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SURVIVAL, GROWTH, STEM FORM AND WOOD BASIC DENSITY OF FIVE *PINUS MERKUSII* PROVENANCES AT BUHINDI, MWANZA, TANZANIA

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IDDI, S., MADUKA, M.S.B., MUGASHA, A.G., CHAMSHAMA, S.A.O., NSHUBEMUKI, L. & MALIMBWI, R.E. 1998. **Survival, growth, stem form and wood basic density of five *Pinus merkusii* provenances at Buhindi, Mwanza, Tanzania.** This study was carried out to assess the performance of five *Pinus merkusii* provenances (Phayao, Phai, Maisot and Surin from Thailand and Pekalongan from Java, Indonesia) planted at Buhindi, Mwanza, Tanzania, in terms of survival, height and diameter growth, stem form and wood basic density. Previous assessment data were obtained from the Lushoto Silviculture Research Centre, Tanzania. Final assessment was made at age 21.3 y. Statistical analysis of the data showed that there were significant differences ($p<0.05$) between provenances in survival at ages of 0.7, 11.2 and 21.3 y; in height on all assessment dates except at 0.7 y; and diameter at breast height and basal area at 11.2, 14.8 and 21.3 y. At 11.2 y, Phai provenance had the highest survival (80%) while Maisot provenance had the least survival (62.0%). At 21.3 y of age, Pekalongan and Phayao provenances had the highest and lowest survivals of 64% and 34% respectively. Pekalongan gave the highest mean height (22.1 m) and greatest basal area (53.7 $m^2 ha^{-1}$), while Phai had the least mean height (14.8 m) at 21.3 y. Stem form and wood basic density did not differ significantly ($p>0.05$). An ordinal ranking of the provenances using all parameters showed that the Pekalongan and

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Surin provenances had the best performance. Based on these findings, it is recommended that the two provenances be planted on a limited scale at Buhindi and similar environments following a reconciliation of production objectives and size of individual area(s) to be planted.

Key words: *Pinus merkusii* - provenances - survival - diameter - height - stem form - wood density - Tanzania

IDDI, S., MADUKA, M.S.B., MUGASHA, A.G., CHAMSHAMA, S.A.O., NSHUBEMUKI, L. & MALIMBWI, R.E. 1998. Kemandirian, pertumbuhan, bentuk batang dan ketumpatan asas kayu bagi lima provenans *Pinus merkusii* di Buhindi, Mwanza, Tanzania. Kajian ini dijalankan untuk menilai prestasi kemandirian, ketinggian dan pertumbuhan garis pusat, bentuk batang dan ketumpatan asas kayu lima provenans *Pinus merkusii* (Phayao, Phai, Maisot dan Surin dari Thailand dan Pekalongan dari Jawa, Indonesia) yang ditanam di Buhindi, Mwanza, Tanzania. Data taksiran sebelum ini diperoleh daripada Pusat Penyelidikan Silvikultur Lushoto. Taksiran akhir dibuat pada umur 21.3 tahun. Analisis statistik data tersebut menunjukkan bahawa terdapat perbezaan bererti ($p < 0.05$) dalam kemandirian di antara prover .ns pada umur 0.7, 11.2 dan 21.3 tahun; dalam ketinggian pada semasa tarikh taksiran kecuali pada 0.7 tahun; dan garis pusat paras dada dan luas pangkal pada 11.2, 14.8 dan 21.3 tahun. Pada umur 11.2 tahun, provenans Phai mempunyai kemandirian tertinggi (80%) manakala provenans Maisot mempunyai kemandirian terendah (62.0%). Pada 21.3 tahun, provenans Pekalongan dan provenans Phayao mempunyai kemandirian tertinggi dan terendah masing-masing pada 64% dan 34%. Pekalongan memberikan purata ketinggian yang tertinggi (22.1 m) dan luas pangkal yang paling besar (53.7 m^2 ha^{-1}) manakala Phai mempunyai purata ketinggian yang terendah (14.8 m) pada umur 21.3 tahun. Bentuk batang dan ketumpatan asas kayu tidak berbeza dengan bererti ($p>0.05$). Susunan mengikut kepentingan provenans menggunakan semua parameter menunjukkan bahawa provenans Pekalongan dan provenans Surin mempunyai prestasi terbaik. Berdasarkan penemuan ini, disyorkan supaya kedua-dua provenans ditanam secara terhad di Buhindi dan di persekitaran yang sama berikutan penyesuaian dengan objektif pengeluaran dan saiz setiap kawasan yang akan ditanam.

Introduction

Tanzania has about 89 000 ha of industrial plantations, 75 392 ha of which are planted with softwoods (Nshubemuki *et al.* 1996). The main softwood species planted are *Pinus patula, Cupressus lusitanica, P. elliottii* and *P. caribaea.* The success of any reforestation/afforestation programme depends on, among other things, choice of suitable species, diversifying such species and quality, and provenance selection. Thus, to meet this objective, a number of species and provenance trials have been established in Tanzania over a number of years. One such exotic pine introduced in Tanzania under this programme is *Pinus merkusii* Jungh & de Vriese. *Pinus merkusii* is one of the tropical pines growing from sea-level to over 1800 m. It extends from Burma, Laos, Cambodia and Vietnam in the northeast to Philippines to 2° south of the Equator (Cooling 1968). In its natural range, *P. merkusii* is a light demanding pioneer, normally confined to well-drained granitic sandy and alluvial soils (Cooling 1968). The mean annual rainfall ranges from 1000 to 2500 mm in humid climates with a dry season of two to four months.

Five provenances of *P. merkusii* originating from Thailand and Java were established at Buhindi, Mwanza, Tanzania in 1974. This study was carried out to assess the performance of the provenances in terms of survival, diameter and height growth, stem form and wood basic density.

Materials and methods

Experimental site

The study was carried out at Buhindi (2° 12'S, 32° E; 1200 m a.s.l) on the western part of Lake Victoria, in Mwanza Region. The area receives a mean annual rainfall of about 1100 mm with two peaks: short rains in November-December and long rains in March-May. The vegetation prior to clearing was lowland rain forest and savanna woodland. The dominant species included *Combretum, Commiphora* and *Terminalia* with fairly high growth of *Pennisetum* and *Hyperrhenia* spp. Soils are mainly grey loams with scattered rocks and occasional anthills. These soils are predominately sandy clay loam. The mineral soil pH ranges between 5.1 and 5.5, total N ranges from 0.04 to 0.07% and available P from 3.9 to 13.9 $\mu g\ g^{-1}$. Pedon sample means (0-50 cm depth) of selected soil properties are presented in Table 1.

Table 1. Means of selected soil properties of *Pinus merkusii* provenance experiment at Buhindi, Mwanza, Tanzania

Soil depth (cm)	pH	Electrical conductivity (dS m^{-1})	Organic C	Total N	Total P	Available P ($\mu g\ g^{-1}$)
			(%)			
LFH[1]	5.2[2]	0.456	-	0.13	0.039	17.3
0-10	5.1	0.117	-	0.07	0.041	13.9
10-20	5.3	0.052	-	0.04	0.043	9.5
20-30	5.3	0.025	-	0.04	0.039	3.9
30-40	5.3	0.022	-	0.04	0.040	4.2
40-50	5.5	0.021	-	0.04	0.032	1.9

[1]LFH - Leaf, fermented and humic layers of forest floor.
[2]Number of observations (n) per soil depth increment was 4.

Source of seed

The seed sources of the five provenances planted at Buhindi are shown in Table 2. In this investigation, there was no genetic check-lot (no indigenous species or naturalised land races of exotic tree species were used).

Table 2. Seed sources of *Pinus merkusii* provenances planted at Buhindi, Mwanza, Tanzania[1]

Provenance[2]	Batch No.	Origin		
		Country	Latitude	Longitude
Phayao	2014	Thailand	19°N	100°E
Phai	2019	Thailand	16°N	102°E
Maisot	2022	Thailand	16°N	99°E
Surin	2024	Thailand	15°N	103°E
Pekalongan	2026	Java	6°54'S	109° 37'E

[1]Source: Madoffe *et al.* (1984).
[2]All provenances were from Thailand except Pekalongan which was from Java.

Nursery techniques

The seeds were sown at Buhindi nursery on 28 April 1973 and germinated from 2 to 11 May 1973. After germination, seedlings were transplanted into polythene tubes. A standard potting mixture of 2:1 ratio forest soil to sand (Forest Division 1982)was used.

Experimental design

The experiment was established in January 1974 using a randomised complete block design with four replications. Within each block, each plot (provenance) was made up of 25 trees (5 × 5 rows) planted at 2.5 × 2.5 m spacing. Hence the plot size was 10 × 10 m. During planting out, however, provenance 2026 was replicated five times while provenance 2024 was replicated only three times. The trial covers an area of 0.5 ha and each plot has an area of 0.025 ha. The whole trial is surrounded by two rows of *Pinus caribaea.*

Field procedures

The planting site was cleared of vegetation, pitted and planted at a spacing of 2.5 × 2.5 m. Beating up was done to full stocking one year after planting. The area was weeded and access pruning was done at age 5 y. At the final assessment (March 1995), at age 21.3 y, the trial was found to be heavily invaded by weeds, especially *Lantana camara.* There were no reports of fire at the experimental site. The experiment was not thinned.

Data collection

Data were collected on survival, diameter at breast height (dbh), tree height, stem form and wood basic density. Previous assessment data at ages 0.7, 1.7, 2.7, 3.7, 4.6, 5.3, 11.2, and 14.8 y were obtained from the Lushoto Silviculture Research Centre files. Final assessment was made in March 1995 when the trial was 21.3 y old.

Diameter measurements and tree survival

All trees in a plot were measured for diameter at breast height (dbh) using diameter tape and recorded to the nearest 0.1 cm. The diameter tally also gave tree survival.

Height measurements

Tree heights were measured using Suunto hypsometer. Three biggest trees per plot were measured for height in order to obtain dominant heights. In addition, the heights of four other trees (two small and two medium-sized) were measured. Height was measured to the nearest 0.1 m.

Stem form assessment

Stem form was assessed on all surviving trees in each plot using scoring as follows:

Score	Form
1	Straight stem
2	Stem with a slight bend
3	Crooked stem

Wood basic density

For determination of wood basic density, four trees per plot representing the whole range of tree diameters were sampled. The trees sampled were free from obvious defects and had straight boles. At age 21.3 y, wood cores were taken at dbh point from the selected trees using an increment borer. The cores were inserted in the troughs of fluted paper and immediately air dried to prevent fungal growth. In the laboratory, each core was divided into three equal portions representing inner, middle and outer wood. The core portions were then soaked in distilled water for at least 72 h to regain green condition after which their volumes were measured using the maximum moisture method (water displacement). The portions were then oven dried at 103 ± 2 °C to constant weight and cooled over silica gel before determining their oven dry weight. The basic density of each core portion was calculated as oven dry weight divided by green volume.

Soil sampling and analysis for characterisation of the study site

Eight soil pits were located at random and dug to 70 cm in each block. Within each soil pit, soil samples were taken at the following depth intervals: LFH, 0-10, 10-20, 20-30, 30-40 and 40-50 cm. Soil samples taken from the same depth within each block were composted and a sub-sample taken for laboratory analysis. In the laboratory, soil samples were air dried and ground to pass a 2 mm-mesh sieve. Mineral soil particle size distribution was determined by the hydrometer method. Soil pH was determined by means of hydrogen electrode pH meter at distilled water: soil ratio of 2:1. A sub-sample of 2 mm-mesh sieved soil was analysed for total N, P and C and available P. Total N was determined by Kjeldahl's method. For total P, soil sub-samples were ashed in the muffle furnace at 550 °C for 1-2 h. P was then extracted by placing the ash in sulphuric acid followed by shaking for 24 h. Total P in the filtrate was estimated by the ascorbic acid method. Carbon was estimated by the loss on ignition method. Available P was determined using Bray I.

Data analysis

Data were analysed for survival (%), height (cm), dbh (cm), basal area (m^2 ha^{-1}), stem form (score) and wood basic density (kg m^{-3}) and were subjected to analysis of variance (ANOVA). All the analyses were based on plot means. Prior to ANOVA, arcsine and square root transformations of survival percentage and stem form score data respectively, were done in order to induce normality of variance. Means were separated using Duncan's multiple range test. Ordinal ranking of survival, height, dbh, basal area, stem form and wood basic density was made and the totals for each provenance were used to determine the best provenance (lowest sum) and the worst (highest sum).

Results and discussion

Survival

Table 3 shows a summary of survival for the five provenances. The table shows that survival declined with age. The decline in survival with age may be due to competition between trees. During final assessment of the experiment, dense weeds, especially *Lantana camara,* were observed. Statistical analysis of the survival data showed that there were no significant differences ($p>0.05$) between provenances at ages 1.7 to 5.3 y and 14.8 y. At age 21.3 y (final assessment) there were significant differences ($p>0.05$) between provenances. At this age, provenance Pekalongan (Java) had the highest survival of 64% while Phayao had the lowest survival of 34%. These trends are in agreement with the tenth year assessment by Madoffe *et al.* (1984). Karani (1973) reports a survival of between 79 and 95% for seven provenances of *P. merkusii* including the Pekalongan provenance grown in Uganda at 0.6 y and 13 - 63% at age 3.8 y. According to Karani (1973) the poor survival at 3.8 y was due to:

- the species being a poor starter,
- the species being sensitive to weed competition.

It has also been reported that *P. merkusii* is sensitive to weeds (Karani 1973, Whitmore 1973, Evans 1982, Pousujja 1984, Zobel *et al.* 1987). Weeds directly compete for moisture and nutrients. Sensitivity to weed competition implies the need for inescapable intensive weeding. Considering budgetary limitations, this establishment precondition seems to militate against recommending *P. merkusii* as an alternative species to *P. caribaea* at Buhindi.

Table 3. Survival (%) of *Pinus merkusii* provenances at Buhindi, Mwanza, Tanzania

Provenance[1]	Age (y) 0.7	1.7	2.7	3.7	4.6	5.3	11.2	14.8	21.3
Phayao	89.0ba[2]	87.2a	87.2a	81.0a	80.0a	65.3a	62.3ab	56.0a	34.0b
Phai	99.0a	88.0a	86.0a	86.0a	86.0a	84.0a	80.0a	61.0a	43.0ab
Maisot	91.0b	90.0a	80.0a	75.0a	73.0a	64.0a	62.0ab	59.0a	47.0ab
Surin	93.3ba	91.6a	90.7a	84.7a	84.0a	78.0a	71.0ab	69.3a	62.7a
Pekalongan	90.0b	86.0a	83.0a	78.0a	78.0a	69.3a	69.0b	68.0a	64.0a

[1]All provenances were from Thailand except Pekalongan which was from Java.
[2]Means followed by the same letter(s) within the same column are not significantly different at $p < 0.05$.

Height and diameter growth

Height was assessed at all assessment occasions. Diameter growth was assessed at 11.2, 14.8 and 21.3 y of age. Table 4 shows height, and Table 5 diameter growth for the provenances. Statistical analysis of the diameter data indicated that there were significant differences ($p<0.05$) at all assessment occasions. The Pekalongan (Java) provenance had consistently larger diameter growth followed by Surin. Cooling (1968) reported a dbh of 12.6 cm at 10 y and 28.6 cm at 20 y respectively for *P. merkusii* grown in Java. This is higher than results obtained in this study suggesting that the species performs better in Java than at Buhindi.

Table 4. Mean heights (m) of *Pinus merkusii* provenances at Buhindi, Mwanza, Tanzania at various ages

Provenance[1]	Age (y) 0.7	1.7	2.7	3.7	4.6	5.3	11.2	14.8	21.3
Phayao	0.2	0.2b[2]	0.3b	0.7c	1.5c	2.3c	9.2b	13.5c	15.8b
Phai	0.2	0.2b	0.3b	1.0c	1.6c	2.4c	10.4b	14.1bc	14.8b
Maisot	0.3	0.3b	0.4b	1.1c	1.8c	2.6c	10.9b	14.8bc	15.8b
Surin	0.2	0.3b	0.3b	1.6b	2.6b	4.2b	14.4a	17.2b	19.1a
Pekalongan	0.3	1.1a	1.1a	4.5a	6.5a	8.1a	15.6a	21.6a	22.1a

[1]All provenances were from Thailand except Pekalongan which was from Java.
[2]Means followed by the same letter(s) within the same column are not significantly different at $p < 0.05$.

Statistical analysis of the height data showed significant differences ($p<0.05$) in height growth from ages 1.7 y through 21.3 y and non-significant differences ($p>0.05$) at age 0.7 y. Data from previous assessment (i.e. before the age of 21.3 y) of the experiment indicate that the growth rate was slow especially for Phayao, Phai and Maisot provenances. These provenances showed a somewhat height growth stagnation at 0.7-3.7 y when compared to Pekalongan provenance. The small height growth for these provenances may be due to grass stage which tends to exist during the seedling stage. At that stage, the species hardly put on height increment; instead, growth is in the form of tufts of long needles that look like grass. According to Cooling (1968), Andrew (1973) and Evans (1982), *P. merkusii* provenances from Cambodia, Thailand, Laos, Myanmar (Burma) and Vietnam have grass stage. During the grass stage which lasts about 3-5 y, seedlings make very little height growth. A comparison made in Kuranda forest in Zambia (Evans 1982) showed that at age 4 y, *P. merkusii* had lower height growth of 1.05 m compared to 3.14 m of *P. caribaea* var. *caribaea*. In this study, the Pekalongan (Java) provenance had consistently higher tree heights at all assessment occasions.

Table 5. Diameter at breast height (dbh, cm) and basal area (Ba, m^2 ha^{-1})) for *Pinus merkusii* provenances at Buhindi, Mwanza, Tanzania

Provenance[1]	Age (y)					
	11.2		14.8		21.3	
	dbh	Ba	dbh	Ba	dbh	Ba
Phayao	11.5c[2]	14.6d	14.9c	17.0c	16.8c	12.3d
Phai	13.5c	19.3c	15.5c	19.5c	16.2c	15.6b
Maisot	12.4c	15.3d	15.3c	19.4c	16.3c	18.3c
Surin	17.1b	38.5a	20.7b	39.3b	23.7b	46.2b
Pekalongan	20.3a	34.1b	25.2a	27.8a	27.8a	53.7a

[1]All provenances were from Thailand except Pekalongan which was from Java.
[2]Means followed by the same letter(s) within the same column are not significantly different at $p< 0.05$.

Basal area

Basal area was assessed at 11.2, 14.8 and 21.3 y of age. The Pekalongan (Java) provenance had consistently higher basal area than the other provenances except for the Surin provenance at the first two ages (Table 5). Statistical analysis, however, showed no significant differences ($p>0.05$) in basal area among the provenances.

Stem form

Table 6 gives the mean stem form scores of the five provenances. Although there were no significant differences in the mean scores, the table shows that the Maisot provenance had the lowest mean score, hence the least incidence of lean stem. The Pekalongan, Java provenance had the most crooked stems followed by the Phai provenance. Results from this study are in agreement with the tenth year assessment reported by Madoffe *et al.* (1984) who found that the Pekalongan provenance was the most crooked while Maisot and Phayao provenances had the least stem lean. Cooling (1968) reported that young *P. merkusii* trees, though initially crooked, are usually straighter (have better form) at maturity.

Table 6. Mean score of stem form and wood basic density (kg m^{-3}) of 21.3-y-old *Pinus merkusii* provenances at Buhindi, Mwanza, Tanzania

Provenance[1]	Stem form score	Basic density (kg m^{-3})
Phayao	1.6	435.5
Phai	1.7	425.5
Maisot	1.5	437.0
Surin	1.6	430.7
Pekalongan	1.8	480.0

[1]All provenances were from Thailand except Pekalongan which was from Java.

Wood basic density

Wood basic density was assessed at 21.3 y only. Basic density varied from 425 kg m^{-3} for the Phai, Thailand provenance to 480 kg m^{-3} for the Pekalongan, Java provenance (Table 6). Analysis of variance indicated no significant differences ($p>0.05$) between provenances. These results are in agreement with results obtained in Cambodia and Thailand (Cooling 1968, Andrew 1973) but are lower than the value of 570 kg m^{-3} reported by Chudnoff (1984). This difference may be due to age of the material. The value reported by Chudnoff (1984) is a mean for mature trees which may be more than 22 y old. Older trees are reported to have a high content of resin which increases the density of the wood.

Ordinal ranking of provenances

The ordinal ranking of the five provenances for each of the tree characteristics assessed at 21.3 y showed that Pekalongan and Surin provenances were outstanding (Table 7). The Maisot (Thailand) provenance is in between, while the two other Thailand provenances, Phai and Phayao, were strikingly different.

Table 7. Ordinal ranking of 21.3-y-old *Pinus merkusii* provenances grown at Buhindi, Mwanza, Tanzania

	Rank							
Provenance[1]	Surv.	Height	dbh	Ba	Stem form	Bd	Mean	Overall
Phayao	5	4	4	5	3	3	4	4
Phai	4	5	5	4	4	2	4	4
Maisot	3	3	3	3	1	5	3	3
Surin	2	1	2	2	2	4	2.2	2
Pekalongan	1	2	1	1	5	1	1.8	1

[1]All provenances were from Thailand except Pekalongan which was from Java.

Practical implications

Results from this study show that the Pekalongan (Java), Surin and Maisot (Thailand) provenances of *P. merkusii* had the best performance in that order at Buhindi, Mwanza, Tanzania. Table 8 relates this performance with other pine species that are extensively planted at Buhindi (Nshubemuki *et al.* 1996). It can be seen that although survival seems to be comparable, mean annual increments (in height and dbh) for these provenances seem to be slightly higher than those of *P. caribaea* and *P. oocarpa*. Thus, based on volume production consideration, these *P. merkusii* provenances might be similar or superior to *P. caribaea* and *P. oocarpa* trials that are already existing at Buhindi. However, the choice for *P. merkusii* may be limited by the poor stem form shown by the *P. merkusii* provenances tested at Buhindi. Although observations by Cooling (1968) suggest that the stems tend to straighten toward stand maturity, it is reasonable to suggest that recovery is likely to be affected. If production is focused on pole production this limitation is tolerable. Since there was variation in stem form among trees within each provenance, there is a possibility of producing intra-specific hybrid of improved stem form. Additionally, careful selection of provenances in *P. merkusii* will enhance the performance of the species and make it compete with *P. caribaea* and *P. oocarpa* grown in the region.

Table 8. Performance of *Pinus merkusii* provenances in relation to other pines extensively planted at Buhindi, Mwanza, Tanzania

Species/ provenances	Age (y)	Survival (%)	Mean annual increment Height (m)	Mean annual increment dbh (cm)
Pinus caribaea	17.7	64	1.60	1.52
	9.6	70	0.74	0.67
Pinus oocarpa	12.6	67	0.74	0.67
Pinus merkusii provenances				
Pekalongan		68	1.46	1.70
Surin	14.8	69	1.16	1.40
Maisot		59	1.00	1.03

Basic density assessment has shown that the variation ranges from 425.5 (Phai) to 480 kg m^{-3} (Pekalongan). Bryce (1967) gives a range of 470 to 570 kg m^{-3} as basic density for *P. caribaea*. This indicates that for simple construction, *P. merkusii* might be preferred for its wood is relatively lighter and may be easy to impregnate.

It has been observed that sensitivity to weed competition reduces the prospects of using *P. merkusii* as alternative plantation species at Buhindi. The position might be somewhat different at the level of woodlots for the areas involved are small. It would therefore appear that use of *P. merkusii* at Buhindi calls for reconciling production objectives and ownership (i.e. size of individual areas to be planted).

Conclusion and recommendation

Results from this study show that at 23.1 y the Pekalongan (Java) and Surin (Thailand) *P. merkusii* provenances had the best performance at Buhindi, Mwanza, Tanzania. It is therefore recommended that the two provenances be considered for planting on a limited scale at Buhindi and similar environments following a reconciliation of production objectives and the size of individual areas to be planted.

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