GROWTH PERFORMANCE OF *AZADIRACHTA INDICA* PROVENANCES IN MOROGORO, TANZANIA

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ANDREW, S. M., MALIONDO, S. M. S., MTIKA, J., MSANGA, H. P. & NSOLOMO, V. R. 2004. Growth performance of *Azadirachta indica* provenances in Morogoro, Tanzania. The growth performance of 20 provenances and one land race of *Azadirachta indica* (neem) from 10 countries was evaluated at Mkundi Fuel Wood Forest Reserve in Morogoro region, Tanzania. The experiment was established in a randomised complete block design with six replications. This is one of the provenance trials under the International Neem Network. The assessment involved tree height, diameter at breast height, number of branches, stem quality, survival and total volume after 58 months of planting. Except for survival, differences between provenances as well as between provenance and land race were observed in all the parameters studied. Provenances Ban Bo, Ban Nong (Thailand), Ghaati (India), Doi Tao (Thailand), Ramanaguda (India), Vietianne (Vietnam), Kuliyapitiya (Sri Lanka), Annur, Mandore, Chitradunga (India) and Bandia (Senegal) were the best performers. Yezin (Myanmar), Allhabad (India), Balharshalt (Nepal), Sunyan (Ghana), Lamahal, Geta (Nepal), Chamwino (Tanzania), Chanatorin (India), Muttan, Tibbi Laran (Pakistan) were marginal performers. It is recommended that further assessments on provenance performance be carried out up to half rotation age for identification of promising provenance.

Key words: Neem – land race – breeding – growth – seed production – miombo woodland – afforestation

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pada paras dada, bilangan dahan, kualiti dahan, kemandirian dan jumlah isi padu pokok berumur 58 bulan. Terdapat perbezaan antara provenans dengan provenans dan antara provenans dengan ras daratan untuk semua parameter yang dikaji kecuali kemandirian. Provenans Ban Bo, Ban Nong (negeri Thai), Ghaati (India), Doi Tao (negeri Thai), Ramanaguda (India), Vietianne (Vietnam), Kuliyapitiya (Sri Lanka), Annur, Mandore, Chitradunga (India) dan Bandia (Senegal) merupakan provenans terbaik. Provenans Yezin (Myanmar), Allhabad (India), Balharshalt (Nepal), Sunyan (Ghana), Lamahal, Geta (Nepal), Chamwino (Tanzania), Chanatorin (India), Muttan, Tibbi Laran (Pakistan) menunjukkan prestasi yang sederhana. Adalah disyorkan supaya penilaian prestasi provenans dilanjutkan sehingga separuh umur pusingan bagi menentukan provenans yang berpotensi.

Introduction

Since mid-1960s there has been large increase in demand for agricultural land and wood, which has accelerated deforestation in Tanzania. To rectify the situation, fast-growing exotic tree species were introduced extensively in the country for plantation establishment. Among them were *Tectona grandis, Terminalia* spp., *Pinus elliottii, P. caribaea, P. kesiya, Cupressus lusitanica,* eucalypts, *Acacia mearnsii* and *Cedrella mexicana.* Although introduced several years back, it is only recently that *Azadirachta indica* (neem) has been acknowledged as one of the species with great potential for rural development (Kaale 1984).

Although neem is thought to have originated in Assam and the native dry areas of India, Malaysia, Indonesia, Pakistan, Thailand, Sri Lanka and Myanmar, it is in India that the tree is widely used (Anonymous 1992). The major uses include ornamental purposes, oil (seed), timber, fuelwood, fodder (leaves, oil-seed cake), insecticides, windbreakers, bee forage and for soil conservation (Schmutterer 1990, Mbuya *et al.* 1994).

A fascinating tree, neem (Schmutterer & Ascher 1984) is a fast-growing medium size tree, which under ideal conditions can reach a height of 25 m but when mature and well grown is normally 15 to 20 m tall and 2.5 m in girth (Kaale 1984, Anonymous 1992). Neem performs best in areas with annual rainfall of 400 to 1200 mm. However, it has been planted in regions with rainfall up to 2000 mm and even successfully introduced in areas where rainfall is as low as 150 mm (Kaale 1984). Variations in growth and morphological characteristics are anticipated when neem is grown under different conditions due to genetic adaptations of the provenance to local conditions (Otegbeye 1991). This study was undertaken to evaluate the performance of 20 different *A. indica* provenances and one land race in Tanzania. The information is useful for planning breeding work, generalised planting recommendations and for afforestation programme recommendations in areas similar to Morogoro, Tanzania.

Materials and methods

Study area

The experiment was established at Mkundi Fuel Wood Forest Reserve (6° 40' S, 37° 39' E, 475 m asl) about 20 km from Morogoro town. Rainfall is bimodal with

the long rains starting from March till May and the short rains lasting from October till December. The mean annual rainfall is about 800 mm. Temperature is minimum (16 to 18 °C) from June till July and maximum from October till December and may reach 35 °C. The site is generally flat and soils are sandy loam with pH 6.5. The vegetation prior to site preparation was Miombo woodland dominated by *Dalbergia melanoxylon, Brachystegia* spp., *Balanites aegyptica, Dichrostachys cinerea, Acacia* spp., *Albizia* spp. and *Sclerocarya birrea.*

Seed sources

The *A. indica* trial consisted of 20 provenances and one local land race from 10 different countries (Table 1). The land race was from Chamwino, Dodoma, Tanzania. Potted seedlings were raised at the National Tree Seed Centre, Morogoro using standard cultural techniques (Anonymous 1982). Then seedlings were planted at Mkundi Fuel Wood Forest Reserve.

Experimental design

The site was prepared by manual clearing of all vegetation, burning residues, ploughing and harrowing by a tractor, followed by staking and pitting. Planting of potted seedlings using standard cultural techniques (Anonymous 1982) was done and the distance between blocks or plots was 3.5 m. The experiment had

Table 1 Seed sources for 20 *Azadirachta indica* provenances and one land race planted in Mkundi

Seed source	Provenance	Country	Accession No.	Latitude	Longitude	Altitude (m)	Mean annual rainfall (mm)
03/IND/Man	Mandore	India	CIRAD 95/10300N	26° 18' N	73° 01' E	224	250
04/IND/Chl	Chitradunga	India	CIRAD 95/10301N	14° 02' N	76° 04' E	615	417
05/IND/All	Allhabad	India	CIRAD 95/10304N	25° 28' N	81° 54' E	320	950
06/IND/Ano	Annur	India	CIRAD 95/10305N	11° 17' N	77° 07' E	360	875
07/IND/Gha	Ghaati	India	CIRAD 95/10302N	13° 22' N	77° 34' E	950	741
08/IND/Sag	Chanatorin	India	CIRAD 95/10299N	21° 51' N	78° 45' E	527	1405
09/IND/Bal	Balharshalt	India	CIRAD 95/10300N	19° 51' N	79° 25' E	250	1000
10/IND/Ram	Ramanaguda	India	CIRAD 95/10296N	19° 05' N	83° 49' E	250	1100
11/LAO/Vle	Vietianne	Vietnam	DFSC 01945/95	18° 00' N	102° 45' E	180	1540
12/MYA/YEZ	Yezin	Myanmar	DFSC 01954/95	19° 51' N	96° 16' E	100	1269
14/NEP/Lam	Lamahal	Nepal	DFSC 01959/95	27° 52' N	82° 31' E	440	1500
15/NEP/Get	Geta	Nepal	DFSC 01961/95	28° 46' N	80° 34' E	170	1725
16/PAK/Tib	Tibbi Laran	Pakistan	DFSC 01957/95	28° 24' N	70° 18' E	115	140
17/PAK/Mul	Muttan	Pakistan	DFSC 01958/95	30° 11' N	71° 29' E	200	276
18/SRI/Kul	Kuliyapitiya	Sri Lanka	DFSC 01962/95	07° 80' N	80° 00' E	100	1397
20/THA/Non	Ban Nong	Thailand	DFSC 01943/95	14° 05' N	99° 40' E	40	1145
21/THA/Bo	Ban Bo	Thailand	DFSC 01942/95	16° 17' N	103° 35' E	150	1400
22/THA/Doi	Doi Tao	Thailand	DFSC 01944/95	17° 57' N	98° 41' E	300	1250
23/GHA/Sun	Sunyan	Ghana	DFSC 01956/95	07° 21' N	02° 21'W	1000	1400
24/SEN/Ban	Bandia	Senegal	DFSC 01963/95	14° 30' N	17° 02'W	50	436
25/Tan/Cha	Chamwino	Tanzania	DFSC 01941/95	06° 20' S	35° 50' E	1030	475

two guard rows made up of the land race. A randomised complete block design (RCBD) with six replications was adopted. The number of trees per replication was 336 trees and spacing between plants was 3 m. Weeding was done thrice to reduce competition from unwanted vegetation, once in the dry season and twice in the rain season. Pruning was done only once and no thinning had yet been carried out.

Data collection

Tree height was measured using Suunto Hypsometer or a graduated pole and tree diameter at breast height (DBH) measured by calliper to the nearest 0.1 cm. The DBH tally gave survival data. Tree branches with diameter ≥ 2 cm were also counted. Stem quality was assessed and categorised into three groups: straight stem given number 1 and crooked stem given 3. Tree volume was calculated based on the following formula:

$$V = fdh$$

where

V = total volume of individual tree (m^3)
f = form factor of 0.6
d = DBH (cm)
h = height of an individual tree (m)

Analysis

Data analysis was carried out using Statistical Analysis System Programme (1991). Survival percentage (arc sine transformed), height, DBH, branch number, stem quality and total volume were subjected to analysis of variance (ANOVA) using plot means. Student-Newman-Keuls Test following Steel and Torrie (1987) was used to separate provenances that were significantly different. The General Linear Model (GLM) procedure of Statistical Analysis System Programme was used for statistical analyses. To identify the best and the worst overall performing provenance/land race at 58 months, ordinal ranking was adopted. For each variable evaluated, provenances were assigned ranks from the best (assigned 1 point) to the worst (assigned 21 points) performing provenance. Thereafter, ranks were added, averaged and the overall score was taken as a basis of the overall provenance ranking.

Results

Survival

Provenances were not significantly different ($p > 0.05$) in survival at the age of 58 months (Table 2). Transformed survival ranged from 75% for Mandore to 95% for Bandia and Ghaati provenances. Survival was poor for Mandore (75%) and Chamwino (78%).

Height and DBH

Statistical analysis showed that there were significant ($p < 0.05$) differences in mean height between provenances and between provenance and land race studied (Table 2). The provenance of Mandore performed poorly in height (4.0 m) while that of Doi Tao performed the best (7.8 m). There were highly significant differences ($p < 0.0001$) between DBH for the provenances/land race. Tibbi Laran showed the least DBH (4.7 cm) while Doi Tao performed the best with 10.7 cm.

Number of branches, stem quality and volume growth

The number of branches of trees was significantly different ($p < 0.001$) between provenances (Table 2). Mean number of branches ≥ 2 cm ranged from 7 for Geta to 14 for Ban Bo. Generally, all 20 provenances had good stem quality. Statistically, stem quality differed significantly ($p < 0.001$) between provenances (Table 3). The

Table 2 Transformed (arcsine) and untransformed survival percentages, mean height, DBH and number of branches of 58-month-old *Azadirachta indica* provenances / land race grown in Mkundi

Provenance / land race	Country	Untransformed survival (%)	Transformed survival (%)	Mean height (m)	DBH (cm)	Number of branches ≥ 2 cm
Mandore	India	60.0	75.0 a	4.04 g	4.70 f	8 d
Chitradunga	India	71.1	89.6 a	6.00 bcde	7.10 cde	10 abcd
Allhabad	India	73.2	91.7 a	5.70 bcde	6.40 def	10 abcd
Annur	India	66.7	84.4 a	5.60 bcde	7.10 cde	13 ab
Ghaati	India	76.8	94.8 a	6.50 bc	8.20 cd	10 abcd
Chanatorin	India	66.7	84.4 a	4.74 efg	5.90 ef	9 bcd
Balharshalt	India	64.3	81.3 a	5.30 cdef	6.80 de	10 abcd
Ramanaguda	India	70.1	88.5 a	5.90 bcde	7.40 cde	12 abc
Vietianne	Vietnam	65.8	88.3 a	6.30 bcd	8.70 dc	9 abcd
Yezin	Myanmar	73.2	91.7 a	5.30 cdef	5.50 ef	12 abc
Lamahal	Nepal	71.1	89.6 a	5.01 defg	6.30 def	9 bcd
Geta	Nepal	67.5	85.4 a	5.40 cdef	6.50 def	7 d
Tibbi Laran	Pakistan	62.8	79.2 a	4.08 gf	4.65 f	8 cd
Muttan	Pakistan	65.1	82.3 a	5.01 defg	6.10 def	9 cd
Kuliyapitiya	Sri-Lanka	71.1	89.6 a	5.50 bcde	7.20 cde	12 abcd
Ban Nong	Thailand	67.5	85.4 a	6.40 bcd	8.90 bc	12 abc
Ban Bo	Thailand	72.0	90.5 a	6.70 b	10.00 ab	14 a
Doi Tao	Thailand	70.1	88.5 a	7.80 a	10.72 a	11 abcd
Sunyan	Ghana	62.8	79.2 a	5.40 cdef	6.40 def	12 abc
Bandia	Senegal	76.8	94.8 a	5.40 cdef	6.70 de	11 abcd
Chamwino	Tanzania	62.1	78.1 a	5.20 cdefg	6.20 def	10 abcd
P and F-value			ns	$p < 0.05$	$p < 0.001$	$p < 0.001$
RMSE			14.31	0.71	1.074	2.17
CV			16.63	12.68	15.28	21.19

Values followed by the same letter in the same column are not significantly different at the 0.05 probability level. ns = not significant; RMSE = root mean square error; CV = coefficient of variation (%)

Table 3 Stem quality and volume of the 58-month-old *Azadirachta indica* provenances/land race grown in Mkundi

Provenance	Country	Stem quality	Volume (m^3)
Mandore	India	1.40 abcd	0.0560 f
Chitradunga	India	1.77 d	0.1710 cdef
Allhabad	India	2.00 d	0.1310 def
Annur	India	1.75 cd	0.1700 cdef
Ghaati	India	1.65 abcd	0.2400 cde
Chanatorin	India	1.50 abcd	0.1100 ef
Balharshalt	India	1.68 bcd	0.1600 cdef
Ramanaguda	India	1.53 abcd	0.1740 cdef
Vietianne	Vietnam	1.00 a	0.2600 cd
Yezin	Myanmar	1.74 bcd	0.0900 f
Lamahal	Nepal	1.59 abcd	0.1252 def
Geta	Nepal	1.51 abcd	0.1400 def
Tibbi Laran	Pakistan	1.37 abc	0.0600 f
Muttan	Pakistan	1.30 ab	0.1000 ef
Kuliyapitiya	Sri-Lanka	1.56 abcd	0.1500 def
Ban Nong	Thailand	1.17 ab	0.2800 bc
Ban Bo	Thailand	1.19 ab	0.3700 b
Doi Tao	Thailand	1.35 ab	0.5000 a
Sunyan	Ghana	1.72 bcd	0.1270 def
Bandia	Senegal	1.60 abcd	0.1400 def
Chamwino	Tanzania	1.58 abcd	0.1250 def
P and F-value		$p < 0.001$	$p < 0.001$
RMSE		0.2461	0.0725
CV		16.13	41.78

Values followed by the same letter in the same column are not significantly different at the 0.05 probability level. RMSE = root mean square error; CV = coefficient of variation (%)

provenance Vietianne had the best stem quality (1.0), followed closely by Muttan (1.3) and Ban Nong (1.2). Table 3 shows that there are significant differences ($p < 0.001$) in volume between provenances and between provenance and local land race at Mkundi. Volume of *A. indica* at the age of 58 months ranged from 0.06 m^3 for Mandore to 0.50 m^3 for Doi Tao.

Ordinal ranking of provenances

An ordinal ranking for the provenances / land race for a given morphological growth trait was developed (Table 4). The overall best performing provenances were Ban Bo and Ban Nong of Thailand, while the worst performers were Muttan and Tibbi Laran from Pakistan.

Discussion

The study showed that there were significant variations in growth performance between provenances for DBH, height, number of branches, stem quality and volume. Rawat (1994) and Tewari *et al.* (1996) reported similar results in arid areas

Table 4 Ordinal ranking of 58-month-old *Azadirachta indica* provenances / land race grown in Mkundi

Provenance / land race	Country	Mean height	Mean DBH	Mean no. of branches	Mean stem quality	Mean survival	Mean volume	Mean score	Overall ranks
Yezin	Myanmar	14	19	4	18	3	19	11.14	10
Ban Bo	Thailand	2	2	1	3	5	2	3.71	1
Ban Nong	Thailand	4	3	3	2	11	3	6.14	2
Doi Tao	Thailand	1	1	8	5	10	1	6.43	4
Vietianne	Vietnam	5	4	15	1	15	4	8.14	6
Chamwino	Tanzania	16	16	14	12	20	15	14.00	15
Chitradunga	India	6	8	12	20	6	7	9.71	8
Ghaati	India	3	5	10	15	2	5	6.29	3
Mandore	India	21	20	20	7	21	21	18.71	8
Allhabad	India	8	14	11	21	4	13	11.86	11
Annur	India	9	9	2	19	13	8	9.71	8
Sunyan	Ghana	12	13	5	17	18	14	12.14	12
Ramanaguda	India	7	6	6	10	9	6	6.57	5
Chanatorin	India	19	18	17	8	14	17	14.71	16
Tibbi Laran	Pakistan	20	21	19	6	19	20	17.86	18
Muttan	Pakistan	17	17	18	4	16	18	15.71	17
Geta	Nepal	13	12	21	9	12	12	13.57	14
Lamahal	Nepal	18	15	16	13	8	16	13.29	13
Balharshalt	India	15	10	13	16	17	9	11.86	11
Kuliyapitiya	Sri-Lanka	10	7	7	11	7	10	9.43	7
Bandia	Senegal	11	11	9	14	1	11	10.29	9

of western Rajasthan. Survival was generally high and showed no significant difference between provenances. This is a good indication of the adaptation of these provenances to the local climate in Morogoro, which has two rainy seasons. However, the poor survival of Mandore (75%) and Chamwino (78%) indicates that for these provenances replacement of the dead ones may be required in afforestation programmes.

The land race Chamwino, Tanzania ranked low in ordinal ranking (Table 4) and was among the last five. Usually when land races are developed in one region, they often become useful in another similar region (Zobel & Talbert 1991). The poor performance of the land race in this study is an indication that the seed source may have come from plantations of inferior or narrow genetic base. The land race is probably more adapted to drier areas such as Chamwino in central Tanzania where it has most likely adjusted itself to the soil and local climate conditions.

Provenance variation indicates the existence of large genetic variation at the population level. Large variation within species is also common in other species. In Tamil Nadu, India, Jambulingam (1990) reported high heritability estimates for height and diameter growth between 6- and 12-month-old *Casuarina* spp. Hakizimana (1999) also reported differences in growth traits of *Grevillea robusta* provenances in Iringa and Morogoro, Tanzania.

Based on the ordinal ranking of all traits assessed, the best five provenances were Ban Bo, Ban Nong, Ghaati, Doi Tao and Ramanaguda.

Conclusions

Based on the growth traits assessed at the age of 58 months, three provenances from Thailand and two from India were found superior and should be used for further breeding work. However, since the research included few growth variables and the trees are still young, it is strongly recommended that observations be continued over a longer period before the best performers are confirmed. Therefore, it is advisable to assess provenance performance up to half rotation age.

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