# Heartwood, Calcium and Silica Content in Five Provenances of Teak (*Tectona grandis* L.)

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## Abstract

Heartwood percent and content of silica and calcium were estimated in a 17 year old provenance trial of teak *(Tectona grandis* L.). Large variation were found both within and between the five tested provenances. Average contents of silica was significantly different between provenances ranging from 0.27% to 0.66%. Percent of heartwood and content of calcium were also significantly different between provenances and significantly correlated to tree size. Large trees had the highest heartwood percent, but the lowest calcium content. Average heartwood percent ranged from 47% to 67%. Average contents of calcium varied between provenances from 0.22% to 0.58%.


*Key words: Tectona grandis,* wood quality, provenance trials, heartwood, calcium, silica.

*FDC:* 165.52; 232.12; 811.52; 852.17; 176.1 *Tectona grandis.*

## Introduction

Teak (*Tectona grandis* L.) is an important tropical timber species. It has a large natural distribution area in South East Asia (parts of India, Myanmar, Thailand and Laos (KAOSA-ARD, 1981)). It is also grown as an exotic species in several tropical countries in Asia, Africa, Central and South America (WHITE, 1991). Today, it is considered to be one of the most promising tropical plantation species (KEOGH, 1996). The timber is highly estimated due to appearance and valuable wood properties including high durability and resistance to chemicals (SANDERMANN and DIETRICHS, 1959). A number of studies therefore have focused on wood characteristics (see e.g. references in GOTTWALD and PARAMESWARAN, 1980; DAHMS, 1989). Numerical data on wood properties have been compiled by Tree Talk Inc. (1996).

For centuries teak wood has been traded according to its place of origin: Java-teak from Indonesia, Malabar-teak from The Malabar (India), Siam-teak from Thailand, Burma-teak from Myanmar, and wood quality has been said to be depending on the origin of the wood. Studies have compared the wood properties of different geographical sources in order to clarify this issue (e.g. SMEATHERS, 1951, comparing teak from Trinidad and Myanmar; BIANCHI, 1937, comparing teak from Indonesia, Thailand and Burma), but these studies could not separate the effect of environments from provenance variation.

Provenance trials (KEIDING et al., 1986; KJÆR et al., 1995; BINGCHAO et al., 1986) – comparing the performance of different seed sources in field trials – have revealed important differences between provenances in terms of growth and external stem quality (e.g. stemform, number of epicormics, buttressing) but these studies did not include internal wood quality traits.

The present study was initiated in order to shed light on the possible provenance variation in wood properties of teak. Three traits were examined in the present study: the percent of heartwood at breast height, the content of calcium, and the content of silica. Heartwood formation is a very important economical trait, especially because still shorter rotation ages are planned in teak plantations. Si% is known to influence the ease of processing, and content of only 0.05% is considered to affect machining properties negatively. Both silica and calcium phosphate can have impact on the appearance of the wood, which is a very important economic parameter.

## Material and Methods

*Description of trial and tested provenances*

A field trial with 5 provenances was established at St. Croix, the Virgin Islands, by the Institute of Tropical Forestry USDA, Forest Service, Rio Paedras, Puerto Tico as a part of an international series of provenance trials. The trial includes 5 provenances *(Table 1)* laid out in a 4-tree plot design with 12 randomised replications.

The trial is located in a wind exposed tract, and the location is not typical for teak plantations. Several trees have been turned over in a storm prior to the time of assessment. The health status (HEALTH) of the trees was therefore scored using three classes: 1 if trees were dead or of very poor health, 2 if trees were fallen, but still seemed healthy, and 3 if trees were healthy and standing (trees with health status 1 was later excluded from the analysis as described below).

*Measurements*

The field trial was assessed in 1991 when the trees were 17 years old. Wood discs were sampled at breast height from one tree in each plot and used for the further analysis (i.e. 12 trees per provenance). A number of external bole quality traits were recorded for the sampled trees at the location: persistence of terminal axis (the relative height of the unbroken axis), stem form, wood density, occurrence of protuberant buds, branch thickness (score) and bark thickness. Wood density was estimated as penetration of the pilodyn tester (see COWN, 1978). A detailed description of these traits and their assessment is given by KJÆR et al. (1995), where the trial number is IP047.

The percentage of the heartwood (HEART%) was determined from the wood disc. The area of the heart wood, and the full area of the disc (DISCSIZE), were measured with a planimeter. HEART% was calculated as heartwood area relative to the full area of the wood disc.

A small wood sample was taken from each disk and used for further analysis following a protocol modified after YOSHIDA et al. (1976). The samples were grinded into small particles (<0.2 mm). Calcium and silica were extracted by adding 50 ml acid mixture ($HNO_3$ : $H_2SO_4$: $HClO_4$ = 5:2:1) to 5 gm grinded sample. The mixture was kept at 320°C for 2 to 3 hours. Silica was extracted from the solution by filtration (Whatman filterpaper No. 1). The filter paper with residue of the extract was dried at 80°C, charred by a naked flame and turned to ash at 550°C for two hours. The ash were cooled in a desiccator and the weight of the sample determined. Silica (Si%) content was

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*Table 1.* – The origin of the studied provenances.

| Provenance | Location | Latitude | Longitude | Elevation m | Annual Rainfall mm |
|---|---|---|---|---|---|
| I-1 | Mount Stuart , Tamil Nadu, India | 10°30' | 76°47' | 671 | 2032 |
| I-2 | Nilambur, Kerala, India | 11°21' | 76°21' | 49 | 2565 |
| J | Ngliron, Indonesia | 7°12' | 111°22' | 150 | 1200 |
| A | Jamar, Ghana | 7°50' | 1°50' | 267 | – |
| L | Landrace, Mexico | 18°00' | 65°50' | – | 2000 |

calculated as the weight of the ash relative to the original 5 gm grinded sample. Calcium content (Ca%) was determined directly by atomic absorption of the filtrate.

*Statistical analysis*

A simple two-way, univariate, analysis of co-variance was used to test for significant differences between provenances in HEART%, Si%, and Ca%. Trees with HEALTH class 1 (dead or dying trees) was significant different from trees with class 2 and 3 in all three traits. "Health class 1" trees were therefore deleted from the data set prior to further analysis, because this variance was seen as a potential bias. DISCSIZE was included as covariate in the analysis in order to take the effects of size into account. Least square estimates of average performances were calculated from the analysis of co-variance. The variation due to both DISCSIZE and HEALTH was thus removed to the extent possible. The SAS-program package (SAS, 1990) was used for all data analyses.

Simple phenotypic correlations were calculated between all traits based on single tree values (e.g. correlations due to mixed effects of seed source and environment). Correlation between provenance average values, as well as genetic correlations, were not calculated because of the low number of provenances in the trial.

## Results

The results of the analysis of variance are presented in *table 2*. Significant differences (1%-level) between provenances were found for both HEART%, Ca% and Si%. HEART% correlated positively with DISCSIZE, whereas Ca% correlated negatively with DISCSIZE *(Table 2)*.

*Table 2.* – *F*-Tests (*F*) and levels of significance for differences between provenances (*DF* = 4, 33) and effect of DISCSIZE (*DF* = 1, 33).

| | Provenance | | DISCSIZE | |
|---|---|---|---|---|
| | *F* | *P* | *F* | *P* |
| HEART% | 4.34 | 0.006 | 5.54 | 0.025 |
| Ca% | 6.59 | 0.001 | 5.44 | 0.026 |
| Si% | 6.82 | 0.001 | 2.40 | 0.131 |

Large variation was observed within provenances for all three traits *(Table 3)*. Still, differences between provenance values were surprisingly large and significant. The average HEART% varied (after correction for differences in DISCSIZE) from 68% for the Kerala provenance (I-2) to 46% and 47% for the tested Indonesian and African landraces (J and A). Ca% varied (after correction for differences in DISCSIZE) from 0.22 for the African provenance (A) to 0.58 for the Tamil Nadu provenance (I-1). Average Si% was only 0.22% in the Mexican landrace (L) compared to 0.66% for the provenance from Kerala (I-2).

Phenotypic correlations are presented in *table 4*. Correlations are in general not significant, and none of the shown correlation are significant if tested according to the sequential BONFERRONI method (tests not shown, please refer to RICE (1988) for details on this method). Still, the tests for $r_p = 0$ are weak due to the low number of trees.

## Discussion

The present study includes trees from only five provenances, and the results should thus be seen only as a first indication of potential variability in the examined traits.

Percent of heartwood was found to differ significantly between provenances. The percent of heartwood is especially important when teak is grown in short rotation age, which may become increasingly important in the future (see also KJÆR and FOSTER, 1996). The present data show a positive correlation between tree size and heartwood percent as would be expected. Fast growth is therefore important, if teak are to be grown in short rotation.

HOFFMAN (unpublished) analysed two provenance trials in Thailand for sapwood %, colour and black streaks in wood samples. No statistical analysis is presented, but the findings presented by HOFFMAN (unpublished) in general support the results from the present investigation: important variation in heartwood % may be present, and heartwood production is therefore an interesting parameter to take into consideration when domesticating teak.

It is not possible to separate the large within provenance variation into genetic and environmental effects. It will be valuable to analyse progeny trials in future investigations in

*Table 3.* – *LS*-estimates for mean performance (*LSMEAN*) of the tested provenances. Standard error (*STDERR*) are LS-estimates of the standard error on the corresponding LS-means estimates. *Range* indicates the highest and lowest measurement in each provenance.

| Provenance id | | HEART% | | | Ca% | | | Si% | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *LSMEAN* | *STDERR* | *Range* | *LSMEAN* | *STDERR* | *Range* | *LSMEAN* | *STDERR* | *Range* |
| I-1 | Mount Stuart | 56.7% | 4.3% | 23-92% | 0.58% | 0.06% | 0.23-0.86% | 0.27% | 0.08% | 0.18-0.40% |
| I-2 | Nilambur | 67.2% | 4.4% | 37-85% | 0.52% | 0.06% | 0.12-0.92% | 0.66% | 0.08% | 0.20-1.40% |
| A | Jamar | 47.4% | 3.5% | 30-57% | 0.22% | 0.05% | 0.13-0.40% | 0.24% | 0.06% | 0.20-0.40% |
| J | Ngliron | 48.0% | 3.9% | 32-71% | 0.30% | 0.06% | 0.11-0.60% | 0.50% | 0.07% | 0.20-0.80% |
| L | Mexico | 60.0% | 4.2% | 35-69% | 0.35% | 0.06% | 0.14-0.64% | 0.22% | 0.07% | 0.20-0.40% |

*Table 4.* – Phenotypic correlations between the examined quality characters. Test for correlation = 0 is shown in italic.

| | Ca% | Si% | HEARTH% | DISCSIZE | Branch size | Protub. buds | Pilodyn | Stem form | Axis persistence | Bark Thick. |
|---|---|---|---|---|---|---|---|---|---|---|
| Ca% | 1 | 0.04 | 0.16 | -0.14 | 0.17 | -0.53 | 0.03 | -0.03 | -0.09 | 0.18 |
| | | *0.780* | *0.267* | *0.315* | *0.425* | *0.003* | *0.872* | *0.875* | *0.647* | *0.241* |
| Si% | | 1 | 0.14 | 0.00 | 0.09 | 0.14 | -0.05 | -0.07 | -0.13 | -0.02 |
| | | | *0.344* | *0.992* | *0.676* | *0.462* | *0.769* | *0.712* | *0.516* | *0.992* |
| HEARTH% | | | 1 | 0.38 | -0.21 | -0.27 | -0.14 | 0.09 | -0.03 | 0.39 |
| | | | | *0.007* | *0.312* | *0.154* | *0.389* | *0.633* | *0.867* | *0.011* |
| DISCSIZE | | | | 1 | 0.06 | -0.19 | -0.18 | 0.37 | -0.17 | 0.38 |
| | | | | | *0.772* | *0.315* | *0.254* | *0.056* | *0.384* | *0.011* |
| Branch size | | | | | 1 | -0.16 | 0.14 | -0.15 | -0.19 | -0.16 |
| | | | | | | *0.451* | *0.525* | *0.469* | *0.376* | *0.464* |
| Protuberant buds | | | | | | 1 | 0.05 | 0.07 | 0.32 | -0.46 |
| | | | | | | | *0.802* | *0.743* | *0.124* | *0.017* |
| Pilodyn | | | | | | | 1 | -0.36 | -0.20 | -0.25 |
| | | | | | | | | *0.071* | *0.351* | *0.112* |
| Stem form | | | | | | | | 1 | 0.52 | 0.24 |
| | | | | | | | | | *0.010* | *0.231* |
| Axis persistence | | | | | | | | | 1 | 0.02 |
| | | | | | | | | | | *0.942* |
| Bark thickness | | | | | | | | | | 1 |

High value for pilodyn indicates low wood density (*i.e.* negative correlation with pilodyn indicates positive correlation with wood density). High score for branch size indicates fine branches (*i.e.* positive correlation with branch size indicates positive correlation with fine branches).

order to estimate the heritability of these traits. Studies on wood quality in other species have shown that several economical important internal wood quality traits are under moderate to high degree of genetic control (ZOBEL and JETT, 1995). It seems as if teak fits into this pattern, but more investigations are required.

We do not know the exact economic importance of Si% and Ca% content, but the large differences observed in this study should attract more attention to the issue. DUPUY and VERHAGEN (1993) reports that silica content can be as low as 0.03% in timber from Ivory Coast to as high as 1.40% in timber from Togo. SHERMA (1971, here after in GOTTWALD and PARAMESWARAN, 1980) found silica content as high as 3% in wood samples from India. The observed silica contents in the present study is therefore not extreme for the species, but the variability is certainly interesting.


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