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Performance of Teak (Tectona grandis L. f.) Provenances Seventeen Years after Planting at Longuza, Tanzania

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Summary

A provenance trial for teak (*Tectona grandis* L.f.) containing seed sources from Tanzania (3), India (3), Java (1), New Britain (1), Nigeria (1), Sudan (1), Trinidad (1) and Vietnam (1) was established at Longuza, Tanzania, in December, 1965. Data has been compiled on survival, growth and stem characteristics for 17 years.

At 17 years, analysis of variance demonstrated fairly uniform survival and growth rates among the provenances. Height growth ranged from 22.4 to 26.4 m, with the Tanzania provenance (F) from Mtibwa showing the best growth. Similar values for DBH and volume production were 18.2 to 21.5 cm and 207.9 to 333.5 m³/ha respectively, with provenance (J) Coimbatore, India being the best for both parameters. All provenances grew remarkably well and gave yields comparable to site quality I and II reported in the literature for India, Central America and the Caribbean. Both stem straightness and self pruning were satisfactory for all provenances. Buttressing, forking and fluting were rare to non-existent. It is therefore recommended that selection for tree improvement be made from superior trees of all the provenances in order to maintain a broad genetic base for teak in Tanzania.

Key words: Teak provenances, growth and yield, Tanzania.

Zusammenfassung

Ein Herkunftsversuch für Teak (*Tectona grandis* L.f.) von Tanzania (3 Herkünfte), Indien (3), Java (1), Neu-Britanien (1), Nigerien (1), Sudan (1), Trinidas (1) und Vietnam (1) wurde im Dezember 1965 in Longuza, Tanzania begonnen. Wachstumsraten und Stammeigenschaften wurden nach siebzehn Jahren bewertet.

Überlebens- und Wachstumsraten waren ziemlich gleichartig in den verschiedenen Herkünften. Das Höhenwachstum bewegte sich zwischen 22,4 bis 26,4 m; die Herkunft von Mtibwa, Tanzanien hatte das beste Höhenwachstum. Der BHD variierte zwischen 18,2 und 21,5 cm, und die Volumenproduktion zwischen jeweils 207,8 und 333,5 m³/ha. Alle Herkünfte zeigten außerordentlich gute Wuchsleistungen, wobei die Herkunft Coimbatore, Indien, noch die besten Leistungen zeigte. Erträge waren vergleichbar mit jenen auf Standortsklassen I und II in Indien, Zentralamerika, und in den Karibischen Inseln. Stammform und natürliche Astreinigung waren ausreichend für alle Herkünfte. Brettwurzeln, Zwiesel und Spannrückigkeit kamen selten oder nie vor. Die Selektion für die Zuchtbaumauslese sollte aus Plusbäumen aller Herkünfte bestehen, um auf diese Weise eine breite genetische Basis für Teak in Tanzania zu gewährleisten.

Introduction

Teak (*Tectona grandis* L.f.) produces one of the world's most valuable timbers (BRYCE, 1966). Its natural range covers most of India, Burma, Thailand, Laos, Malaysia and Indonesia. Unlike many fine timber species of the tropics, the silviculture of teak is well understood (KADAMBI, 1972). Therefore, the species has been raised with success in plantations, both in its natural range and as an exotic in many countries (WOOD, 1967; KADAMBI, 1972; EGENTI, 1978; KEOGH, 1982).

The Germans introduced teak into Tanzania in the later part of the 19th century using seed from Calcutta, India. Later, trial plots were established in different parts of the country from 1905 to 1936 using seed sources from Burma, Java, India, and Thailand (WOOD, 1967). Good performance of teak in trial plots led to the establishment of teak plantations in Longuza, Mtibva and Rondo since 1952. Today, neanly 5000 ha have been planted with the species in Tanzania.

The plantation program in Tanzania generally uses three major seed sources. For long however, wide variations have been recognized in the performance of different teak ecotypes (BEARD, 1943; KEIDING, 1973; KEOGH, 1979). A provenance

trial was therefore established at Longuza in December 1965, to compare the performance of the three main local seed sources with different teak provenances from other countries. The report presents data on survival, growth and yield by the provenances 17 years after planting.

Materials and Methods

Planting Area

The planting area was located on the foothills of the East Usambara mountains at Longuza, near Tanga (4° 55' latitude and 38° 40' E longitude at 180 m.a.s.l.). The mean maximum temperatures vary from 27—33° C and the minimum from 19—23° C. The total mean annual rainfall is 1500 mm falling between October and May. The period June—September represents a dry season. The estimated potential evapotranspiration is 1320 mm annually. A detailed soil description for the area has been reported earlier (Anderson, 1963).

The natural vegetation comprise a lowland tropical evergreen forest with *Cephalosphaera usambarensis, Blaischmedia kweo, Newtonia buchananii, Chlorophora excesla, Antiaris usambarensis* and *Khaya nyasica* as the dominant canopy species. Prior to planting, merchantable timber was extracted from the proposed five ha trial site followed by clearfelling the rest of the vegetation and slash burning.

Seed Sources and Nursery operations

Twelve seed sources from Tanzania (3), India (3), Nigeria (1), Sudan (1), Vietnam (1), Trinidad (1), Java (1) and New Britain (1) were used for the study (*Table 1*).

Table 1. — Sources of *Tectona grandis* provenances grown at Longuza, Tanzania.

Provenance Code	Origin	Description of the Site*)		
		Latitude	Longitude	Altitude (m)
A	Kihuhwi, Tanzania	5°12'S	38°39'E	200
B	Mtibwa, Tanzania	6°80'S	37°38'E	400
C	Trinidad	10°00'N	61°00'W	-
D	Sudan	-	-	-
E	Saigon, Vietnam	11°00'N	107°00'E	-
F	Mtibwa, Tanzania	6°80'S	37°38'E	400
G	Keravat, New Britain	4°00'S	152°00'E	-
H	Lembaya, Java	7°00'S	110°00'E	-
I	Eastern Region, Nigeria	10°00'N	8°00'E	-
J	S. Coimbatore, India	11°00'N	79°00'E	-
K	S. Chanda, India	20°00'N	80°00'E	-
L	Hoshangabad, India	22°30'N	78°00'E	-

*) A dash means data is unavailable.

The seed lots were put in separate gunny bags and soaked for 72 hours in a small river where water was continuously running. They were then removed, sun dried and broadcasted in the Longuza forest nursery in November 1964. After 4 weeks, the seedlings were transferred to polythene tubes filled with forest soil. Planting was done in December 1965.

Experimental design and management

The experiment was arranged in a randomized block design, replicated 4 times. In each of the 4 blocks, individual provenances were planted in square plots containing 100 trees. The spacing between and within tree rows was 1.83 m. For purposes of measurement, the inner core of 64 trees formed the plot measurement unit. In addition, five guard rows were planted around the whole experiment to avoid edge effects.

The trial was clean weeded twice annually for the first three years and there after slashing of grass was continued annually until canopy closure in 1971. In June 1980, a selective thinning operation removed 30% of the crop. Emphasis was on the removal of the poorest individuals and maintenance of near uniform stocking between treatments (*Table 2*).

Data Collection and Analysis

Survival and height measurements were made annually for the first five years (Persson, 1971). Beginning year 6 in 1971, measurements were made biannually on diameter at breast height (DBH), toal height, height from the ground to the first living branch (extent of self pruning) and stem straightness. Data were also collected on forking, flutting, buttresing and flowering/seeding. In the final measurement, stem straightness was coded on a 5 point subjective scale described by Pinyopusarerk and Keiding (1981). In the scale, 5 points represents a straight tree and 1 point a very crooked tree, points 4, 3, and 2 being intermediate. Forking, fluting, buttressing and flowering were recorded as present or absent for each tree in a plot. Individual tree height and DBH measurements were used to determine volume production using Tanzania standard volume table for teak (Micski and Ackhurst, 1972). For each provenance, individual tree volumes were added up to obtain plot totals which were expanded to a hectare basis.

Plot values for survival, mean height, extent of self pruning, DBH, basal area and volume were subject to analysis of variance for randomized block design (Cochran and Cox, 1957). Survival percentages were transformed to arcsine values before statistical analysis. Significant provenance means were separated by Duncan's multiple range test (Alder and Roesller, 1972).

Results and Discussion

Survival

All the provenances studied survived well at Longuza (*Table 2*). Statistical analysis did not show significant differences in survival between provenances. At 10 years, survival ranged from 67% for the Keravat provenance (G) to 87% for the Kihuhwi provenance (A). The relatively lower survival for the Keravat (G), Saigon (E), S. Chanda (K) and Hoshangabad (L) provenances were due in part to a fire that affected Block No 1 and part of Block No 2 in February, 1967 (Persson, 1971). Some trees in these provenances were also attacked by a root rotting fungi (Hocking and Jafaar, 1966). After selective thinning in 1980, a satisfactory stocking was maintained for each provenance (*Table 2*).

The uniformly high survival of the provenances was expected in view of the generally high survival attained in teak plantations in Tanzania (Wood, 1967). In fact, plantation planting stock is raised in "flying nurseries[1])" and planted as stumps with 15—25 cm root stocks and 2—3 cm shoot. Splitting of the stumps to increase the planting stock has also been practised without significantly reducing field survival and early growth.

[1]) Flying nurseries are temporary nurseries established for each proposed planting site. The location of the nursery in a different place annually earns the term "flying".

Table 2. — Survival trends in 12 provenances of *Tectona grandis* at various ages after outplanting at Longuza, Tanzania.

Provenance	Survival (%)				
	1-	3-	5-	10-	15 years*
A - Kihuhwi, Tanzania	98	90	87	87	52*
B - Mtibwa, Tanzania	97	83	82	81	61
C - Trinidad	92	82	81	81	56
D - Sudan	97	85	83	83	55
E - Saigon, Vietnam	95	73	73	72	58
F - Mtibwa, Tanzania	96	79	79	79	55
G - Keravat, New Britain	95	68	67	67	48
H - Lembaya, Java	96	82	81	80	56
I - Eastern Region, Nigeria	96	85	84	84	58
J - S. Coimbatore, India	98	84	84	83	58
K - S. Chanda, India	94	77	76	76	58
L - Hoshangabad, India	92	79	78	78	57

*) Column represents stocking after thinning.

Height Growth

All the provenances grew very fast in the first 5 years (Persson, 1971), the initial fast growth rate then declined gradually (*Table 3*). At 17 years, the mean annual increment (MAI) ranged from 1.32 to 1.55 m compared to 2.29 to 2.70 m at 5 years. Similar observations have been made in Trinidad where the height in the best teak sites were equivalent to site quality I in India and Burma at 5 years but slowed down to site quality II at 25 years (Lamb, 1957). Despite the decrease in growth rates in Tanzania after 5 years, at 17 years, most provenances showed mean heights comparable to top height for 20 year old site quality I (23.16 m) in India (Kadambi, 1972). The Mtibwa provenance (F) from Tanzania gave the highest mean height (26.4 m) at final assessment, attaining statistical superiority over all the other provenances. Mean heights in the rest of the provenances were very uniform, ranging only from 22.5 to 24.1 m.

Most growth data for teak is presented in the literature as dominant height (mean height of the 100 tallest trees/ha) or top height (mean height of the largest 100 trees/ha) (Horne, 1966; Kadambi, 1972; Keogh, 1982). Direct comparisons of values in other studies with our data is therefore hampered by the generally lower stand height values obtained at Longuza at age 17 years, place all the provenances dominant or top height. However, the mean heights obtained at Longuza at age 17 years, place all he provenances studied within site quality I and II of India and Burma (Kadambi, 1972). In addition, 10 of the 12 provenances studied 1982) and Nigeria (Horne, 1966) which are based on dominant or top height.

It is generally recommended that a top height $\geqslant$ 24.0 m at 50 years is required for teak planting on a large scale (Keogh, 1979). Our data shows that all the provenances tested at Longuza will exceed this top height in less than 30 years. Based on this criteria therefore, these provenances are good candidates for teak afforestation in Tanzania and therefore provide a broad genetic base from which selection for tree improvement can be made.

Diameter and Volume Production

Data for DBH, basal area and volume production at 17 years are presented in *Table 4*. The mean DBH values were very uniform between provenances (18.8 to 20.9 cm) and generally higher than mean values reported for 15 to 20 year old teak in Nigeria (Egenti, 1978) and comparable to data of similar age in Malaysia (Tang and Jaffaar, 1979). Similarly, the basal area data recorded at Longuza (25.8 to 39.5 m^2/ha) are higher for all provenances than the 23.16 m^3/ha indicated for a 20 year old site quality I in India. (Kadambi, 1972). In addition, 10 of the 12 provenances studied gave higher volume production at 17 years than the 227 m^3/ha indicated for a 20 year old site quality I in India. When adjusted for age the yields in the poorest 2 provenances, K and L (see ranking *Table 4*) are also comparable to site quality I for India.

It is interesting to note too that the MAI estimated for quality I sites in Trinidad, Jamaica, and El Salvador range from 13—16 m^3/ha/year (Keogh, 1979) comparted with 13.7 to 19.6 m^3/ha/year for the best 10 provenances at Longuza. Longuza can therefore be classified as a prime site for teak growing in Tanzania.

Stem Form and Other Traits

Data on stem straightness and extent of self pruning, are also presented in *Table 4*. The most straight provenances were S. Coimbatore (J) and the two Mtibwa provenances

Table 3. — Height development in 12 provenances of *Tectona grandis* after planting at Longuza, Tanzania.

Provenance	Height (m) in different years							
	1-	2-	3-	4-	5-	10-	15-	17 years
A - Kihuhwi, Tanzania	2.1 ab*	5.1 a	9.5 a	11.1 a	13.5 a	18.8 a	20.6 a	23.8 a
B - Mtibwa, Tanzania	1.6 bc	4.0 b	8.5 a	10.7 a	13.2 ab	19.1 a	21.0 a	22.7 b
C - Trinidad	1.6 bc	4.8 ab	8.8 a	10.7 a	12.8 ab	18.7 a	20.2 ab	23.2 b
D - Sudan	1.8 b	4.5 ab	8.8 a	10.5 a	12.5 b	19.0 a	19.8 ab	23.2 b
E - Saigon, Vietnam	1.3 c	4.3 ab	8.4 a	10.5 a	12.7 ab	19.4 a	20.3 ab	23.7 b
F - Mtibwa, Tanzania	1.4 c	4.1 b	8.8 a	10.8 a	13.3 ab	19.1 a	21.2 a	26.4 a
G - Keravat	2.0 ab	4.1 b	8.7 a	10.4 a	12.8 ab	19.2 a	19.8 ab	23.7 b
H - Lembaya, Java	1.8 b	4.4 ab	10.0 a	11.0 a	13.5 a	19.1 a	20.5 ab	24.1 b
I - Eastern Region, Nigeria	1.3 c	4.3 ab	8.6 a	10.4 a	12.7 ab	18.5 a	19.0 b	23.1 b
J - S. Coimbatore, India	1.4 c	5.2 a	9.1 a	10.5 a	13.3 ab	19.5 a	21.3 a	22.5 b
K - S. Chanda, India	1.6 bc	4.1 b	8.6 a	9.4 a	11.6 c	19.1 a	20.2 ab	22.5 b
L- Hoshangabad	1.5 bc	4.5 ab	8.2 a	9.4 a	11.4 c	18.8 a	20.2 ab	22.5 b

*) Within a column, values with the same subscript are not statistically different, $p < 0.05$.

Table 4. — Diameter, stem characteristics and volume production by 12 provenances of *Tectona grandis* 17 years after planting at Longuza, Tanzania.

Provenance	Diameter DBH (cm)	Self Pruning (m)	Straight-ness (Scores)	Basal Area (m^2/ha)	Volume Production (m^3/ha)	Rank**
A - Kihuhwi, Tanzania	19.3 a*	13.7 a	4.1 ab	33.6 bc	280.9 ab	4
B - Mtibwa, Tanzania	19.8 a	13.5 a	4.2 ab	33.9 bc	288.3 ab	2
C - Trinidad	18.8 a	13.7 a	3.9 bc	32.7 bc	270.3 b	7
D - Sudan	19.5 a	14.1 a	4.0 abc	32.7 bc	279.3 ab	5
E - Saigon, Vietnam	20.9 a	17.7 a	4.0 abc	31.6 bc	272.2 b	6
F - Mtibwa, Tanzania	19.7 a	14.5 a	4.3 a	34.8 ab	285.8 ab	3
G - Keravat, New Britain	20.4 a	14.0 a	4.0 abc	27.2 cd	232.7 b	10
H - Lembaya, Java	19.6 a	14.2 a	4.1 ab	31.7 bc	264.6 b	8
I - Eastern Region, Nigeria	18.2 a	14.0 a	4.1 ab	31.0 bc	256.3 b	9
J - Coimbatore, India	21.5 a	14.7 a	4.3 a	39.5 a	333.5 a	1
K - S. Chanda, India	19.9 a	13.4 a	3.8 c	25.2 d	209.3 c	11
L - Hoshangabad, India	19.0 a	13.8 a	4.1 ab	25.8 cd	207.9 c	12

*) Within the same column values with the same subscript are not statistically different, $p < 0.05$.
**) Provenance ranking based on volume production.

(B and F). The least straight was one of the lesser well performing Central Indian provenance from S. Chanda (K). The other provenances were rather uniform with only a few trees being crooked.

The extent of self pruning was not significant between provenances. In general however, all provenances showed good self pruning properties, with most stem boles being more than 50% branch free.

Forking, fluting and buttresses were rare to absent in all provenances. However, buttressing may be expected at a later stage. Flowering started as early as 4 years in the Keravat provenance (G) which was nearly 50% flowering in 1969 (Persson, 1971). At 17 years, all provenances held moderate to abundant flowers/seeds. The early initiation of flowers in some provenances does not seem to have negatively affected their stem form as suggested in other studies (Egenti, 1978).

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Geographic Variation in Cones of Norway Spruce (Picea abies (L.) Karst.)

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Abstract

The geographic variation of Norway spruce (*Picea abies* (L.) Karst.) was studied using (*i*) provenances growing along the Italian Alpine margin; (*ii*) the relic provenance from the Tuscan Apennine (Italy); (*iii*) provenances from the extremes of the Norway spruce European natural range (Bulgaria and Norway).