniate in juveniles. Mature leaflets are very variable in shape from obliquely ovate to oblong, more or less asymmetric or even falcate; base obtuse to rounded distally; apex acute to acuneate. Subglabrous adaxially; numerous long pointed and simple hairs abaxially with foveola (small pits) in axils between the midrib and secondary veins. There is also another type of hair which is less numerous, robust and multicellular with blunt rounded ends (similar to raised oil glands) scattered on both sides of leaves but more abaxially (Fig. 4). There are 6–20 pairs of entire leaflets arranged alternately but the first two pairs are opposite, the subapical the largest 10–17.5 × 3.5–6.5 cm, the most proximal as small as 4 × 2.2 cm, petiolules 2–8 mm long.

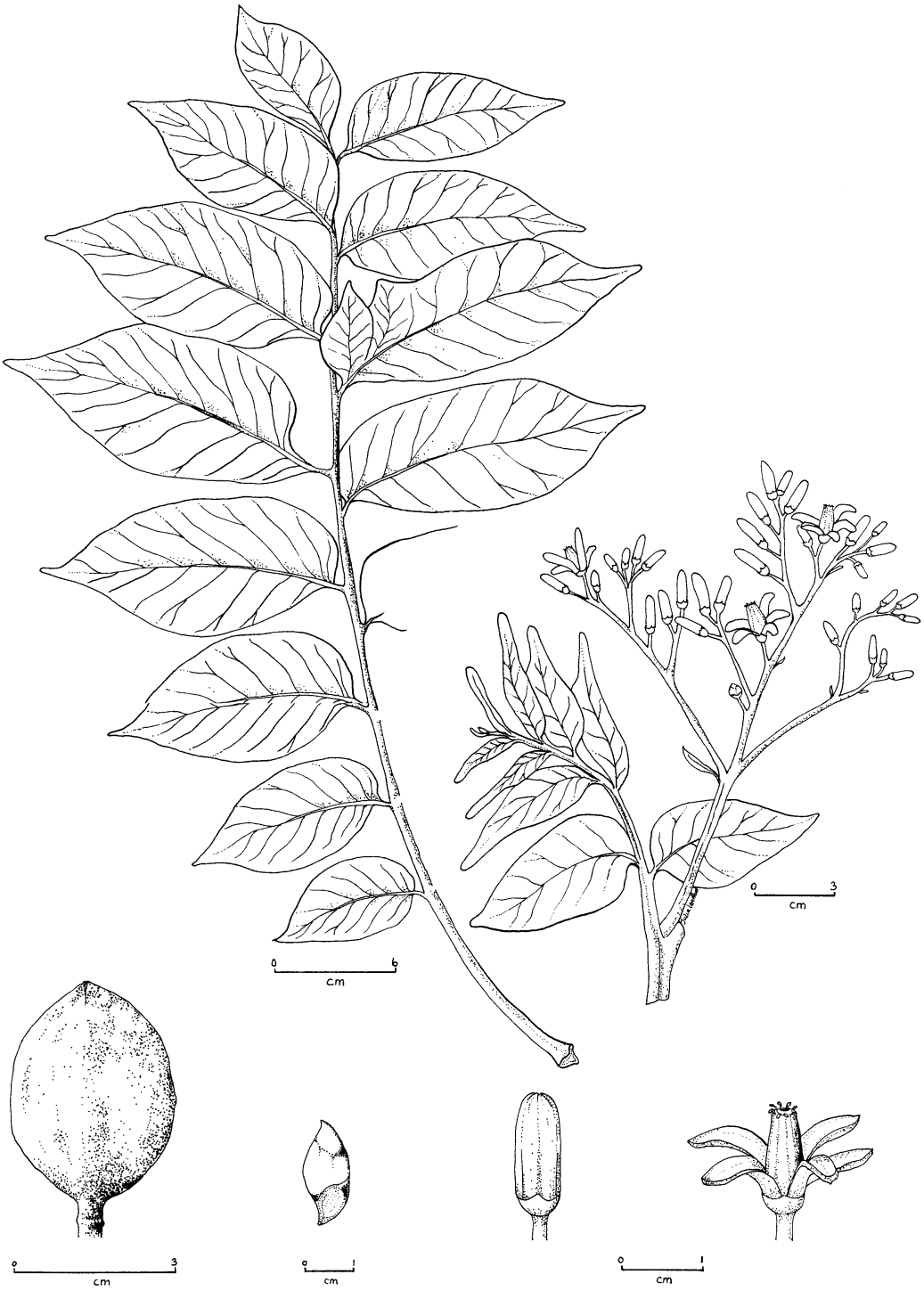

Figure 1. Chukrasia. *A, mature leaf (*C. tabularis, *Hoa Binh, Vietnam); B, inflorescence; C, capsule: D, seed; E, flowering bud; F, open flower.*

Figure 2. *A mature* Chukrasia *tree in Kanchanaburi, Thailand (left) has more deeply fissured bark than that in Moc Chau, Vietnam (right).*

Figure 3. Chukrasia *develops pinnate leaves (sample from Hoa Binh, Vietnam) and bipinnate leaves (sample from Lampang, Thailand).*

Inflorescence

Thyrses in axils of youngest leaves so as often to appear terminal, 10–30 cm long; primary branches to 16 cm, secondary to 4 cm, bearing fascicles of sweetly-scented flowers.

Flowers c.1.5 cm long, unisexual or bisexual. Axes short-pubescent; bracts 2–7(–10) mm, narrowly triangular, often caducous, bracteoles similar but smaller; pedicels 3–4 mm, articulated with pseudopedicels 2 mm long, continuous with calyx. Calyx green, pink or red; 4–5 lobes, 2.5–3.5 mm diameter; lobes obtuse. Petals 4 or 5, free, contorted and much longer than calyx in bud, reflexed in open flowers; 12–20 mm long, narrowly oblong to subspathulate, creamy green or yellowish, often tinged pink, subglabrous or puberulous. Staminal tube broadly cylindrical, somewhat narrowing distally, margin entire to crenulate; anthers attached to margin; glabrous, colour as petals; anthers 1 mm long, oblong. Disc in male flowers stipitate, scarcely distinguishable from the base of the pistillode; in female flowers narrowly cushion-shaped. Ovary flask-shaped, 3–5-locular, each locule with numerous ovules; style slender; style-head capitate with 3–5 stigmatic ridges; densely pubescent. Pistillode scarcely distinguishable from the pistil; loculi and rudimentary ovules well-developed.

Fruit (capsule) woody, brown, ovoid or ellipsoid, 2.5–5 cm long and 1.8–4 cm diameter, slightly mucronate at tip, dehiscent by 3–5 valves from the apex, the valves splitting into an outer and inner bifid layer; columella with 3–5 sharply angled ridges, extending to apex of capsule; seed-scars conspicuous.

Seeds flat with a brown membranous wing twice the length of the seed, the whole 0.8–1.8 cm long and 0.4–1.0 cm wide; 60–100 per locule arranged in layers, alternately head to toe.

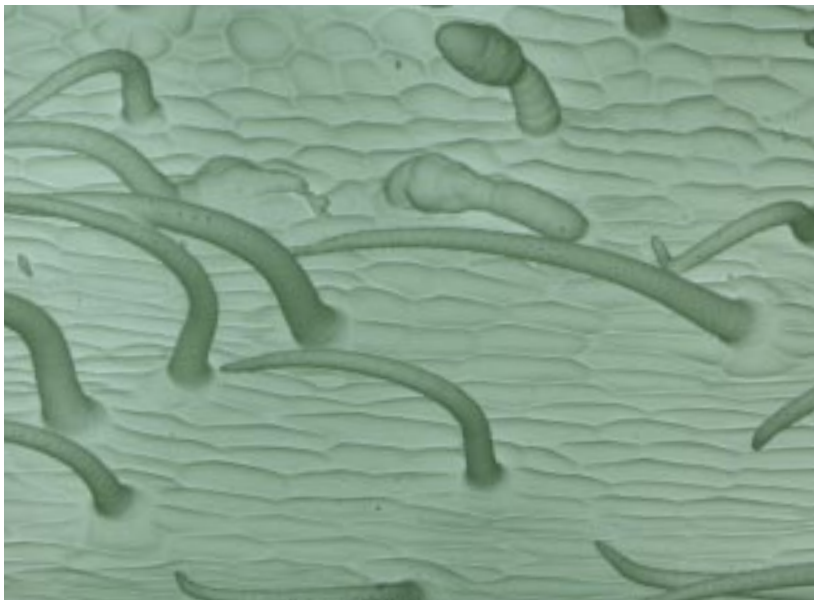

Figure 4. *SEM photo (× 280) on the abaxial side of a* Chukrasia *leaf from Ledagyi Leway, Myanmar reveals two types of hair.*

Distribution

Natural occurrence

Chukrasia is usually found scattered in evergreen dipterocarp rainforest, moist semi-evergreen forest and mixed deciduous forest at altitudes from 20 m to 1450 m asl. The natural distribution extends from India, Sri Lanka and the east and southeast of southern China to Indochina, Myanmar, Thailand, Peninsular Malaysia (not in the south) and Sarawak, Sumatra (north but rare) and the western tip of Borneo (West Kalimantan, Indonesia) (Fig. 5) (Anderson 1980; Ho and Noshiro 1995; Mabberley and Pannell 1995; P. Clegg, Raja Garuda Mas International Forest Service, Indonesia 2000 pers. comm.). This natural distribution range lies between latitude 1° and 25°N and longitude 73° and 120° E. The species is also believed to occur in Bangladesh, Nepal and Pakistan (Mabberley and Pannell 1995). However, Sahibzada Hafeez (Punjab Forestry Research Institute 1997 pers. comm.) confirms Chukrasia is not native in Pakistan.

In India, *Chukrasia* occurs in Assam, Arunachal Pradesh, West Bengal, Andaman Islands and in the Indian Peninsula, mainly on the Western Ghats. It also extends to Konkan, in North Kanara (Karnataka), the Sandur Hills in Bellary and in Salem (Tamil Nadu) and in Cuttack (Orissa) (Anon. 1974). The main occurrence is about 180 m asl although some protected trees around temple groves stand at altitudes above 700 m in Madras (Streets 1962).

In Sri Lanka, the species occurs at Kandy, Deltota Hanguranketha, Randenigala, Mahiyangane, Monalegala, Koslanda towards Kaltota, Balangoda, Polonnaruwa, Habarana, Anuradapura and in Ampara areas (Bandara 1999). The altitudinal range is from 150 m to 1000 m.

In China, *Chukrasia* is distributed below 750 m asl mainly in Guangdong, Hainan and Guangxi provinces. In Guangdong, it occurs at Lianxian, Ruyuan and Yangjiang Counties. In Hainan province, it occurs in Changiang, Baisha, Baoting, Lingshui and Yaxian Counties (Zeng 1999b).

In Vietnam, *Chukrasia* occurs mainly in the northern and central parts of the country from an altitude of 20 m to 1450 m in the provinces of Hoa Binh, Son La, Vinh Phu, Tuyen Quang, Thai Nguyen, Lang Son, Cau Bang, Gia Lai, Nghe An and Ha Tinh (Nguyen Ba Chat 1996; Nguyen Ngoc Chinh *et al.* 1996).

The occurrence in Laos is mostly at altitudes 700–800 m in the northern provinces of Luangprabang, Oudomxay, Luangnamtha, Phongsaly and Xayabury (Vidal 1960; Samountry 1999).

In Thailand *Chukrasia* occurs almost throughout the country, except in the far south, at altitudes 180–550 m. Specimens have been noted in Chiang Mai, Kanchanaburi, Kamphaengphet, Khon Kaen, Lam Pang, Mae Hong Sorn, Phitsanulok, Prachuap Khiri Khan, Ratchaburi, Tak, Uthai Thani and Uttaradit (Wasuwanich 1999).

In Myanmar, it is found in Moeswe Pyinmana, Ledagyi Leway, Popa Kyaukpadaung and Khin Aye Pale. The altitude of these areas is from 150 m to 220 m.

In Malaysia, *Chukrasia* is confined to the northern states in Peninsular Malaysia. It is found in Sarawak in the limestones areas (Anderson 1980; Appanah and Weinland 1993; Mabberley and Pannell 1995; Rasip and Kassim 1999; K. M. Aken, CSIRO Forestry and Forest Products 2000 pers. comm.). Its presence in Sabah cannot be confirmed (Mabberley and Pannel 1995). The altitudinal range is 300–800 m.

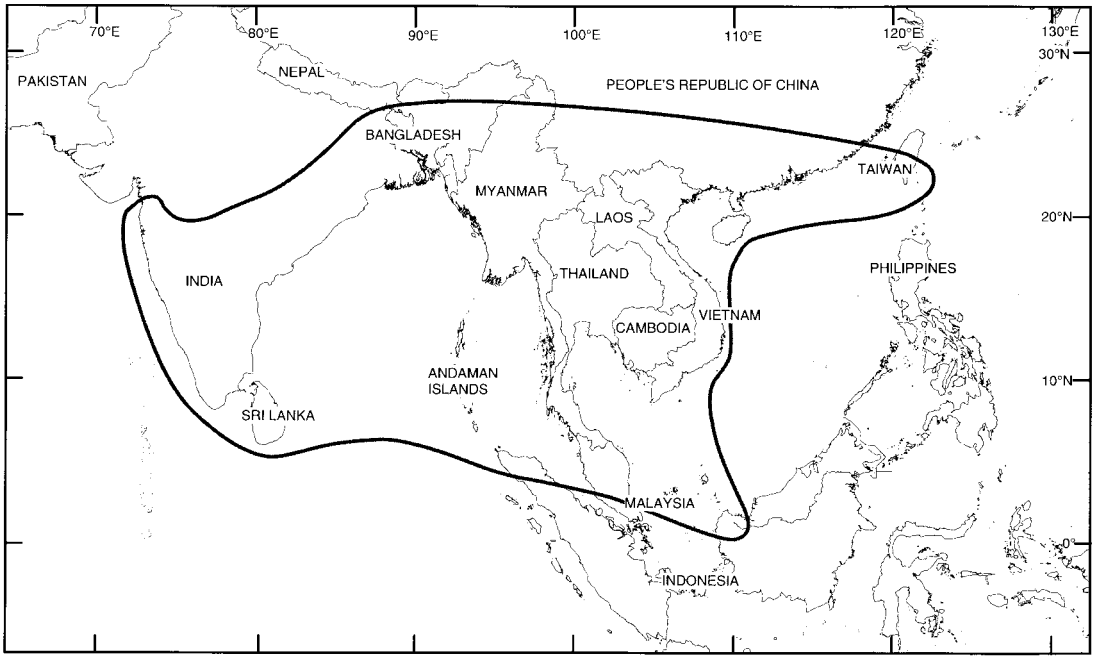

Figure 5. *Natural distribution range of* Chukrasia.

Location of introductions

Chukrasia has been introduced to many countries outside its natural range where it is grown as a timber tree. It has been tested in Africa (Cameroon, Nigeria and South Africa) and in Central America (Puerto Rico and Costa Rica) (Streets 1962; Ho and Noshiro 1995). Small plantations can be found in Hawaii, South Africa and in countries of natural occurrence. In Australia, it is an aggressive species that produces large seed crops and may form pure stands in disturbed forest. It has become naturalised on parts of the Atherton Tablelands where it was initially established in plantations (Hyland and Whiffin 1993).

Ecology

Climatic requirements

Rainfall

Over most of its natural distribution, *Chukrasia* occurs in areas with a mean annual rainfall of 1100–3800 mm with a few dry months (Streets 1962; Anon. 1974; Ho and Noshiro 1995; Mabberley and Pannell 1995; Wasuwanich 1999). In Sri Lanka, Bandara (1999) reported that *C. tabularis* occurs in areas with high rainfall (1500–1750 mm per year) and *C. velutina* in areas with annual rainfall less than 1500 mm. Some areas in Myanmar (e.g. in Yezin) where Chukrasia is distributed have a mean annual rainfall around 1000 mm (C. Harwood, CSIRO Forestry and Forest Products 2000 pers. comm.).

Temperature and humidity

In the natural range the mean annual temperature lies between 14° and 27°C. In Vietnam, Nguyen Ba Chat (1996) and Le Dinh Kha and Phi Quang Dien (1999) reported the mean annual maximum temperature range to be 18.9–32.4°C and the mean annual minimum temperature range 12.7–23.2°C. The absolute minimum temperature is –3°C and the absolute maximum shade temperature is 42°C (Anon. 1974; Nguyen Ba Chat 1996; Le Dinh Kha and Phi Quang Dien 1999). The coldest area in Vietnam where *Chukrasia* occurs is Sapa, Cau Bang which is 1500 m asl. Although the species can tolerate temperature below zero degrees, some damage to leaves and young terminal buds may occur. The seedlings are less damaged by frost than might be expected in a tropical species (Troup 1921; von dem Bussche 1982a,b).

In India, the mean relative humidity in January varies from 45% to 90% and in July from 70% to 100% (Anon. 1974). In Vietnam, it varies from 78% to 85% in July to less than 20% in December–January (Nguyen Ba Chat 1996).

Light

Chukrasia is light-demanding. However, young seedlings in natural regeneration may tolerate some degree of shading. It is a dominant tree occurring mostly in the top canopy in natural forests (Anon. 1974; Nguyen Ba Chat 1996).

Soil requirements

The soils on which *Chukrasia* occurs are red-yellow, brown-red and brown-yellow derived from basalt, limestone, schist and mica schistose. It is most common on limestone (Ho and Noshiro 1995; Nguyen Ba Chat 1996). The species is usually found on deep, fertile and well-drained soils in the plains and on the hills (Anon. 1974; Nguyen Ba Chat 1996; Le Dinh Kha and Phi Quang Dien 1999). These soils have a good ability to retain moisture, having 3–4.7% humus in the surface layer; 0.1–3% nitrogen, 7–11 mg/100 mg soil for P2O5, and 4–10.5 mg/100 mg soil for K2O. It does not grow well where hard pans underlay lateritic soils or on barren hills. It is usually absent from heavy-textured and waterlogged soils.

Phytosociology

Chukrasia is a gregarious species capable of invading gaps in the forest. It is common in former shifting cultivation areas and occasionally occurs as a colonist of bare land, including road cuttings (Appanah and Weinland 1993; Ho and Noshiro 1995).

In Vietnam, the most common associates of *Chukrasia* include species of *Aglaia, Artocarpus, Cinnamomum, Dillenia, Elaeocarpus, Erythrophloeum, Garcinia, Gironniera, Knema, Litsea, Markhamia, Parapentace, Pasania, Styrax* and *Vatica* (Nguyen Ba Chat 1996; Le Dinh Kha and Phi Quang Dien 1999). In Thailand common associates are species of the genera *Anogeissus, Berrya, Erythrina, Dillenia, Garuga, Haldina, Kydia, Lagerstroemia, Pterocarpus, Tectona, Terminalia, Vitex* and *Xylia* (Wasuwanich 1999).

Vidal (1960) reported a detailed study in Laos where *Barringtonia, Canarium, Cratoxylon, Crypteronia, Dillenia, Holarrhaena, Sapium, Shorea, Sterculia, Vitex* and *Wrightia* species are associates of *Chukrasia* in secondary rainforest. In the mixed-deciduous forest, most common associates are species of *Bombax, Dracaena, Lagerstroemia, Pahudia, Parkia, Pterocarpus* and *Tetramyxis.* In the rain forest,

Arenga, Aphanamyxis, Artocarpus, Cananga, Capparis, Chisocheton, Diospyros, Elaeocarpus, Eugenia, Ficus, Garcinia, Haplophragma, Hymenodictyon, Lagerstroemia, Miliusa, Nephelium, Polyalthia, Pometia, Protium, Terminalia, Tetrameles, Trewia, Sapindus, Schleichera and *Xerospermum* species are common associates.

Qualitative aspects of development

Seedling development

Germination is epigeal. The leafy cotyledons are unequal-sided. The radicle emerges from the end of the seed opposite to the wing; the hypocotyl arches slightly at first and in straightening raises the cotyledons above ground.

The seedling primary root is moderately long, terete, tapering and wiry. Lateral roots are moderately long and numerous, fibrous and well distributed down the main root. Juvenile leaflets are deeply lobed, becoming entire when mature (Fig. 6). Seedlings start to develop mature leaves 5–6 months after germination by which time they have developed about 18 leaves (range 14–26). Observations of seedlings raised under glasshouse condition revealed that sources from countries such as China, Laos, Malaysia and Vietnam (referred to as *C. tabularis*) develop mature leaves earlier than those from Myanmar and Thailand (referred to as *C. velutina*).

Figure 6. *Four-month old* Chukrasia *seedlings from sources in Sri Lanka (Higurukaduwa) and China (Jianfengling).*

Development of the tree

Young saplings tend to develop a small and sparse crown. As the tree grows the crown becomes deeper and denser but still maintain a good length of branchless bole. Mature trees usually have a clear bole for more than half of total height. The development of a clear bole indicates good natural pruning. However, in plantations *Chukrasia* trees tend to have coarse branching and produce epicormic shoots which may require early pruning (Nguyen Ba Chat 1996).

Deciduous habit

Chukrasia trees are typically deciduous. In the cooler parts of its range it is usually leafless during the winter, when conditions are dry and cool. In Vietnam it sheds its leaves during the early winter months in November to December (Nguyen Ba Chat 1996). New flushes of leaves can be seen towards the end of the dry season, e.g. in March in Thailand. There are reports of the trees being evergreen in India (Troup 1921; Anon. 1974).

Flowering and fruiting

The age to first flowering of *Chukrasia* is 5–6 years. The flowering pattern is very irregular and varies from country to country (Table 3). The frequency of flowering and fruiting in *Chukrasia* is unknown but trees in Laos appear to produce a good seed crop every second year. About six months elapse from flowering to seed maturity (Nguyen Ba Chat 1996). Once the fruit capsule has dehisced the winged seed is disseminated by wind. The empty capsules hang for some time on the tree after opening, and can be easily seen when trees are leafless. Eight kilograms of fruit yield one kilogram of clean seed (Anon. 1974). The number of seeds per kilogram ranges from 71 000 to 160 000. The Australian Tree Seed Centre recorded an average viability of 64 000 seeds kg^{-1} from tests conducted after recent range-wide provenance collections of the species.

Table 3. Times of flowering and fruit maturation of *Chukrasia* in its natural range

Country	Flowering time	Fruit maturation	References
Cambodia	July	December–February*	Pellegrin 1908
China	March–June	August–January	Su *et al.* 1994; Zeng 1999b
India	April–May	December–March	Bourdillon 1908; Troup 1921; Anon. 1974
Indonesia	July–August*	March	Clegg, Raja Garuda Mas International Forest Service, Indonesia 2000 pers. comm.
Laos	May–June	November–January	Samountry 1999
Malaysia	June–August*	January–March	Ho and Noshiro 1995
Sri Lanka	April–May	November–January	Alston 1938; Bandara 1999
Thailand	June–August	January–March	Anon. 1980; Ratanaporncharoen, Royal Forest Department 1999 pers. comm.
Vietnam	April–July	November–January	Nguyen Ba Chat 1996; Le Dinh Kha and Phi Quang Dien 1999

Notes: * indicates that these times are estimated

Genetic Variation and Breeding

Until recently there was little systematic work on genetic variation or breeding of *Chukrasia*. The only evidence of such past work appears to be a germplasm bank and a seed orchard of 25 clones in India (Beniwal and Singh 1990). In cytological studies, somatic counts revealed chromosome numbers of 2n = 26 (Khosla and Styles 1975; Mabberley and Pannell 1995). No intraspecific chromosomal races for *Chukrasia* have been reported.

Since 1999, systematic studies of genetic variation in *Chukrasia* species have been undertaken through a research project coordinated by CSIRO Forestry and Forest Products, Australia with collaborators in Laos, Malaysia, Thailand and Vietnam. These studies include establishment of provenance trials with seed collected from throughout the species' natural distribution, observations of seedling morphology to determine geographic variation, and isozyme assay to determine the level and distribution of genetic variation. Few results are available yet, but early data from Vietnam showed considerable variation between provenances in tolerance to cold wind in the winter; provenances from Myanmar and Thailand (probably *C. velutina*) were more sensitive than those from Laos, Malaysia and Vietnam (probably *C. tabularis*).

All species in Swietenioideae are reported to be monoecious with male and female flowers on the same inflorescence (Styles 1972; Styles and Khosla 1976). However, *Chukrasia* flowers have been described as either unisexual or bisexual, and are insect pollinated. Knowledge on the floral biology of a tree species is essential for understanding the breeding system and for future establishment of seed orchards. Information on the floral biology and breeding systems of *Chukrasia* would assist management of future improvement programs and operational seed production. Flower structure and development, the breeding systems and pollination mechanisms of *Chukrasia* are being studied in Vietnam.

Many of the natural provenances of *Chukrasia* are small in extent, and it is possible some individual provenances could be lost through shifting cultivation and logging. Therefore both *in-situ* and *ex-situ* conservation schemes are to be encouraged; in particular more effort on *in-situ* conservation is needed.

Range-wide provenance seed collection of *Chukrasia* has been coordinated by the CSIRO Australian Tree Seed Centre. In total 30 seedlots comprising 252 separate families have been collected from both natural and derived occurrences in Australia, China, India, Laos, Malaysia, Myanmar, Sri Lanka, Thailand and Vietnam. These seedlots are available to the international community for research and mainly for the establishment of *ex-situ* conservation stands. Requests for seed can be made by writing to the CSIRO Australian Tree Seed Centre, PO Box E4008, Kingston ACT 2604, Australia.

3. Cultivation

Silviculture and Management

Silvicultural characteristics

Key biological attributes of *Chukrasia* should be considered when applying or developing silvicultural systems in both natural stands and plantations. *Chukrasia* is fast growing and a heavy but irregular seed producer. It is a pioneer tree capable of colonising bare land and can tolerate some degree of shade in the early stages. It has an ability to coppice and produce root suckers. It can be easily regenerated in natural forests. The ability of individual trees to coppice profusely after cutting offers a potentially important silvicultural management option, especially for managed stems in plantations. Sites for plantations and farm forests should be fertile with deep and well-drained soils.

Trees are susceptible to attack by shoot borers which results in a loss of stem form over time. There is a need to minimise this damage. Planting companion trees with *Chukrasia* to minimise shoot borer attacks has been considered.

Natural regeneration

Natural regeneration is generally good where there are gaps in or near the edge of the forest. In Vietnam, Nguyen Ba Chat (1996) reported saplings within 50–70 m around the mother tree, sometimes extending to 120 m. However, poor regeneration was recorded under closed forests: germination of seeds was poor and seedlings died after eight months due probably to insufficient light.

Ho and Noshiro (1995) reported that natural regeneration is rather sparse in the semi-evergreen forests. In India, *Chukrasia* regenerates freely but judging from the few saplings or established trees most of the seedlings seem to perish in the early stages. In China, natural regeneration is adequate in semi-deciduous and in evergreen monsoon forests in lowlands (Zeng 1999b). Many saplings are observed under shade of the above forests but are rarely seen developing in secondary open forests.

Plantation establishment

Seed collection

Seed collection time varies with locality but is mainly between October and March (Table 3). Collection is made from the trees as mature fruits (capsules) will split, resulting in the seeds being dispersed by wind. Fruits can be taken from the trees once they turn brown. Collection from over-mature fruits should be avoided as germination tends to be poor and the resultant seedlings have high mortality (Nguyen Ba Chat 1996).

After collection, the fruits are dried in the sun for 2–3 days to dehisce and the seed separated by threshing. Special care should be taken to protect them from being blown away by wind.

Seed storage

Correct seed storage regimes are important to extend the longevity of the seed. *Chukrasia* seed has been reported to lose viability within three months (von dem Bussche 1981b; Rai 1985) or one year (Troup 1921; Dent 1948). However,

Pinyopusarerk *et al*. (2000) found that *Chukrasia* seeds which were stored for more than three years at room temperature (23°C) had a mean germination of 29% to 79%. For long-term storage it is recommended that the seed be held in a cool room or freezer in airtight containers.

Nursery techniques

Direct sowing, containerised seedlings, bare-root seedlings and stumps can be used for artificial regeneration of Chukrasia. However, planting with containerised stock is most common. Propagation is mainly by seed although vegetative propagation by grafting and cuttings is feasible.

The seed is sown broadcast at the rate of about 7.5 to 30 g m^{-2} in raised beds under shade (Anon. 1974; Zeng 1999b). No seed pretreatment is required. For quick and full germination seed should be covered with mulch after sowing (Beniwal *et al.* 1989). Germination usually takes place in 1 week and may continue up to 6 weeks. In tests in Malaysia 35% of the seeds sown germinated in 1–2.5 weeks and 78% in 4 weeks (Ng 1992). In India 80–90% of the seed germinated within 4 weeks (Rai 1985). In a glasshouse experiment in Canberra, Australia, 90% of the seeds germinated within 4 weeks but some germinated 10 weeks after sowing. Watering of seedlings should be light in the nursery as excess soil moisture may cause damping-off.

The germinated seedlings are ready for pricking out into containers when they have produced two pairs of leaves including cotyledons, i.e. about 4–6 weeks after germination. A friable, well-drained potting mix is recommended, with complete fertilizer incorporated in the mix or applied regularly in aqueous solution. The recommended potting mix for *Chukrasia* species in Thailand is coconut husk, burnt rice husk and sand in a 3:2:1 ratio (Royal Forest Department 1999). In Australia a mixture of tree bark, sand, coconut fibre peat, perlite and vermiculite in a 5:3:1:1:1 ratio and a supplement of slow-release fertilizer gave good results. In South Africa, pots are filled with a mixture of sandy soil, semi-decomposed pine bark and compost (von dem Bossche 1982b). Shade, 50% of sunlight, is required during the first week after pricking out, but may then be removed gradually depending on prevailing local climatic conditions. Thereafter, seedlings should receive up to 75% of sunlight. Healthy potted seedlings up to 30 cm tall can be produced within 5–6 months in the nursery and seedlings ready for transplanting into the field. Seedlings are hardened off by gradually reducing watering and removing shade two weeks before they are transported to the planting site.

If bare-root seedlings are preferred as planting stock, seedlings in germination beds are thinned to a spacing of about 20 cm × 20 cm. These seedlings will be ready for lifting 8–12 months after sowing. Usually 90% of the seedlings survive (Anon. 1974).

Stumps are sometimes used in planting of *Chukrasia*. Stumps are prepared from seedlings which are raised in nursery beds for about 12 months (Anon. 1974), at which time the plants are about 0.7–1.2 m tall and 1–2 cm in diameter at the root collar. Seedlings are lifted from the nursery beds at planting time. The stem is cut off 3–5 cm above the root collar and the lateral roots are trimmed from the tap-root.

Regardless of the type of planting stock, planting sites are cleared of ground vegetation and debris burnt. Erosion control measures have to be taken on steep slopes. Nguyen Ba Chat (1996) recommends such sites be divided into strips of 20–40 m wide by alternating cleared and uncleared bands 20 m wide.

Direct sowing

Fair success has been attained by direct sowing on newly prepared ridges about 30 cm high in India (Anon. 1974). Up to 67 kg of seeds per ha was sown for a 1.8 m × 1.8 m spacing plantation. Such a quantity of seed is excessive and uneconomical as many seeds are wasted. Nguyen Ba Chat (1996) did not recommend this method because of the poor yield of seedlings and the painstaking tending required after germination.

Containerised stock planting

The area is disc-ploughed twice in a grid pattern one month before planting time. Planting holes, 25–30 cm × 25–30 cm × 25–30 cm, are dug. Seedlings are removed from their containers before putting them in the holes. The roots should be disturbed as little as possible. The holes are then filled with soil. Dead seedlings should be replaced within one month. The most suitable time for planting containerised seedlings is during the wet season (Nguyen Ba Chat 1996; Royal Forest Department 1999).

Bare-root planting

This planting method is not widely used although it has given good results in China (Zeng 1999b). Planting is recommended in spring or in the rainy season. Site preparation is the same as that for containersied stock planting.

Stump planting

Stump planting of *Chukrasia* is carried out in China and India. Planting holes are dug to a depth of 25–30 cm. Stumps are placed carefully in the hole so that at least 2–3 cm of stem protrudes above the soil. When sprouts attain 20–30 cm they are thinned to the single best shoot. Stumps from 2-year-old plants have given good results (Anon. 1974). In India stumps are planted in January–February. In China, stumps are planted during the rainy season (May–September) on Hainan Island, and in spring (March–May) in Guangdong and Guangxi Provinces (Zeng 1999b).

Mixed planting

The planting of *Chukrasia* in mixture with other fast-growing species is recommended to minimise the problem of shoot borers, especially *Hypsipyla* sp. A mixed-species plantation can be obtained by direct sowing a mixture of seed of *Chukrasia* with other species, e.g. *Terminalia myriocarpa* and *Acrocarpus fraxinifolius*, at the rate of 1 part of *Chukrasia* to 15 parts of other species (Anon. 1974). The two companion species grow faster than *Chukrasia* and provide some shade to *Chukrasia* seedlings, assisting their early growth and providing some protection against shoot borers. In India alternate rows of *Chukrasia* and other species have been used (Lahiri 1987).

Planting density

Initial planting densities vary from 2500 to 3000 stems ha^{-1} (1.8 × 1.8 m to 2.2 × 2.2 m) in India (Anon. 1974) and Vietnam (Nguyen Ba Chat 1996). The planting density chosen depends mainly on the end-use objective and on site quality.

In Vietnam, 2500 stems ha^{-1} are used on fertile lands. This spacing requires an early thinning, but if there is no market for small stems close spacing is uneconomic and an initial planting of 1100 stems ha^{-1} (3 × 3 m spacing) is recommended (Nguyen Ba Chat 1996) (Table 4). In South Africa, a spacing of 5 × 5 m (400 stems ha^{-1}) was tested for timber production on very fertile lands (von dem Bossche 1982a).

Table 4. Comparison of two first-thinning regimes proposed in Vietnam (after Nguyen Ba Chat 1996)

	Normal regime	New regime
No. of stems ha^{-1}	1100	1100
Age at first thinning (years)	5	3
Thinning intensity (%)	50	60
No. of stems ha^{-1} after first thinning	550	500
Height (m)	9.7	11.0
Diameter at breast height (cm)	10.1	12.0
Crown diameter (m)	3.7	3.9

Notes: height, diameter at breast height and crown diameter were measured at age 7 years

Maintenance and tending

Weeding

In the first few years, *Chukrasia* plants should be kept free of weed competition by regular removal of ground vegetation. In South Africa, slashing of unwanted plant growth around the young trees is necessary at least once a year during early summer and in most cases again in late summer (von dem Bussche 1982b). Stumps are fast growing in Bengal (India) and little weeding is required after three years (Homfray 1937).

For older plantations or in enrichment planting, tending is generally by clearing climbers and unwanted ground vegetation on an as-needed basis.

Fertilizer

The main objective of fertilizer application is to produce uniform, fast-growing plantations. Uniformity makes it easier to prescribe thinning operations.

A starter-dose of complete fertilizer (NPK 15:15:15) to help in successful establishment is recommended (Pinyopusarerk *et al*. 1999). Fertilizer should be applied at 100 g plant^{-1} in two applications at 50 g each; the first application immediately after planting and the second one month thereafter. In Thailand, 150 g of fertilizer (NPK 15:15:15) was applied to each seedling and good growth was obtained at 6 months (Royal Forest Department 1999). Dibble around the seedling and drop in the required dose of fertilizer.

Established 2.3- and 3.5-year-old *Chukrasia* seedlings used in revegetation of bauxite mines in Weipa, Queensland, Australia had a good response to phosphate and nitrogen fertilizers (Nicholson 1974). However, the most effective combination for P and N was not determined.

Thinning

Most plantations in Vietnam are planted at 2500 stems ha^{-1} and require one or two thinnings before they reach the rotation age of 20 years. The first thinning of 20–35% of the stems takes place at 5–7 years of age when the trees are 7–8 m tall with stems 7–8 cm in diameter, and a crown diameter of 2.5 m. If planting density is low (1100 stems ha^{-1}), the first thinning (60% intensity) takes place 3–5 years after planting, and the second thinning (50% intensity) at 12–15 years. Final stocking is about 100-110 stems ha^{-1}. This prescription is based on mean diameter at breast height (dbh) of the plantation at an initial density of 1100 stems ha^{-1} (Nguyen Ba Chat 1996): the dbh is highly correlated with crown diameter from 3 to 10 years (r = 0.8–0.9), and that initial

wide spacing (3 × 3 m) and early thinning of inferior trees promote faster growth. Natural regeneration of other species, if any, should remain untouched to enhance a mixed-species environment.

Rotation

The rotation age for *Chukrasia* in Vietnam is 20–25 years for production of sawlogs (Le Dinh Kha, Forest Science Institute of Vietnam 2000 pers. comm.). In India, the rotation age in natural forest is fixed at 60 years while trees in plantations grow faster and a rotation age of about 10 years for plywood logs is feasible (Ghoshi and Singh 1981).

Growth and Yield

Chukrasia grows fast during the first few years and an annual height increment of up to 3 m can be attained in plantations under favourable conditions (Fig. 7). Seedlings usually reach 0.7–1.0 m tall in the first few years, and 2.1 to 2.7 m in the second year (Anon. 1974). In India, height growth of 2.7–5.5 m after 2 years and 8.5–9.1 m after 5 years, and an annual diameter increment of more than 2.5 cm up to six years were obtained (Troup 1921; Anon. 1974). However, growth is slow where soil fertility is low. In Vietnam, 5-year-old trees attained a mean height of 5.7 m on site class 3 as compared to 9.3 m on site class 1 (Table 5).

Figure 7. Chukrasia *attains 3 m tall in one year in a provenance trial in Kanchanaburi, Thailand.*

A mean height of 31 m and a mean dbh of 37 cm were obtained at 35 years in Buxa, Kalimpong and Kurseong (West Bengal), India (Anon. 1974). This would yield about 197 m^3 ha^{-1} where the stand stocking is 146 stems ha^{-1}. Over the 35-year rotation the mean annual increment (MAI) is 5-7 m^3 ha^{-1} (Table 6). In Northern Transvaal, South Africa, four trees have reached a mean height of 37 m and a mean dbh of 63 cm after 49 years (von dem Bussche 1982a). In Malaysia, a mean height of 39 m and a mean dbh of 93 cm were recorded for a 69-year-old plantation (Rasip and Kassim 1999).

Table 5. Height of *Chukrasia* tabularis at different site classes in Nghia Dan region, Vietnam (after Nguyen Ba Chat 1996)

Age (yr)	Mean height (m)		
	Site class 1	Site class 2	Site class 3
3	6.2	4.9	3.6
4	7.8	6.3	4.7
5	9.3	7.5	5.7
6	10.6	8.6	6.6
7	11.9	9.7	7.5
8	13.1	10.7	9.0
9	14.1	11.7	9.1
10	15.2	12.5	9.9
11	16.1	13.4	10.6
12	17.1	14.3	11.3

Table 6. Yield table for *Chukrasia* based on mean data of three sites (Kurseong, Kalimpong and Buxa) in West Bengal, India (after Anon. 1974)

Age (yr)	Stand density (stems ha^{-1})	Mean dbh (cm)	Mean height (m)	Basal area (m^2 ha^{-1})	Total Volume (m^3 ha^{-1})
5	1117	8.9	9.8	6.9	31.8
10	521	10.5	16.2	9.2	64.7
15	368	20.1	20.4	11.6	101.0
20	277	24.6	23.8	13.2	132.0
25	222	29.0	26.2	14.7	160.7
30	180	33.0	28.7	15.2	182.0
35	146	36.8	30.5	15.5	197.0
40	126	39.9	-	15.7	-
45	106	43.4	-	15.7	-
50	96	46.0	-	16.0	-

In Yezin, Myanmar, *Chukrasia* trees attained 12 m high and 15 cm dbh at 16 years of age and were relatively poor in form. In the same area *Pterocarpus macrocarpus*, *Albizia lebbek*, *A. procera* and *Acacia catechu* grew faster than *Chukrasia* (C. Harwood, CSIRO Forestry and Forest Products 2000 pers. comm.).

Zeng (1999b) reported growth rates of *Chukrasia* at different locations in China. Planted trees at Jianfengling, Hainan Island, in 9 years reached a mean height of 8 m and a mean dbh of 12 cm; in Xiashi, Guangxi, 12 m and 26 cm at 10 years; in Fuzhou Arboretum, Jujian, 8 m and 16 cm at 11 years; and in Longdong, Guangzhou, 13 m and 34 cm at 18 years. Natural stands have grown more slowly, for example in Jianfengling, 42-year-old trees had an average height of 14 m and dbh of 28 cm.

Pests and Diseases

Insects

Little is known about insect pests associated with *Chukrasia*. Browne (1968) mentioned only a few lepidopterous pests of *C. tabularis* such as *Hypsipyla robusta, Episparis tortuosalis, Orthaga rhodoptila* and *Zeuzera coffeae* of which *H. robusta*, a shoot borer, appears to be the most serious. This shoot borer is the main threat to the domestication of *Chukrasia* species in its natural range (Anon. 1974; Hutacharern and

Tubtim 1995; Le Dinh Kha and Phi Quang Dien 1999). In Malaysia *Chukrasia* was more susceptible to shoot borer attack than other species of Meliaceae (e.g. *Toona sureni*) in the nursery (Noraini *et al.* 1996). The shoot borer also occurs in South Africa (von dem Bussche 1982a) and Central and South America (Ho and Noshiro 1995) where *Chukrasia* is planted as an exotic.

The larvae of the *Hypsipyla* shoot borer feed on the apical shoots, destroying them and causing multiple leaders to develop with subsequent loss of tree form (Figs. 8 and 9). Numerous investigations have been carried out to prevent the damage, but no practical and effective methods have been developed (Valera 1997; Boland 2000). Valera (1997) suggested a combination of silvicultural, biological and perhaps chemical control methods to control *Hypsipyla.* Some consider that the insect could be controlled through the identification and selection of individual trees which are resistant to its attack, within the framework of a genetic improvement program (e.g. Gripjma 1976; Newton *et al.* 1993; Mayhew and Newton 1998).

Another borer, *Zeuzera coffeae*, has attacked young plants in *Chukrasia* provenance trials in Thailand (Royal Forest Department 2000) (Fig. 8). The larvae tunnelled the stems and caused death of some seedlings. A leaf-eating insect *Hypomeces squamosus* and a stem-boring beetle *Heterobostrychus* sp. (Bostrychidae: Coleoptera) also damaged young trees in the same trials. Other pests attacking *Chukrasia* seedlings, mainly in the nursery, include grasshoppers, e.g. *Xenocatontops humilis* and *Caryanda diminuta* (Acrididae) and various species of Hemiptera, Hamoptera and Coccoidea (Noraini *et al*. 1996; Royal Forest Department 2000). A leaf-eating beetle, *Anomala* sp. (Scarabaeidae) has attacked young *Chukrasia* trees. A snail (*Succinea* sp.) has also been observed feeding on *Chukrasia* seedlings (Noraini *et al*. 1996; Pitpreecha, Royal Forest Department 2000 pers. comm.).

Dead wood is liable to be attacked by borer species of Anthribidae, Brennthidae and Buprestidae (Anon. 1963).

Fungi

Rhizoctonia solani is pathogenic to seedlings of *Chukrasia* in nurseries in China (Zeng 1999b), India (Rai 1985), Sri Lanka (Bandara 1999) and Vietnam (Nguyen Ba Chat 1996). This fungus causes damping-off in conditions of excessive moisture. Suitable watering regimes and light sowing reduce the risk. The use of Bordeaux mixture at 1% to control outbreaks gave good results in Vietnam (Nguyen Ba Chat 1996).

In India, *Fomes senex* has caused a heart-rot of living trees in over-mature trees, while *Fomes lividus*, a very common decay fungus causing a white fibrous rot, has attacked *Chukrasia* logs (Anon. 1963).

Animals

Young *Chukrasia* trees are damaged by rodents and buck in South Africa (von dem Bussche 1982b), and in India by grazing wild and domestic animals, e.g. deer (Anon. 1974). In Thailand, the stem of small plants is damaged by rabbits (Royal Forest Department 2000).

Figure 8. Hypsipyla *tip borer attacking a young* Chukrasia *plant at Kuiburi, Thailand.*

Figure 9. *A young* Chukrasia *plant tunnelled by* Zeuzera coffeae *shoot borer in Uttaradit, Thailand.*

4. Utilisation

Wood Properties

Most descriptions of Chukrasia *timber appear to refer to* C. tabularis, *though some may refer to* C. velutina. *Anon. (1963) described the timbers of both species together because they have similar and indistinguishable anatomical features. However, Rodger (1936) stated that* C. velutina *wood is harder and not as decorative as that of* C. tabularis. *Gamble (1922), Pearson and Brown (1932), Desch (1954), Anon. (1963), Anon. (1974), Keating and Bolza (1982), Ho and Noshiro (1995) and Mabberley and Pannell (1995) have all described the wood and various uses of* Chukrasia, *as summarised below.*

The heartwood and sapwood gradually grade into each other. The sapwood is greyish or yellowish-white, occasionally with a pinkish touch, turning darker on exposure. The heartwood is rather variable in colour, usually pale buff or brownish-yellow when freshly exposed, ageing to dark brown or golden brown; sometimes also light brown to brownish-red with a yellowish to greenish cast. On seasoning, the wood tones down to a golden mahogany shade with a beautiful satiny sheen and is often figured handsomely.

Anatomical structure

Chukrasia has a diffuse-porous wood. Growth rings are distinct, about 2–4 cm^{-1}, delimited by concentric lines of parenchyma and also sometimes by dense and dark-coloured fibrous tissue. When both parenchyma types are present, the growth rings are prominent; occasionally some parenchyma lines are too closely spaced to be considered annual.

Vessels are small, hardly visible, moderately few to moderately numerous (4–16 mm^{-2}), normally evenly distributed, but occasionally with a row of tangentially-aligned vessels on the face of the growth ring giving the impression of semi-ringporous structure. Vessels are solitary or in radial multiples of 2–3 (usually 2), round to oval in shape and often plugged with yellow-orange deposits. Vessel lines are rather numerous but not conspicuous.

Parenchyma is not abundant, brown to reddish-brown in colour and visible as concentric lines delimiting the growth rings. It also forms a thin sheath round the vessels, hardly distinct under the lens due to more or less similar colour of the surrounding tissue.

Rays are fine to very fine, scarcely visible, light reddish-brown in colour, usually better seen in sapwood, fairly closely spaced; fine ray-flecks are noticeable on the quarter-sawn surface. Gum canals are vertical and of traumatic type, occasionally present in tangential rows.

Mechanical properties

The mechanical properties of *Chukrasia* wood are summarised in Table 7. The wood is moderately hard to hard, moderately heavy to heavy but low in stiffness. The grain is straight, sometimes irregularly interlocked and sometimes wavy, producing a roe figure, with moderately fine but uneven texture. The timber is durable under cover but not in contact with the ground.

Table 7. Mechanical properties of Chukrasia (after Anon. 1963 & 1974; Ho and Noshiro 1995).

Property	Anon. (1963 & 1974)	Ho and Noshiro (1995)
Density (kg m^{-3}) (moisture content)	666–673 (12%)	625–880 (15%)
Static bending (kg cm^{-2})		
Fibre stress at elastic limit	475	
Modulus of rupture	866	820–1010
Modulus of elasticity	113 100	108 000–143 000
Impact bending		
Fibre stress at elastic limit (kg cm^{-2})	1243	
Maximum height of drop of a 22.68 kg hammer (cm)	94	
Modulus of elasticity (kg cm^{-2})	181 900	
Compression parallel to grain (kg cm^{-2})		470–640
Compressive stress at elastic limit	247	
Maximum crushing stress	509	
Modulus of elasticity	117 000	
Compression perpendicular to grain (kg cm^{-2})		110–120
Compressive stress at elastic limit	116	
Shear (kg cm^{-2})		150–180
Radial	110	
Tangential	120	
Tension perpendicular to grain (kg cm^{-2})		
Radial	33	
Tangential	51	
Cleavage (kg cm^{-2})		
Radial		600
Tangential		710

Seasoning, preservative treatment and working qualities

Chukrasia is a moderately refractory timber, which should be converted green, and the sawn timber dried under cover. The timber seasons easily as about 6 months under moderate weather conditions is sufficient to air-dry material 5 cm thick. In India, kiln seasoning takes 12–15 days. The rates of shrinkage are rather low: from green to 15% moisture content c. 1.3% radial and 1.75% tangential, from green to oven dry 3.9% radial and 6.0% tangential. Usually no degrade of any kind is reported except slight development of original heart shakes and end cracks but these can be reduced by end-sealing and careful stacking. Fine hair-line surface checks may develop when thick boards are dried.

The wood of *Chukrasia* is moderately resistant to extremely resistant to preservative treatment (Ho and Noshiro 1995).

Although tests in Malaysia showed *Chukrasia* wood is difficult or very difficult to saw, tests elsewhere (probably with different *Chukrasia* species) showed it is easy to saw and work by hand or machine. The wood takes a very high polish but it is preferable to polish it after allowing the natural colour to develop to a suitable shade. Nailing, screwing and gluing properties are good. It can be peeled and sliced into veneers which can be glued satisfactorily to produce decorative plywood.

Uses

Wood products

The wood of *Chukrasia* species is of considerable economic importance especially in Southeast Asia and India. Major uses are fine furniture, turnery, doors, windows and

light flooring. The wood has variable resistance to termite attack and is susceptible to marine borer attack. In the Hanoi market in Vietnam sawn timber of *Chukrasia* is sold for US$1000 m^{-3} (Le Dinh Kha, Forest Science Institute of Vietnam 1996 pers. comm.). The timber is very suitable for tea chests, commercial and moisture-proof plywood and packing cases. It can be used for domestic construction and house building as posts, scantling and planks. In India, the timber is in high demand for cabinet making, piano cases and decorative boards for various ornamental work. It is also suitable for carving and pulp.

Non-wood products

Flowers contain a red and yellow dye. The bark and leaves contain commercial gums and tannins and the astringent bark has medicinal uses. A yellow transparent gum exudes from the trunk and is marketed with other gums in India. An extract from the twigs has proved an effective anti-feedant against *Pieris rapae* (cabbage white butterfly) in southern China (Mabberley and Pannell 1995).

Land use, agroforestry

It is planted as a shade tree for coffee plantations in India (Rai 1985), and is being domesticated for agroforestry and green manure in China (Zeng 1999a).

Amenity

Chukrasia is planted as an ornamental tree in parks and avenues in Vietnam. In Europe, it has been cultivated as a greenhouse ornamental (Mabberley and Pannell 1995).

5. Conclusions

Chukrasia is a fast-growing tropical tree of economic importance. It is relatively easy to grow and has a wide variety of uses. However, its taxonomy has to be better defined as the genus probably comprises two species as shown by distinctive leaf and bark types.

Chukrasia in natural forests is heavily exploited for timber. It is not widely used in plantations, probably because silvicultural treatments are not well understood and *Hypsipyla* tip moth attack in pure plantations is severe. Further studies are warranted on thinning regimes and species mixtures in plantations as part of the domestication process. In addition, tree improvement efforts must place importance on productivity characteristics and on ways to minimise damage from tip moth. Selection of the most productive and pest-resistant individuals should be included in future tree improvement programs. An alternative to tree breeding would be to pursue biological control of the tip moth in areas where plantations are grown (Boland 2000).

The contradictory reports on the sex of *Chukrasia* flowers suggest a need for more research to elucidate the breeding system. Floral characteristics, flowering and fruiting phenology, and breeding system are currently being investigated by the Research Centre for Forest Tree Improvement of the Forest Science Institute of Vietnam. Major animal visitors that are potential pollinators should be identified.

Forest resources are becoming scarce despite increased public concern and increasing operational resources for forestry enterprises. Therefore, urgent measures are required to conserve and sustainably use the genetic resources of *Chukrasia* (and of course other trees). On-going research, especially the genetic improvement, could rapidly expand the availability of selected germplasm of high genetic value for general social benefit. In view of the potential economic importance of *Chukrasia* on farms, there is a need for a detailed study on the integration of the tree on-farm in Southeast Asia and elsewhere. With appropriate replanting and management programs, backed by research and development, *Chukrasia* could again make a substantial contribution to the forestry sector.

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