SURVIVAL, GROWTH AND WOOD DENSITY OF *PINUS KESIYA* PROVENANCES AT BUHINDI, MWANZA, TANZANIA

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Key words: Pinus kesiya - provenance - survival - growth - wood density - Tanzania

CHAMSHAMA, S. A. O., CHINGONIKAYA, E. E., IDDI, S., MUGASHA, A. G., NSHUBEMUKI, L. & MALIMBWI, R. E. 1999. Kemandirian, pertumbuhan dan ketumpatan kayu di provenans *Pinus kesiya* di Buhindi, Mwanza, Tanzania. Objektif kajian adalah untuk menilai prestasi 13 provenans *Pinus kesiya* di Buhindi, Mwanza, Tanzania. Data mengenai kemandirian, diameter pada aras dada, ketinggian, bentuk batang dan ketumpatan asas diambil dari semasa ke semasa. Penilaian akhir dijalankan pada 18.3 tahun untuk kemandirian, garis pusat paras dada dan ketinggian. Kesemua

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pemboleh ubah berbeza dengan bererti (p< 0.05) antara provenans kecuali ketumpatan asas kayu. Provenans yang mempunyai prestasi memuaskan disyorkan bagi penanaman secara kecil-kecilan di Buhindi: Benguet Kabayan dan Zambales (ex Filipina), Dalat (ex Vietnam), Rhodesia (Zimbabwe) dan Chati (ex Zambia).

Introduction

Pinus kesiya Royle *ex* Gordon is a Southeast Asian species that ranges naturally from Assam (India) through Burma, Thailand, Laos, Cambodia, Vietnam and the Philippines (Forest Division 1982). The species was first introduced into Tanzania in 1935 at Kigogo Arboretum, Sao Hill (Madoffe *et al.* 1984). Several trials have since been established aimed at broadening the exotic tree species base and widening the genetic base of individual species so as to reduce risk of pests and diseases. The performance of *P. kesiya* trials located in 11 different locations in Tanzania is described by Nshubemuki *et al.* (1996). The ranges for mean annual height increment varied from 0.96 (Vikundi near Dar es Salaam) to 1.44 m (Kome Island near Mwanza). Ranges for mean annual breast height diameter increment (same locations) varied from 1.02 to 2.12 cm. These data do not include the present study site, i.e. Buhindi, Mwanza, Tanzania. The objective of this paper is to compare the performance of 13 provenances of *P. kesiya* at Buhindi.

Materials and methods

The trial (Experiment No. 868) is situated at Buhindi ($2^{\circ} 30$ 'S, $32^{\circ} 20$ 'E), Mwanza, Tanzania. The altitude is about 1200 m asl. The forest plantation area is gently sloping or flat plateau. The site of the experiment is flat. The soil is light yellowish-brown to reddish-yellow, structureless, gritty, sandy loam; pH varies from 4.5 to 6.0, while exchangeable bases vary from 1 to 5% (Scott 1962). This somewhat low fertility is possibly due to the soil being derived from acid gneisses, migmatites and associated granites and granitediorites (Saggerson 1962).

The area experiences two rainy seasons, long rains from February to May and short rains from October to December. The mean annual rainfall fluctuates between 760 and 1270 mm. The average minimum and maximum temperatures are 16 °C and 27 °C respectively.

The original vegetation of the area was a *Combretum - Comiphora - Terminalia* type of woodland with abundance of *Pennisetum* and *Hyperrhenia* grass species.

The trial is made up of 13 *P. kesiya* provenances summarised in Table 1. The trial was planted in a randomised complete block design with two replications. The plots are square measuring 7.5×7.5 m, each with 16 trees at a spacing of 2.5×2.5 m. The trial has a buffer zone of two rows of *Pinus caribaea* planted at a spacing of 2.5×2.5 m.

Provenance	Seed batch	Latitude	Longitude	Altitude (m)	Rainfall (mm)	Temperature (°C)
Choma, Zambia	0599	_	-	_	_	-
Madagascar*	1370	21° 30' N	40°00'E	1600	<u>:</u>	-
Chati, Zambia	0577	13°00'S	27° 14'E	1300	-	-
Kalaw Reserve, Burma	2090	20° 30' N	97°00'E	1300	-	-
Chichele, Ndola,						
Zambia	0528	13°00'S	27°00'E	1270	-	-
Assam, India	1849	25° 30'N	92°00'E	1400	1000	24.0
Rhodesia*	2213	18° 40'S	32° 50'E	1500	700	24.0
Samfya, Zambia	0540	11° 30'S	20° 30'E	1300	-	-
Thailand*	1965	16° 15'N	103°00'E	1400	1000	27.9
India*	1849	24° 58'N	92° 58'E	760	1700	20.8
Benguet Kabayan,						
Philippines	9262	16° 30'N	121° 20'E	1600	2500	18.0
Dalat, Vietnam	1871	12°00'N	108° 30'E	1600	1800	18.1
Zambales, Philippines	9269	15° 45'S	120° 15'E	600	2500	25.0

Table 1. Seed sources of Pinus kesiya provenances planted at Buhindi, Mwanza, Tanzania

*Name of location not available.

Seedlings were raised using standard cultural techniques (Forest Division 1982). The site was prepared by manual clearing of all vegetation and burning of residues. Planting was done in November 1976. Regular weeding (manual) was carried out until canopy closure which resulted in suppression of weeds.

Previous assessment data (at ages 0.8, 1.8, 2.7, 8.8 and 11.8 y) made for survival, breast height diameter (DBH) and height were obtained from the Tanzania Forestry Research Institute - Silviculture Research Centre, Lushoto. Final assessment was made at the age of 18.3 y (March 1995). At final assessment, data were collected on survival, DBH, height, stem quality and wood basic density.

All surviving trees were measured for DBH using a diameter tape and recorded to the nearest 0.1 cm. The DBH tally also gave the survival data. In each plot, four previously marked trees (small, medium and large sizes) were measured for height using Suunto hypsometer. Height was measured to the nearest 0.1 m.

Stem quality of all surviving trees was assessed using a three point scoring system as follows:

Form
Straight stem
Stem with slight bend
Crooked stem

Four defect-free trees (vigorously growing and disease/damage free) with straight boles and representative of the DBH ranges of each plot were sampled for wood basic density determination. An increment borer (6 mm internal diameter) was used to bore at breast height taking one core from each selected tree. Each core was inserted in the trough of fluting paper and immediately air dried to prevent fungal growth. The cores were then packed and stored in paper bags. In the laboratory, each core was divided into three equal portions representing inner, middle and outer wood. The cores were saturated in distilled water for at least 72 h in order to regain green condition. The green volume (GV) of each portion was then measured by the water displacement method. Next, the cores were oven dried at a temperature of 103 ± 2 °C to constant weight and cooled over silica gel before determining the oven dry (OD) weight. The basic density of each core portion was calculated as follows:

Wood basic density = OD/GV 1

The basic density values of core portions of each sampled tree were added and averaged.

Data were analysed for survival (%), DBH (cm), height (m), basal area per ha (m² ha⁻¹), stem quality and density (kg m⁻³) using routine statistical procedures. Analysis of variance (ANOVA) was done on all variables assessed. Prior to ANOVA arcsine transformations of percentage values and square root transformation of stem form scores were done to attain normality and equal variance (Sokal & Rohlf 1989, Kilinganire & Hall 1993). Significant treatment differences were separated by Duncan's New Multiple Range Test (Steel & Torrie 1980).

To identify the best and the worst overall provenances at 18.3 y, ordinal ranking was developed. This was done as follows. For each block and each significant variable evaluated, provenances were assigned ranks from the best (assigned 1 point) to the worst (assigned 13 points) performing provenance. Thereafter, ranks were added, then averaged and the overall score was taken as a basis of the overall provenance ranking.

Results and discussion

Survival

Significant differences in survival between provenances were only noted at final assessment (Table 2). At the age of 8.8 y, survival was highest in the Vietnam (Dalat) provenance (97%) and lowest in the Chati provenance (66%).

The drop in survival between 8.8 and 18.3 y was due to competition. At a spacing of 2.5×2.5 m, competition in some pines sets in at around 8 y of age (Micski 1970, Forest Division 1982).

Trials of *P. kesiya* provenances in various parts of the tropics have shown varying results. A trial at Sao Hill, Tanzania (Madoffe *et al.* 1984, Mugasha *et al.* 1996), showed outstanding survival of all provenances tested. Similar results have been reported for trials in Zimbabwe (Mullin *et al.* 1984), and Swaziland (Morris 1984), among others. Poor performance in some trials (Chagala 1984, Das & Stephan 1984) has been associated with off-site planting. According to Armitage and Burley (1980), *P. kesiya* performs best in lower montane, savanna and derived savanna lands (altitude 700–1800 m, rainfall > 700 mm).

Provonance						
	0.8	1.8	2.7	8.8	11.8	18.3
Choma, Zambia	81	81	75	75	69	65.6a
Madagascar	100	100	100	81	81	59.4a
Chati, Zambia	88	88	81	66	63	53.1ab
Kalaw Reserve, Burma	97	94	94	88	69	44.3bc
Chichele, Ndola, Zambia	94	94	94	84	72	49.6bc
Assam, India	97	94	91	88	63	45.6bc
Rhodesia	97	97	97	81	75	65.6a
Samfya, Zambia	100	100	100	94	75	68.8a
Thailand	100	100	100	88	87	78.1a
India	94	94	94	81	72	62.5a
Benguet Kabayan, Philippines	97	91	91	88	84	75.0a
Dalat, Vietnam	97	97	97	97	88	62.5a
Zambales, Philippines	100	100	97	94	81	78.1a
C.V (%) ²	6.91	7.51	10.4	16.3	17.7	18.0
Significance	³ ns	ns	ns	ns	ns	⁴ *

Table 2. Average survival percentage of Pinus kesiya provenances at Buhindi, Mwanza, Tanzania

¹Within this column figures for provenances followed by the same letter(s) are not significantly different (DMRT) at p < 0.05; ²C.V.(%) - coefficient of variability; ³ns - not significant (p < 0.05); ⁴* - significant at p < 0.05.

Diameter, height and basal area

Diameter and basal area differed significantly between provenances at all assessment occasions (Table 3). At the final assessment (18.3 y), breast height diameter and basal area were highest in the Vietnam (Dalat) and Philippines (Benguet Kabayan) provenances respectively. The lowest values were recorded in the Chichele provenance for diameter and Assam provenance for basal area.

Provenance	Age after planting (y)						
	8.8	11.8	18.3	8.8	11.8	18.3	
	Breast height diameter			Basal area			
Choma, Zambia	21.4a ¹	23.9a	24.9a	35.7ab	48.4ab	49.3ab	
Madagascar	17.6abcd	19.1bc	20.6ab	34.5ab	39.9bc	34.6bc	
Chati, Zambia	20.3ab	22.8ab	24.8a	35.7ab	39.7bc	41.3abc	
Kalaw Reserve, Burma	16.9bcd	19.4bc	24.2a	32.7abc	32.7bcd	35.7bcd	
Chichele, Ndola, Zambia	14.5dc	15.5cd	16.8b	23.5bc	23.5bc	21.5cd	
Assam, India	14.3d	15.8cd	16.9b	20.4c	20.4c	20.0d	
Rhodesia	20.9a	22.8ab	24.6a	45.2a	50.5ab	52.3ab	
Samfya, Zambia	17.8abcd	19.6bc	20.9ab	36.2ab	42.8ab	41.0abc	
Thailand	18.6ab	19.9ab	21.7a	44.2a	51.0ab	49.1ab	
India	18.2abc	20.4ab	20.9ab	36.5ab	39.3bc	37.0abc	
Benguet Kabayan, Philippines	20.3ab	22.3ab	24.5a	45.3a	54.6ab	58.8a	
Dalat, Vietnam	19.7ab	22.9ab	25.4a	46.6a	60.2a	53.3ab	
Zambales, Philippines	19.2ab	22.3ab	24.0a	45.9a	52.6ab	53.9ab	
C.V (%) ²	8.73	8.06	10.4	15.6	19.0	24.6	
Significance	³ *	*	*	*	*	*	

 Table 3. Breast height diameter (cm) and basal area (m² ha¹) of Pinus kesiya provenances at Buhindi, Mwanza, Tanzania

¹Within a column figures for provenances followed by the same letter(s) are not significantly different (DMRT) at p < 0.05.

²C.V.(%) - coefficient of variability; ³* - significant at p < 0.05.

Significant differences in mean height between provenances were noted at the last three assessment occasions (age 8.8, 11.8 and 18.3 y) (Table 4). At the final assessment, mean height was highest in the Vietnam (Dalat) provenance and lowest in the Assam provenance.

Provenance	Age after planting (y)							
	0.8	1.8	2.7	8.8	11.8	18.3		
Choma, Zambia	1.0	3.8	4.7	16.6abc1	21.5ab	24.2a		
Madagascar	1.0	2.4	4.8	16.1abc	20.4ab	23.8a		
Chati, Zambia	1.1	2.2	4.7	17.1abc	19.8abc	24.5a		
Kalaw Reserve, Burma	0.9	1.8	3.7	15.3abcd	19.4bc	24.3a		
Chichele, Ndola, Zambia	0.7	1.9	3.6	14.2cd	17.0cd	19.6bc		
Assam, India	0.9	1.8	3.6	13.1d	16.5d	17.9c		
Rhodesia	1.1	2.4	4.9	18.0ab	22.4a	24.7a		
Samfya, Zambia	0.9	2.4	4.6	16.0abcd	19.8abc	23.4a		
Thailand	1.1	2.6	5.1	16.2abcd	20.2ab	22.5ab		
India	1.0	2.3	4.8	17.2abc	20.4ab	24.2a		
Benguet Kabayan, Philippines	1.2	2.2	5.2	18.7a	22.3ab	25.3a		
Dalat, Vietnam	1.2	2.4	5.6	18.2ab	22.2ab	25.4a		
Zambales, Philippines	1.1	2.6	5.3	18.8a	22.6a	24.9a		
C.V (%) ²	18.0	27.8	16.1	8.26	5.98	6.43		
Significance	⁸ ns	ns	ns	¹ *	*	*		

Table 4. Height (m) of Pinus kesiya provenances at Buhindi, Mwanza, Tanzania

Within a column figures for provenances followed by the same letter(s) are not significantly different (DMRT) at p < 0.05;

 2 C.V.(%) - coefficient of variability; 3 ns - not significant (p < 0.05); 4 - significant at p < 0.05.

The diameters, heights, and basal areas obtained in this trial for the outstanding provenances are comparable with those in other *P. kesiya* trials growing in Tanzania (Forest Division 1982, Madoffe *et al.* 1984, Mugasha *et al.* 1996) and elsewhere (Granhof 1984, Morris 1984, Mullin *et al.* 1984).

This shows that site conditions at Buhindi are suitable for the growth of *P. kesiya*. The growth rates recorded in this study are equal to or at times surpass those of the widely planted exotics in Tanzania, namely *Pinus patula* and *Cupressus lusitanica*.

Stem form and basic density

At the age of 18.3 y, stem form differed significantly between provenances (Table 5). Differences in basic density were not significant (Table 5).

Stem form (straightness) is one of the most consistently criticised characteristics of *P. kesiya* (Chagala 1984, Gibson & Barnes 1984). The results of this study show that most of provenances tested have good stem form.

The basic density values are higher than those obtained in a *P. kesiya* trial at Sao Hill, Tanzania (Mugasha *et al.* 1996) but within the range reported for the species (Armitage & Burley 1980, Mullin *et al.* 1984).

Provenance	Stem from score	Wood base density		
Choma, Zambia	2.0a ¹	401		
Madagascar	2.0a	446		
Chati, Zambia	1.0b	443		
Kalaw Reserve, Burma	2.0a	441		
Chichele, Ndola, Zambia	1.0b	433		
Assam, India	1.0ь	425		
Rhodesia	2.0a	433		
Samfya, Zambia	1.5ab	477		
Thailand	1.5ab	471		
India	2.0a	427		
Benguet Kabayan,				
Philippines	1.5ab	434		
Dalat, Vietnam	2.0a	385		
Zambales, Philippines	1.5ab	498		
C.V (%) ²	21.0	15.6		
Significance	⁴ *	³ ns		

 Table 5.
 Stem form and wood basic density (kg m³) of 18.3-y-old

 Pinus kesiya provenances at Buhindi, Mwanza, Tanzania

¹Within a column figures for provenances followed by the same letter(s) are not significantly different (DMRT) at p < 0.05;

 2 C.V.(%) - coefficient of variability; 3 ns - not significant at p < 0.05;

⁴* - significant at p < 0.05.

Conclusion and recommendations

The experiment has never been thinned. Competition between trees reduced diameter growth and therefore basal area increment, thus affecting the ranking for these variables at the age of 18.3 y.

Similarly, volume calculations were not made due to the non- existence of volume tables or equation for the species in Tanzania. However, the high correlation that is known to exist between volume and the independent variables of basal area and height can be used to testify to the productivity of the species.

Using the results up to the age of 18.3 y as summarised by ordinal ranking (Table 6), all provenances except Kalaw, Assam and Chichele have shown satisfactory performance at Buhindi. These provenances should be introduced on small-scale planting at Buhindi and around Lake Victoria zone as alternative species to *P. caribaea*, the widely planted species at Buhindi, Rubya and Rubare where earlier trials are promising (Nshubemuki *et al.* 1996).

Provenance	Mean growth parameter rank					Overall	Overall
	Surv.1	Ht	DBH	BA	SF	mean	rank
Choma, Zambia	8	8	6	5	7	6.2	7
Madagascar	9	9	11	10	7	9.2	11
Chati, Zambia	10	5	2	7	1	5.0	5
Kalaw Reserve, Burma	13	6	5	11	7	8.4	10
Chichele, Ndola,							
Zambia	11	12	13	12	1	9.8	12
Assam, India	12	13	12	13	1	10.4	13
Rhodesia	5	4	3	4	7	4.6	7
Samfya, Zambia	4	10	10	8	7	7.8	8
Thailand	1	11	8	6	4	6.0	6
India	7	7	9	9	7	7.8	8
Benguet Kabayan,							
Philippines	3	2	4	1	4	2.8	1
Dalat, Vietnam	7	1	1	3	7	3.0	3
Zambales, Philippines	1	3	7	2	4	3.4	2

 Table 6. Ordinal ranking of statistically significant growth variables of 18.3-y-old

 Pinus kesiya
 provenances at Buhindi, Mwanza, Tanzania

¹Surv. - survival; Ht - height; DBH - diameter at breast height; BA - basal area; SF - stem form.

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