

Performance of a five-year-old provenance trial of *Chukrasia* in the Northern Territory, Australia.

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Abstract

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A provenance trial of *Chukrasia* A. Juss. was established at Berry Springs near Darwin in the Northern Territory of Australia to assess the potential of this species as a commercial plantation tree for the production of high value wood. The trial comprised 16 seed sources from the species natural distribution in China, Laos, Myanmar, Thailand, Vietnam, and from a local planted stand in Darwin probably of Sri Lanka origin. In order to gauge the performance of the species, assessments of height and diameter growth; axis persistence associated with apical dominance and single stem growth; stem straightness; bark character and incidence of suckering and termite damage were made when the trial was 5.4 years old. Survival varied considerably among provenances but differences were not significant, nor for stem straightness score. There were significant differences between seed sources in growth traits with seedlots from deciduous forest environments associated with the rough corky bark *C. velutina* growing faster than the smooth barked *C. tabularis* from the moister ecological environments. The seed source from Darwin had less than one fifth of the volume of the most productive provenance. Axis persistence, bark characteristics and other traits assessed all showed significant differences.

Introduction

The genus *Chukrasia* A. Juss. probably consists of two species, namely *C. tabularis* and *C. velutina*. Some authors (e.g. Smitinand 1980; Gardner *et al.* 2000) consider these to be distinct taxa while some others (e.g. Mabberley 1995) regard the latter as merely a form or ecotype of the former. *Chukrasia* is a deciduous tree, typically 20-25 m in height, but can grow to 40 m tall and over 120 cm in diameter at breast height under favourable conditions (Kalinganire and Pinyopusarek 2000). The stem is generally straight with large convex buttresses to 150 cm from ground. *Chukrasia velutina* is reported to be a smaller tree than *C. tabularis* (Gardner *et al.* 2000). The straight bole and self-pruning ability makes it a suitable plantation species. The wood is of considerable economic value especially in Southeast Asia. Major uses are fine furniture, turnery, doors, windows and light flooring. The timber is durable under cover but not in contact with the ground; it is moderately termite resistant and heartwood extremely resistant to preservative treatment (Keating and Bolza 1982). Tests in Malaysia showed *Chukrasia* wood is difficult or very difficult to saw but elsewhere it is regarded as easy to saw and work by hand or machine (Ho and Noshiro 1995).

Chukrasia is widely distributed in South Asia, occurring in Bangladesh, India, parts of Indonesia to include the western tip of Kalimantan associated with limestone and rare occurrences in northern Sumatra, Nepal, Sri Lanka, Myanmar, Thailand, northern Peninsular Malaysia, Sarawak, Vietnam and southern China (Kalinganire and Pinyopusarek 2000) (Figure 1). The latitudinal range is from approximately 27°N to the equator. Altitudinal range is from 20 m to 1450 m. The natural habitat is associated with lowland evergreen rain forest, moist-evergreen forest or deciduous forest at 300-800 m altitude (Ho and Noshiro 1995). *C. tabularis* is associated with moist evergreen rainforest and is distinctive in having smooth bark. By contrast, *C. velutina* is associated with drier deciduous forest and has a fissured rough and corky bark (Pinyopusarek and Kalinganire 2003).

Chukrasia is a gregarious species capable of invading gaps in the forest. It is common in former shifting cultivation areas and occasionally colonise bare land. It is essentially a light demanding species although it can tolerate shade in the early stages of growth (CABI 2000). The tree produces coppice shoots and has a tendency to branch and fork. *Chukrasia* is susceptible to attack by the shoot tip borer *Hypsipyla robusta*.

The straight bole and self-pruning ability of the species makes it a suitable plantation species. The wood is of considerable economic value especially in Southeast Asia. Major uses are fine furniture, turnery, doors, windows and light flooring. The timber is durable under cover but not in contact with the ground. It is moderately termite resistant and heartwood extremely resistant to preservative treatment (Keating and Bolza 1982). Tests in Malaysia showed *Chukrasia* wood is difficult or very difficult to saw but elsewhere it is regarded as easy to saw and work by hand or machine. It can be peeled and sliced into veneers that can be glued to produce decorative plywood (Ho and Noshiro 1995).

Chukrasia has been introduced as a potential timber tree to many countries in Africa (Cameroon, Nigeria and South Africa) and central America (Puerto Rico and Costa Rica (Streets 1962; Ho and Noshiro 1995). In Australia it has been trialled in the Atherton region and Northern Territory mainly between Darwin and Katherine. Under favourable conditions the species is aggressive, having strong suckering ability and producing copious quantities of seeds.

There is a growing interest in the utilisation, conservation and genetic improvement of *Chukrasia* species. Provenance seed collection from most countries where the species were known to occur was organised by CSIRO Australian Tree Seed Centre for development of domestication strategies for *Chukrasia*. A sub-sample of these seedlots was planted in a provenance trial near Darwin, Northern Territory. This paper reports growth performance at age 5.4 years of this trial.

For the purpose of clarity in this paper, we will refer to the two species as distinct entities as there were marked differences in growth and related bark characteristics between the two entities in the trial.

Materials and methods

Planting material

Planting stock comprising 15 natural provenances from China, Laos, Myanmar, Thailand and Vietnam, and one landrace from Darwin was raised from seed in the nursery as containerised seedlings (Table 1). The landrace is considered to have originated from Sri Lanka based on the file records associated with the trial from which the seed was collected.

Planting site

The planting site is on private property owned by the Keitells and located at Berry Springs south of Darwin (latitude 12° 43'S, longitude 131° 02'E, altitude 40 m). Mean annual rainfall for Howard Springs, the closest representative meteorological station is 1935 mm mainly falling between November and March. Table 2 provides rainfall figures at the trial site over the duration of the trial between 1998 and 2003. Mean annual temperatures range from a maximum of 32°C to a mean minimum of 23°C with an absolute minimum of 12°C. No frosts are recorded. The soil is a Ferric, Mesotrophic, Red Kandosol; medium non-gravelly, clay loam with a pH of 6.0. The trial site is almost level with a slight depression on the northern edge of the trial. This depression is subject to seasonal flooding and consists of a hard impenetrable clay pan that impedes growth and survival.

Experimental design

The experiment was laid out in a Randomised Complete Block design. The trial comprised four replicates each containing 16 plots arranged in 2 rows of 8 columns. Plots were 5 rows by 5 trees at 3m by 3m spacing. Two guard rows of excess seedlings were planted surrounding the entire experiment. The experimental area had previously been cleared of native trees. Planting holes were dug by hand using a mattock prior to planting in April-May 1999 (B. Robertson *pers. comm.* 2004).

Cultural management

Drip irrigation (button drippers) was provided to the trees during the first two dry seasons. Following the first dry season after planting, dead trees were replaced with seedlings of *Pterocarpus*. The grass was kept mown on an as needs basis by the land owner. A pruning, generally up to head height, was carried out mainly for the purpose of removing double leaders.

Assessment

At five years and four months after planting, all trees in the trial were measured for height (*Ht*) and diameter at 1.3 m above ground level (*Dbh*). Plot mean survival was calculated by counting the number of trees presented in the height data. Conical volume (*Vol*) was calculated for all trees using the equation

$$Vol = \frac{1}{3} \pi (Dbh/2)^2 Ht$$

In addition, each tree was scored respectively for three morphological characteristics: axis persistence; stem straightness and bark character. A tally was made of the number of trees that suckered in each plot. Observations were also made for the presence of termite damage by *Mastotermes darwiniensis* and shoot tip borer damage (*Hypsipyla robusta*). Details of the characteristics assessed in the trial are presented in Table 3.

Data analysis

Although the trial was laid out as a RCB design, the rectangular design of the trial enabled the analysis to be done using row-column structure in order to account for site variation.

Trial data presented used the results from the analysis carried out on the full 25 trees per plot. An analysis was also carried out on the inner plot of nine trees for comparison. The results showed that apart from survival, which improved from $p < 0.05$ to $p < 0.01$, there were no change in the level of significance for the other traits. The error term for all the traits decreased when analyses were done using all the trees in the plot. The only exception was bark score, but this did not change the level of significance ($p < 0.001$). From the above, there is very little difference between analysis of the inner nine tree plot and the full 25 tree plot.

Results

A summary of the results of the trial assessment are presented in Table 4. During the analysis of the trial data, no assumption was made between seedlots and species or bark characteristic.

Survival

Mean survival ranged from 72% for seedlot 20030 from Hainan Island, China to as high as 96% for seedlot 20119 from northern Thailand. Survival amongst seedlots of *C. velutina* ranged from 90% to 96%, while those of *C. tabularis* ranged from 72% to 95%. The Darwin seedlot had a survival of 92%. The trial was planted in about April/ May 1999 at the end of the wet season (B. Robertson *pers. comm.* 2004). For the months of May to September, no rain was recorded. It was also in this period

that most of the plant fatalities occurred. Had the trial been planted under optimum conditions then survival may well have been considerably better.

Growth

Seedlots from Myanmar and Thailand associated with *C. velutina* outperformed *C. tabularis* from China, Laos and Vietnam (Table 4). *C. velutina* seedlots had a mean stem volume per tree in the range of 15-24 dm³ compared with 2-5 dm³ for *C. tabularis*. The local Darwin seedlot (suspected to be from Sri Lanka) was also well down on the growth rankings with an average tree volume of 4.5 dm³. In terms of Dbh, the best seedlot was 20118 with a mean of 10.6 cm. This works out at an average of about 2 cm diameter growth per year.

Stem form

Two assessments were made for stem form (Table 3). Axis persistence, categorised into six classes following Pinyopusarerk *et al.* (2004) classification, was to assess the ability of the tree to retain its primary stem axis. The second stem assessment was on straightness of the bole assessed into four classes.

There were no significant differences between seedlots with the results indicating that the species has a strong apical dominance. The Darwin seedlot had the greatest level of forking. In a number of the high growth plots mainly associated with replicate 1, vigorous branch development of individual trees was considered to be causing competition for apical dominance with the leading bole.

There were no significant differences in stem straightness score, with most seedlots having 1 to 2 small bends to slightly crooked with more than 2 small bends.

Bark

Trees were scored against three bark types; 1 smooth; 2 intermediate and 3 rough corky bark. The results clearly split the seedlots into either smooth or rough bark with the exception of the Darwin seedlot that was intermediate. During the assessment some discussions were held over the scoring of certain plots where trees were more vigorous in growth and displayed bark characters between smooth and intermediate. However, these were the exception rather than the rule. Seedlots from Myanmar and Thailand featured the rough corky bark characteristic of *C. velutina*, whereas seedlots from, China, Laos and Vietnam featured the smooth bark of *C. tabularis*.

Root suckering

The results of the assessment showed variation between seedlots and a relationship between growth rate and root suckering (Table 4). Suckering ranged from 1.5% of trees in seedlot 20030, the seedlot with the lowest growth rate, to the second highest record of suckering in seedlot 20119 with 22%. The highest incidence of suckering was the Darwin landrace at 25%. No plausible explanation can be given for why the Darwin seedlot had the highest rate of suckering. At the time of assessment root suckering appeared as bushy growth up to 30 cm tall and within 1 m of the tree. Mowing of the trial had occurred previously, which may have affected the growth of the suckers making most of them fairly uniform in size.

Insect attack

No signs of termite attack by *Mastotermes darwiniensis* were observed throughout the trial. It should be noted that the trial is located in an open stretch of cleared land that acts as a deterrent to termites as they prefer forested areas for their food supply.

Shoot tip borer damage later confirmed to be *H. robusta* by Dr. Renkeng Peng from the University of the Northern Territory (D. Reilly, *pers. comm.* 2004) was found on four trees. All four trees were located in the Darwin seedlot in replicate 1.

Discussion

The results of the *Chukrasia* provenance trial at Berry Springs just south of Darwin in the Northern Territory indicated marked variation among species and provenances. Clearly, seedlots of *C. velutina* from Myanmar and Thailand grew faster than those of *C. tabularis* from China, Laos, Vietnam and the Darwin landrace. The results show a strong correlation between growth performance and bark type. As reported by Kalinganire *et al.* (2002), these bark characteristics are also observed on trees from the same seed sources in provenance trials established in many countries in South-east Asia. The same authors also reported a strong correlation between bark structure and mean annual rainfall at the place of provenance origin (Table 1) and associated forest type. The smooth bark *C. tabularis* is typically associated with an annual rainfall in excess of 1600 mm in moist forests. By contrast the rough bark *C. velutina* is associated with areas of rainfall below 1400 mm in seasonally dry deciduous forests.

The northern boundary of the trial area has a hard clay pan subject to seasonal flooding. This hard pan affected part of the end row plots in replicates 1, 2 and 3. In this area which was clearly visible from the surface, almost all *Chukrasia* plants had died or were very stunted, a sign that the species does not tolerate impenetrable soils. This growth response is backed up by a trial in Hawaii in which an impenetrable soil layer at 30 cm below ground level caused the failure of the species in a trial reported by Ho and Noshiro (1995).

Chukrasia demonstrated strong apical dominance across all seedlots (though differences were significant) while stem straightness score was related mainly to tree size rather than seedlot. What was observed and may have ramifications for potential growers of the species for high value timber is the possible tendency for vigorous lateral branches to compete with the main leader. The effect of this might be the development of a flattened crown thereby impeding the development of a vigorous leading apical shoot and subsequent height growth. In a number of the more vigorous plots across both species the trees had the propensity to develop large branches which were showing signs of competing with the leading shoot. To prevent the potential for these undesirable traits from developing, it may be necessary to reduce the spacing between trees and or consider a nurse tree crop to inhibit side branching and epicormic shoots and promote apical shoot growth.

It was also noted that where pruning of the branches had taken place, vigorous regrowth emerged from the cambium area surrounding the wound. Such a trait should be discouraged to prevent excessive branching leading to the possibility of wood defects. Small epicormic shoots emerging from the trees bark were also observed on a number of trees. As reported in the literature, *Chukrasia* (*C. tabularis*) is self pruning (CABI 2000). The effect of pruning on branch habit and epicormic shoot response required to be assessed along with the question of optimum tree spacing.

A major limiting factor to plantation development in the 'Top End' of the Northern Territory has been the destructive effect of *Mastotermes darwiniensis*, the giant northern termite to standing trees and forest products. This has greatly limited plantation development in the 'Top End'. The lack of evidence of termite attack on trees in the *Chukrasia* trial supports observation made by B. Robertson and D. Reilly (*pers. comm.* 2004) that planted *Chukrasia* and *Khaya senegalensis* are resistant to *Mastotermes* as living trees. It is not clear whether or for how long logs of *Chukrasia* will remain resistant to termite attack when resting on the ground.

Up until very recently, insects associated with shoot tip borer damage to include *Hypsipyla robusta*, a major pest associated with species of Meliaceae, had not been recorded in the 'Top End' of the Northern Territory (D. Reilly *pers. comm.* 2004). Shoot tip borer damage has been observed on a few trees of *Khaya senegalensis* in the Darwin area and this paper reports on the identification of similar damage to *Chukrasia*. *Hypsipyla robusta* damage has all but excluded the commercial potential of growing species of Meliaceae along the eastern seaboard of Australia in other countries where the insect is prevalent. In the case of the 'Top End', it may have been excluded through isolation in the past. However, now that there are confirmed sightings of its presence, careful monitoring of the incidence of tip borer attack will need to be a high priority as any significant increase in the incidence

of *H. robusta* will have ramifications when determining whether to plant *Chukrasia* and other species prone to attack by shoot tip borer.

Leaves of *Chukrasia* may be highly toxic to stock given the experience of the property owners at Berry Springs. Following the pruning of the Berry Springs trial the land owner removed the branches from the trial and fed them to the goats. Within a matter of days the goats showed severe signs of distress and had to be killed (B. Robertson *pers. comm.* 2004).

Clearly the problem of weediness associated with *Chukrasia* is a matter for careful consideration if the species is to be planted in Australia. The results of the trial did not indicate any genetic correlation between seedlot and suckering. More vigorous seedlots had a higher incidence of suckering except in the case of the Darwin landrace. Hyland and Whiffin (1993) report that *Chukrasia* is an aggressive introduced species tending to form pure stands in disturbed rainforest habitats on the Atherton Tableland. It produces large seed crops. A species introduction trial (EP346) established at Howard Springs Forest Reserve just south of Darwin in 1969/70 (B. Robertson *pers. comm.* 2004) contained three seedlots of *Chukrasia* recorded to be from Sri Lanka. One of the plots visited contained a couple of over mature *Chukrasia* in the process of dying. Beneath the trees is a thicket of *Chukrasia* saplings (1-2 cm Dbh) in the immediate vicinity of the old parent trees mostly derived from suckers. There was evidence of seedlings near the parent trees one of which had developed a horizontal main root presumably in response to the impenetrable soil. The evidence suggests that Sri Lankan provenances are predisposed to suckering and should be avoided.

Batainoff and Champion (1993) provided a list of characteristics to assess weediness that was used by Pingle (2003) to assess potential hardwoods for central Queensland. These characteristics included seed production, seed dispersal, retention of seed viability, ease of germination, ability to reproduce vegetatively, invasiveness and ability to adapt to a wide range of environmental conditions. The question is to what extent does a set of criteria have to be met before a species becomes a weed concern. There is also the issue of the unknown lag time when a species may revert to becoming classified as a weed by which time it may be too late to take remedial action.

Conclusion

It is clear from the results that *Chukrasia* is sufficiently fast growing to be considered as a potential high value timber species for the seasonally dry tropics. Selection of the seed sources of *C. velutina* from Myanmar and Thailand are recommended for maximum growth performance in the seasonally dry tropics. However, there is a need to assess wood quality between the two species before making firm decisions on what seedlot or species is most appropriate. Further provenance trials needs to be established to determine provenance variation under different climatic conditions. The Berry Springs trial can continue to yield valuable information both in terms of growth performance and also in cultural management and wood quality. It is recommended that the trial be maintained until approximately 15-20 years to coincide with rotation age. A thinning regime requires to be applied in the next few years. Thinning needs to take into account suckering response, coppicing response and seasonal variation. The effects of pruning require to be better understood through assessing different pruning intensities. Thought should also be given to the establishment of a clonal seed orchard to serve as a future seed source. Apart from individual seedlots being superior to others there are also individual trees across the trial that are significantly larger than the surrounding trees. The species can be propagated vegetatively making available clonal options for further tree breeding work.

The example of the poor performance of the Darwin landrace sends an important message that species trials should contain several seedlots representing the environmental and geographical range of the species.

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Figure 1. Natural distribution range of *Chukrasia* showing location of seedlots used in the trial at Berry Springs, Northern Territory, Australia

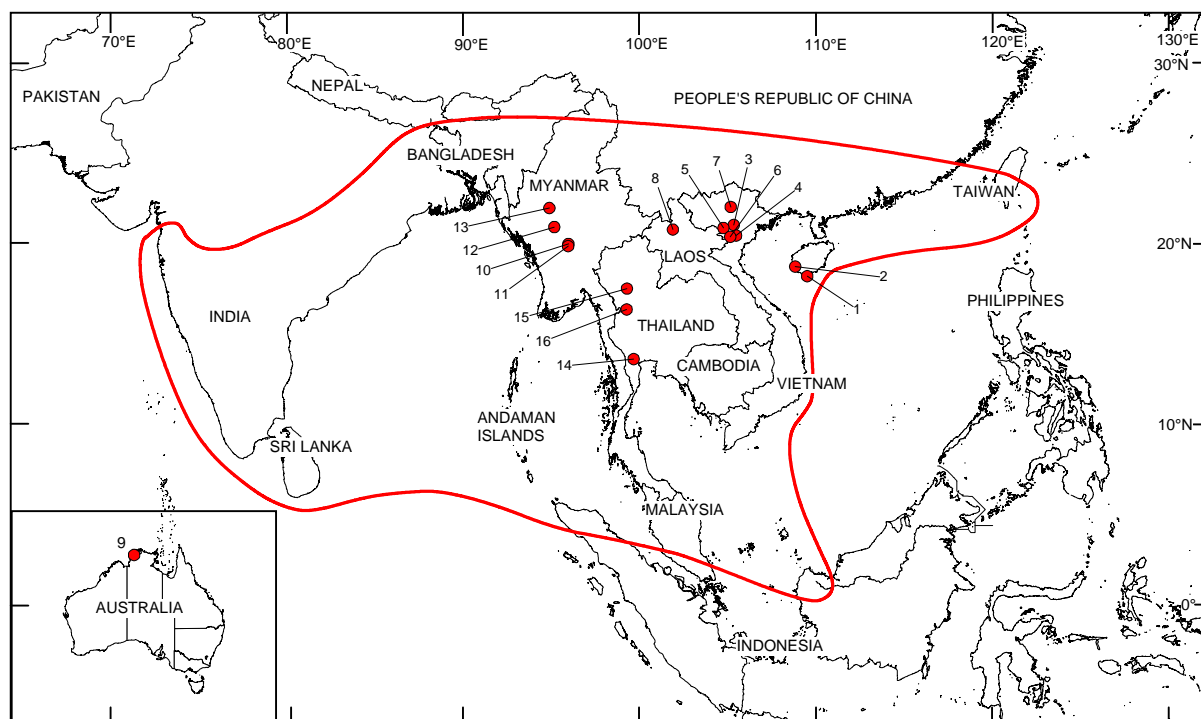


Table 1. Origins of provenances of *Chukrasia* established at Berry Springs, Northern Territory, Australia

Ref No	CSIRO Seedlot	Provenance location	Country	No of parents	Latitude (° ')	Longitude (° ')	Altitude (m)	Rainfall (mm)
<i>C. tabularis</i>								
1	20030	Shanya, Hainan I.	China	10	19 10N	109 30E	45	1700
2	20031	Jianfengling, Hainan I.	China	10	18 42N	108 49E	65	1800
3	19660	Hoa Binh Province	Vietnam	?	21 00N	105 20E	(400)	(2000)
4	20033	Hoa Binh	Vietnam	10	20 25N	105 28E	100	2200
5	20034	Son La	Vietnam	6	20 50N	104 45E	900	2000
6	20035	Thanh Hoa	Vietnam	10	20 21N	105 08E	50	1800
7	20036	Tuyen Quang	Vietnam	9	22 00N	105 10E	75	1900
8	20105	Pak Baeng Oudomxay	Laos	8	20 45N	101 53E	750	
9	Darwin	Landrace (ex S7628)	(Sri Lanka)	(1)				
<i>C. velutina</i>								
10	20099	Moeswe Pyinmana	Myanmar	10	19 57N	95 58E	209	1200
11	20100	Ledagyi Leway	Myanmar	10	19 50N	95 57E	220	1200
12	20101	Popa Kyaukpadaung	Myanmar	10	20 53N	95 10E	180	660
13	20102	Khin Aye Pale	Myanmar	10	21 56N	94 53E	155	710
14	20117	Khao Bin, Ratchaburi	Thailand	30	13 35N	99 40E	230	900
15	20118	Mae Phrik, Lampang	Thailand	12	17 29N	99 17E	180	(1000)
16	20119	Kamphaengphet	Thailand	10	16 20N	90 16E	180	1100

CSIRO Australian Tree Seed Centre seedlot number
() estimated figure

Table 2. Rainfall data (in mm) at the *Chukrasia* trial (Kietell Homestead)) between 1998 – 2003.

Year	July	August	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
98/99		6	18	206	163	698	369	308	461	224			2453
99/00				179	269	228	295	432	460	224	30	3	2120
00/01				126	158	332	349	453	389	79			1886
01/02	4			89	239	171	138	439	196	77	25		1378
02/03			100	5	98	169	606	493	188	1			1660
Average			23	121	185	320	207	425	389	121	11		

Table 3. Characteristics assessed on the *Chukrasia* provenance trial at Berry Springs, Northern Territory, Australia

Characteristic	Unit	Explanation
<i>Quantitative traits at tree level</i>		
Height (Ht)	m	Height of the tallest stem
Diameter (Dbh)	cm	Measured at 1.3 m above ground
<i>Qualitative traits assessed at tree level</i>		
Axis persistence	1-6	Ability of tree to retain its primary stem axis 1 = Multiple stems from ground level 2 = Forking in 1st (lowest) quarter of stem 3 = Forking in 2nd quarter 4 = Forking in 3rd quarter 5 = Forking in 4th quarter 6 = No forking
Stem straightness	1-4	1 = Very crooked, > 2 serious bends 2 = Slightly crooked, > 2 small bends or < 2 serious bends 3 = Almost straight, 1-2 small bends 4 = Completely straight
Bark character	1-3	1 = smooth 2 = intermediate 3 = rough
Survival		Based on presence of height data
<i>Quantitative trait assessments at plot level</i>		
Suckering	No	Number of trees suckering in the plot
Shoot tip borer	No	Number of trees showing signs of tip borer damage

Table 4. Mean values for eight growth characteristics of a *Chukrasia* provenance trial aged 5.4 years at Berry Springs, Northern Territory, Australia.

Seedlot	Locality	Country	Survival %	Ht (m)	DBH (cm)	Vol (dm ³)	Axis persist score (1-6)	Stem straight score (1-4)	Bark char' score (1-3)	Sucker %
19660	Hoa Binh	Vietnam	87	4.0	4.3	1.62	5.4	2.6	1.3	3.4
20030	Shanya, Hainan Island	China	72	3.5	4.1	1.22	5.4	2.6	1.0	1.5
20031	Jianfengling, Hainan Island	China	79	3.9	4.4	1.61	5.2	2.6	1.3	4.5
20033	Hoa Binh	Vietnam	91	4.3	5.2	2.06	4.8	2.3	1.2	4.2
20034	Son La	Vietnam	92	4.4	4.7	2.41	5.3	2.6	1.0	2.1
20035	Thanh Hoa	Vietnam	95	4.6	5.1	2.86	4.8	2.4	1.4	9.3
20036	Tuyen Quang	Vietnam	94	4.7	4.9	2.75	5.1	2.6	1.1	6.3
20099	Moeswe Pyinmana	Myanmar	95	6.1	9.0	9.70	5.2	2.7	3.0	16.0
20100	Ledagyi Leway	Myanmar	92	6.7	9.1	13.71	5.4	2.6	3.0	2.0
20101	Popa Kyaukpadaung	Myanmar	90	6.5	9.5	12.40	5.3	2.4	3.0	11.2
20102	Khin Aye Pale	Myanmar	94	7.3	9.8	15.27	4.5	2.4	3.0	9.1
20105	Pak Baeng, Oudomxay	Laos	87	4.9	4.9	2.86	5.5	2.8	1.0	5.4
20117	Khao Bin, Ratachburi	Thailand	93	6.5	8.1	9.67	5.4	2.3	2.3	12.2
20118	Mae Phrik, Lampang	Thailand	95	7.6	10.6	20.70	5.1	2.5	3.0	13.3
20119	Kamphaengphet	Thailand	96	7.4	9.7	16.17	5.2	2.5	3.0	22.2
Darwin	Howard Springs Reserve	Australia	92	4.2	5.7	3.63	4.6	2.6	2.0	24.8
	Significant level		ns	***	***	***	**	ns	***	***
	Standard error of difference		7.4	0.4	0.6	1.5	0.3	0.1	0.2	5.3

*, **, and *** indicate significant at P • 0.05, P • 0.01 and P • 0.001 respectively, ns indicates no significance.

NB. The means of variates reported in this table are predicted means, calculated independently using GenStat program for the REML mixed-model analysis. Depending on the variate, adjustments have been made for replicate, long column and seedlot as fixed effects, and column within-replicate as random effects. The volume data were analysed as logs, then back-transformed to original units for inclusion in this table. Hence, the volume obtained with this method will not be identical to the volume obtained when calculated using seedlot mean height and DBH.