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Evaluation of a species and provenance trial of *Acacia* at B.G. Kere, India

Trial no. 15 in the arid zone series

by

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Danida Forest Seed Centre (DFSC) is a Danish non-profit institute which has been working with development and transfer of know-how in management of tree genetic resources since 1969. The development objective of DFSC is to contribute to improve the benefits of growing trees for the well-being of people in developing countries. DFSC's programme is financed by the Danish International Development Assistance (Danida).

Preface

This report belongs to a series of analysis reports published by the Danida Forest Seed Centre. It is the intention that the series should serve as a place for publication of trial results for the Centre itself as well as for our collaborators. The reports will be made available from the DFSC publication service and online from the web-site www.dfsc.dk. The scope of the series is in particular the large number of trials from which results have not been made available to the public, and which are not appropriate for publication in scientific journals. We believe that the results from these trials will contribute considerably to the knowledge on genetic variation of tree species in the tropics. Also, the analysis report will allow a more detailed documentation than is possible in scientific journals.

The report presents results of a trial within the framework of the 'International Series of Trials of Arid and Semi-Arid Zone Arboreal Species', initiated by the FAO. Following collection and distribution of seed between 1983-87, a large number of trials were established by national institutions during 1984-1989. An international assessment of 26 trials took place from 1990 to 1994. DFSC is responsible for the reporting of this assessment.

This trial was established and maintained in India by the Forestry Department Karnataka (FDK), in collaboration with Forest Research Institute & Colleges (FRI), under the auspices of Indian Council of Forestry Research and Education (ICFRE). The assessment team consisted of M.S. Beniwal (FRI), K.M. Gamanagatti (FDK), 4 local assessment assistants of FDK and Holger Nielsen (DFSC).

The authors wish to acknowledge the help of the personnel at FDK/FRI with the establishment, maintenance and assessment of the trials, and thank the personnel of DFSC for their help with the data management and preliminary analyses. Drafts of the manuscript were commented on by Marcus Robbins, consultant to FAO, and Mr. B. Basappa, Forest Research and Training Institute (FORTI).

Abstract

This report describes results from a trial with 22 provenances, mainly of the genus *Acacia*. The species *A. aneura*, *A. auriculiformis*, *A. mangium*, *A. nilotica*, *A. planifrons*, *A. senegal*, *A. tortilis* were included with *Dalbergia sissoo* and a hybrid of *Eucalyptus*. The provenances were from India, Africa and Southeast Asia/Australia.

The trial was established with a spacing of 3 x 3 metres at B.G. Kere, India in 1985 and assessed after 7 years in 1992. Different growth parameters were measured and subjected to analyses of variance and multivariate analyses. The fastest growing provenances had increment rates of almost 1 m^2 ha^{-1} y^{-1}, corresponding to a dry weight production of up to 2.6 t ha^{-1} y^{-1}. The provenances of *A. senegal* from Senegal and the hybrid of *Eucalyptus* had particularly fast growth. *A. mangium*, on the other hand, had a poor survival and a relatively slow growth and did not seem apt for the site. For the other species, the performance was intermediate.

A. mangium, *A. nilotica* and *A. senegal* were represented by several provenances. There were no convincing signs of differences between the provenances of *A. mangium*, but within *A. nilotica* and *A. senegal* there were clear and significant differences between the provenances included.

Contents

1. Introduction

This report describes the results from trial no. 15 in a large series of provenance trials within the 'International Series of Trials of Arid and Semi-Arid Zone Arboreal Species'. The main goals of the series were to contribute to the knowledge on the genetic variation of woody species, their adaptability and productivity and to give recommendations for the use of the species. The species included in this series of trials are mainly of the genera *Acacia* and *Prosopis*. A detailed introduction to the series is given by DFSC (Graudal *et al.* 2003).

Most of the approximately 1100 species of *Acacia* are from dry savannas and dry regions of Australia, Africa, India and the two American continents. Some originate from cool, moist areas in temperate regions and tropical climates, whereas a small group is found in the lowland wet tropics (National Research Council 1983). This trial represent at mix of species from the first and the third group, i.e. dryland and savanna species as well as species from the wet tropics.

A. aneura has a wide distribution in the central and southern of the Australian continent (Hall *et al.* 1979). The species is restricted to the arid and semi-arid zone with annual precipitation in the range of 100 to 500 mm. Seed of the species are used for food by the aboriginal people in Australia (John Larmour, pers. com.).

A. auriculiformis is found in southern Irian Jaya and Papua New Guinea as well as northern Australia (Boland *et al.* 1990, Hall *et al.* 1980a, Pinyopusarerk 1990). In its natural habitats it is found only in areas with a permanent or semi-permanent supply of water from ground or surface water, e.g. high water-table habitats, run-on sites or coastal landforms. In Karnataka there are large plantations of the species. The provenance in this trial is a landrace from India.

The natural distribution of *A. mangium* ranges from north-eastern Australia through southern Papua New Guinea to Irian Jaya and Maluku of Indonesia. In this area it usually grows in hot and humid zones below 300 m altitude with an annual precipitation above 1500 mm (Turnbull 1983). In Australia the species grows on flat and gentle slopes or along mangroves, streams and rivers (Hall *et al.* 1980b). In Sabah, Malaysia, it has shown impressive growth and a potential for plantations as well as for soil restoration (Turnbull 1983, National Research Council 1983).

A. nilotica is a very variable species with a natural distribution covering large tracts of the dry tropical and subtropical Africa and Asia, and 9 subspecies are recognised (Brenan 1983, Ross 1979). The eight provenances in this trial were all from India except one of the subspecies *nilotica* from Sudan. According to the collection sheets, the provenances from India represent at least three different varieties: subsp. *indica* var. *cupressiformis*, subsp. *indica* var. *jaquemontii*, and subsp. *indica* var. *vediana*. In the view of Brenan (1983), this nomenclature is not justified. He states that the subsp. *indica* is a separate subspecies, and that subsp. *indica* var. *cupressiformis* is rightfully the subsp. *cupressiformis*. Furthermore, subsp. *indica* var. *vediana* is considered a synonym of subsp. *subalata*, which is native to East-Africa. The occurrence of subsp. *subalata* in India could be due to crossing between two other subspecies, subsp. *indica* and subsp. *hemispherica*. Finally, subsp. *indica* var. *jaquemontii* is considered a separate species, *A. jaquemontii*. Thus there is some confusion with regard to the taxonomy, and the material should be verified before drawing conclusions regarding varieties of this group of provenances. In this report we shall for simplicity use the terminology applied by the seed collectors.

A. planifrons is a relatively unknown species on which little information is available in the literature.

A. senegal is found in most of the Sahel and in Eastern and Southern Africa. The species is considered quite variable, and some authors distinguish four varieties, although this is subject to debate (Ross 1979, Fagg & Barnes 1990). The three provenances in this trial are from Senegal and Yemen, but the varieties have not been specified.

A. tortilis is widespread in the Sahel, East Africa and Arabia (Ross 1979, Brenan 1983, von Maydell 1986, Fagg & Barnes 1990). In this trial, one provenance of the subspecies *spirocarpa* is included.

The last two provenances are *Dalbergia sissoo* and a hybrid of *Eucalyptus*, intended as controls for the *Acacia* species.

2. Materials and methods

2.1 Site and establishment of the trial

The trial is located at B.G. Kere (14°11′N, 76°24′E) in Karnataka, India at an altitude of 735 m. The mean annual temperature is 25.8°C, and the mean annual rainfall is 654 mm. The dry period is approximately 6 months. The slope at the site is gentle and the soil is poor and stony. Further information is given in the assessment report (DFSC 1994) and summarised in annex 1.

The date of sowing is not known, but the trial was established in August 1985. For calculation of annual increments it is assumed that the seed was sown in May 1985.

2.2 Species and provenances

The trial includes 20 provenances of different *Acacia* species as well as a provenance of *Dalbergia sissoo* and a hybrid of *Eucalyptus* (Table 1). The provenances have been given identification numbers relating to their geographical origin (name of province or country followed by a number). The original seedlot numbers are provided in annex 2.

2.3 The experimental design

The experimental design is a completely randomised design with five replicates of each provenance, except for the provenance Maharashtra2 (*A. nilotica*), which was represented by ten replicates. Within each replicate, the provenance is represented by 16 trees in a plot, planted in a square of 4×4 trees. The trees are placed with a spacing of 3×3 m. The layout of the trial is shown in annex 3. Further details are given in DFSC (1994).

2.4 Assessment of the trial

In May 1992 FDK, FRI, FAO and DFSC undertook a joint assessment. The assessment included the following characters:

- Survival
- Health status
- Vertical height
- Diameter of the three largest stems at 0.3 m
- Number of stems at 0.3 m
- Crown diameter

A detailed account of the assessment methods is given by DFSC (Graudal *et al.* 2003), and raw data from the 1992 assessment are documented in DFSC (1994). The plot data set on which the statistical analyses in this report are performed is shown in annex 4. This data set includes directly observed values as well as derived variable values (see below).

Table 1. Species and provenances tested in trial no. 15 at B. G. Kere, India.

Provenance identification	Species	Seed collection site	Country of origin	Latitude	Longi-tude	Alti-tude (m)	Rainfall (mm)	No. of mother trees
Australia1	*A. aneura*		Australia					
India2	*A. auriculiformis*	West Bengal	India					
Indonesia1	*A. mangium*	Piru Ceram	Indonesia	3°04‘S	128°12‘E	150	ca. 2800	9
PNGuinea1	*A. mangium*	Oriomo R.	Papua New Guinea	8°50‘S	143°08‘E	10	ca. 2000	33
Queensland6	*A. mangium*	Rex Range, Qsl	Australia	16°30‘S	145°22‘E	30	ca. 2000	8
Queensland7	*A. mangium*	Walsh’s Pyramid, Qsl	Australia	17°06‘S	145°48‘E	20	ca. 2000	10
Queensland8	*A. mangium*	Trinity Inlet, Qsl	Australia	17°02‘S	145°48‘E	20	ca. 2000	10
Haryana1	*A. nilotica* subsp. *indica* var. *cupressiformis*	Nornaul Singhana (Mahandra Gahr) Bhiwani (Hissar)	India	28°03‘N	76°07‘E	250	714	4
Karnataka1	*A. nilotica*	B.G. Kere	India	14°11‘N	76°24‘E	735	654	
Maharashtra2	*A. nilotica* subsp. *indica* var. *vediana*	Pune	India	18°32‘N	73°51‘E	559	715	25
Maharashtra4	*A. nilotica* subsp. *indica* var. *cupressiformis*	Pune	India	18°32‘N	73°51‘E	559	714	25
Maharashtra5	*A. nilotica* subsp. *indica* var. *cupressiformis*	Akola	India	20°42‘N	77°02‘E	282	877	
Maharashtra6	*A. nilotica* subsp. *indica* var. *vediana*	Akola	India	20°42‘N	77°02‘E	282	877	
Sudan08	*A. nilotica* subsp. *nilotica*	Khartoum Forest	Sudan	15°36‘N	32°33‘E	330	165	25
Uttar Pradesh1	*A. nilotica* subsp. *indica* var. *jaquemontii*	Bawain For-Est Block, Etawah (Mainpuri),	India	26°45‘N	79°00‘E	157	762	26
Tamil Nadu2	*A. planifrons*	Coimbatore, Tamil Nadu	India	11°00‘N	76°57‘E	314	790	
Senegal22	*A. senegal*	Namarel	Senegal	14°46‘N	16°01‘W	50	332	33
Senegal23	*A. senegal*	Windou Tiengoly	Senegal	15°59‘N	15°20‘W	39	350	32
Yemen2	*A. senegal*	Ahwar	Yemen	13°25‘N	46°40‘E	500	225	20
Sudan15	*A. tortilis* subsp. *spirocarpa*	Khartoum, West Nile	Sudan	15°36‘N	32°33‘E	330	165	25
India6	*Dalbergia sissoo*	B.G. Kere ?	India					
India7	*Eucalyptus hybrid*	Hosakote	India					

3. Statistical analyses

3.1 Variables

In this report the following nine variables are analysed:

- Survival
- Vertical height
- Crown area
- Number of stems at 0.3 m
- Basal area of the mean tree at 0.3 m
- Total basal area at 0.3 m
- Dry weight of the mean tree
- Total dry weight
- Damage score

The values were analysed on a plot basis, i.e. ratio, mean or sum as appropriate. Survival was analysed as the rate of surviving trees to the total number of trees per plot. Height, crown area, number of stems and damage score were analysed as the mean of surviving trees on a plot, as were the basal area and the dry weight of the mean tree. The total basal area and the total dry weight represent the sum of all remaining trees in a plot, expressed on an area basis. Note that the calculations of basal area are based on measurements of the three largest stems per tree.

A special problem with the assessment data is that for a few small trees, no assessment of diameter, crown area and/or number of stems were made. For diameter, five measurements were missing, whereas three trees had no observations of number of stems. For crown area six observations were missing. The omission of these data will produce biased results and lead to an over-estimation of the provenances in question, but since the missing observations represent only a small fraction of the total number of trees (1840 trees planted, 1315 surviving), no corrections have been made for this.

The dry weight values were calculated from regressions between biomass and basal area, established in another part of this study (Graudal *et al.* in prep.). For *A. nilotica* the regression used was

$$TreeDW = e^{(2.582 \times \ln(basalarea) - 2.518)}$$

where *TreeDW* expresses the dry weight of the tree in kg tree^{-1}, and *basalarea* expresses the basal area of the tree in cm^2. For *A. senegal* the regression was

$$TreeDW = e^{(2.474 \times \ln(basalarea) - 2.232)}$$

Finally, the regression for *A. tortilis* was

$$TreeDW = e^{(2.711 \times \ln(basalarea) - 2.394)}$$

No regressions were available for the other species.

3.2 Statistical model and estimates

In order to investigate the variation between the provenances in the trial two types of tests were performed. The first of these was a test of differences between the species in the trial according to the model:

$$X_{ij} = \mu + species_i + provenance(species)_{ij} + \varepsilon_{ij}$$

where X_{ij} is the value of the trait in plot *ij*, μ is the grand mean, $species_i$ is the fixed effect of species number *i*, $provenance(species)_{ij}$ is the effect of provenance number *j* nested within species *i*, assumed to be a random effect with an expected value of zero and variance σ_{pr}^2, and ε_{ij} is the residual of plot *ij*, and is assumed to follow the normal distribution $N(0, \sigma_e^2)$. Since the trial was completely randomised, no block effect was included. In the test of species differences the Satterthwaite's approximation was used for calculating degrees of freedom (SAS 1988).

The second type of tests were performed for the species *A. mangium*, *A. nilotica* and *A. senegal* in order to determine if there were differences between the provenances within each of the species. These tests were according to the simpler model

$$X_j = \mu + provenance_j + \varepsilon_k$$

where X_j is the value of the trait (e.g. height) in plot *j*, μ is the grand mean, $provenance_j$ is the fixed effect of provenance number *j*, and ε_{jk} is the residual of plot *jk* and is assumed to follow a normal distribution $N(0, \sigma_e^2)$.

To complement blocks in adjusting for uneven environments, co-variates related to the plot position were included. In the initial models, the co-variates were distances along the axes of the trial, plotx and ploty, and squared values of these distances, plotx2 and ploty2. Another co-variate, level, was also included. This variable describes the vertical position (height) of the surface of each plot related to a reference plot/level.

The co-variates were excluded successively if they were not significant at the 10% level.

Standard graphical methods and calculated standard statistics were applied to test model assumptions of independence, normality and variance homogeneity (Snedecor & Cochran 1980, Draper & Smith 1981, Ræbild *et al.* 2002). Where appropriate, transformation or weighting of data and exemption of outliers were performed to fulfil basic model assumptions (ibid.; Afifi & Clark 1996). In the case of survival, an arcsine transformation was used, whereas crown area was transformed with the square root. Weighting of data with the inverse of the variance for the seedlots was used to obtain normality of the residuals where the seedlots appeared to have different variances.

The P-values from the tests of provenance differences were corrected for the effect of multiple comparisons by the sequential table-wide Bonferroni method (Holm 1979). The tests were ranked according to their P values, and the test corresponding to the smallest P value (P_1) was considered significant on a 'tablewide' significance level of α if $P_1<\alpha/n$, where n is the number of tests. The second smallest P value (P_2) was declared significant if $P_2<\alpha/(n-1)$, and so on (c.f. Kjaer & Siegismund 1996). In this case the number of tests was set to nine, thus equalling the number of variables analysed. The significance levels are indicated by (*) (10%), * (5%), ** (1%), *** (1 ‰) and n.s. (not significant).

Finally the model was used to provide estimates for the provenance values. Two sets of estimates are presented: The least square means (LS-means) and the Best Linear Unbiased Predictors (BLUPs) (White & Hodge 1989). In brief, the LS-means give the best estimates of the performance of the chosen provenances at the trial site, whereas the BLUPs give the best indication of the range of variation within the species.

Since it is assumed in the calculation of BLUPs that the provenances represent a random selection, they are usually presented for the species separately. In this case we only present BLUP estimates for *A. mangium* and *A. nilotica*, since these are the only species with larger number of provenances. In the case of *A. nilotica* it may be an uncertain assumption to consider the provenances a random sample (one provenance from Sudan and seven from India).

A multivariate analysis providing canonical variates, and Wilk's lambda and Pillai's trace statistics, complemented the other analyses (Chatfield & Collins 1980, Afifi & Clark 1996, Skovgaard & Brockhoff 1998).

A more detailed description of the statistical methods used is given by Ræbild *et al.* (2002), and a short description of the analysis of each variable is given in the result section. The statistical software package used was Statistical Analysis System (SAS 1988a, 1988b, 1991, Littell *et al.* 1996).

4. Results

4.1 Survival

Survival is regarded as one of the key variables when analysing tree provenance trials, since it indicates the adaptability of the provenance to the environment at the trial site. It should be noted that the survival reflects only the conditions experienced during the early year's growth of the trial and not necessarily the climatic extremes and conditions that may be experienced during the life span of a tree in the field.

Statistical analysis

There were signs of variance heterogeneity in the original data set, and the analysis was performed on data transformed with the arcsine transformation. One observation from the provenance Maharashtra2 (located at the (x,y) co-ordinates (1,4)) had a lower survival than other observations in the provenance and turned out to be an outlier. However, since there was no obvious explanation of the outlier tendency, the model was accepted with the outlier included. A test demonstrated that the outlier had no major influence on the significance levels of the model.

In this model the co-variate level was highly significant.

It should be noted that the estimates presented in Fig. 1 are based on back-transformed means, which differ from mean values calculated on untransformed data. For illustration of differences between provenances, the estimates in Fig. 1 are the best, however.

Results

The mean survival of the provenances was highly variable, ranging from only 6% in Indonesia1 (*A. mangium*) to 99% in the best provenances of *A. senegal.* There were highly significant differences between the species in the trial, and also within *A. mangium* there were significant differences between the provenances (Table 2). In *A. nilotica* the differences were not as consistent, and the provenance effect was only at the limit of significance. In *A. senegal* there were no signs of significant differences between provenances.

In general *A. mangium* had the poorest survival, ranging between a few percent to a little less than 50% (Fig. 1). India2, the provenance of *A. auriculiformis* had an intermediate survival, whereas provenances of the other species all had survivals between 70 and 100%. It could thus seem that *A. mangium* is a poor choice for the site. Within *A. mangium*, especially the provenance from Indonesia had a low survival, while the provenances PNGuinea1 and Queensland7 had higher survival.

In *A. nilotica*, the provenances Maharashtra5 and Maharashtra6 had high survivals, whereas the provenances Maharashtra4 and Uttar Pradesh1 were at the low end. Note, however, that these differences were only at the limit of significance (Table 2).

The BLUP-estimates, which illustrate the expected gains by selection of provenances assuming that the provenances represent a random selection, are given in Figs. 2 and 3. In *A. mangium* there are large gains by selection of the best provenances, up to 17 percentage point compared to the mean value in the provenance Queensland7 (Fig. 2). In *A. nilotica*, the gains are more modest, varying between only -6 and +7 percentage point (Fig. 3).

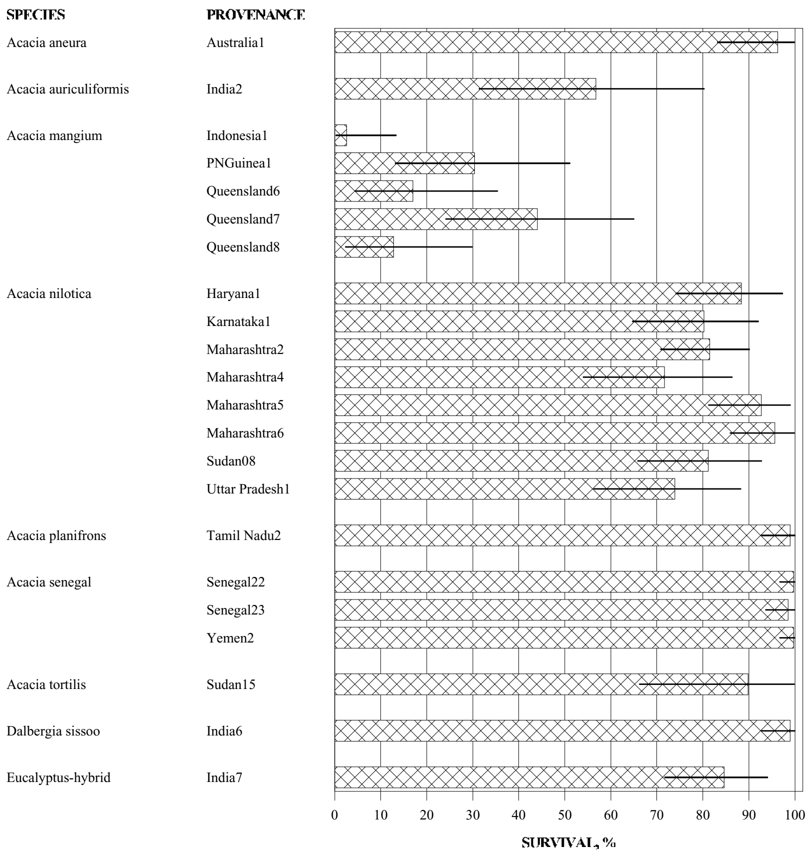


Figure 1. Survival in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 2. Results from analysis of variance of species and provenance differences of survival in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 13.5	1.84	17.3	<0.0001	***
Provenance(species)	13; 92	0.110	2.9	0.002	
Level	1; 92	0.757	19.7	<0.0001	
Error	92	0.038			
A. mangium					
Provenance	4; 20	0.231	4.4	0.01	(*)
Error	20	0.052			
A. nilotica					
Provenance	7; 36	0.0768	2.1	0.07	(*)
Level	1; 36	0.952	25.8	<0.0001	
Error	36	0.0369			
A. senegal					
Provenance	2; 12	0.00871	0.5	0.63	n.s.
Error	12	0.0184			

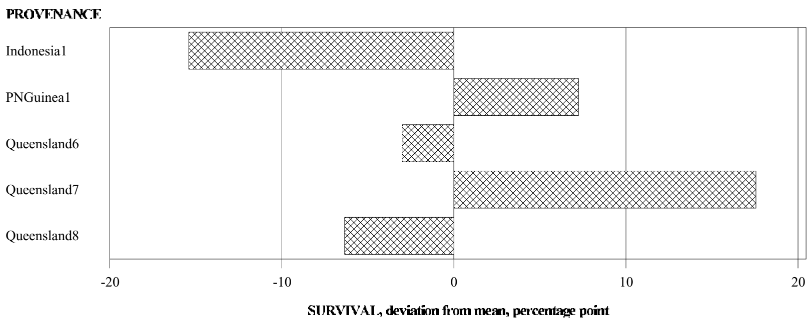


Figure 2. Best linear unbiased predictors (BLUPs) for survival in the *A. mangium* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are deviations from the mean value in percentage point.

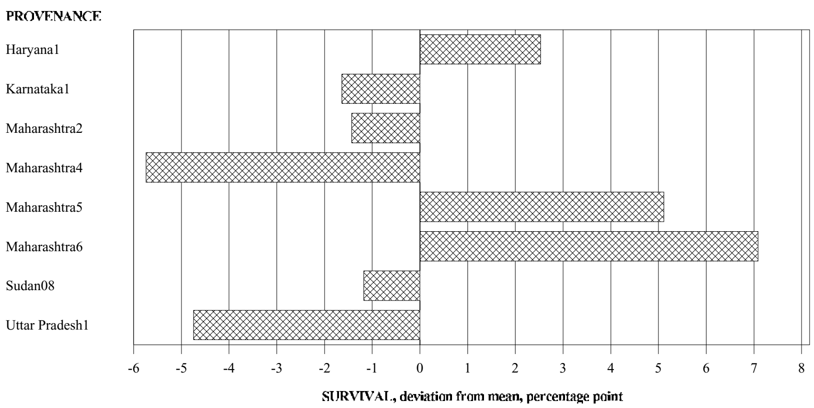


Figure 3. Best linear unbiased predictors (BLUPs) for survival in the *A. nilotica* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are deviations from the mean value in percentage points.

4.2 Height

Height is usually considered an important variable in the evaluation of species and provenances, even though this depends on the main uses of the trees. Apart from indicating productivity, height may also be seen as a measure of the adaptability of trees to the environment, tall trees usually being better adapted to the site than short trees. This interpretation need not always be true, as there have been cases where the tallest provenances are suddenly affected by stress and die-off.

Statistical analysis

In the analysis the provenance India2 had an outlier at the position plotx=2 and ploty=13. Since the outlier had only little influence on the significance levels in the model, the data presented include the outlier. In the model with all species, the co-variates plotx, plotx2 and ploty were significant, but in the *A. mangium* no co-variates were significant, and in *A. senegal* only plotx was significant.

Results

The variation in average height was large, spanning from below 1 m to 5 m in the largest provenance. The *Eucalyptus* hybrid had the fastest growth, and without this, the range of average heights was smaller, the best provenance being only 3.2 m.

The difference between species was highly significant (Table 3), but since the *Eucalyptus* hybrid was so distinctly larger than the rest of the provenances, an additional test was performed without this provenance. According to this test, the effect of species was no longer significant (P=0.08, not shown). Within *A. mangium*, the differences between provenances were only at the limit of significance, but in *A. nilotica* and *A. senegal* the differences were highly significant (Table 3).

Apart from India7 (*Eucalyptus*) the following provenances were among the best: Austrialia1 (*A. aneura*), India2 (*A. auriculiformis*), PNGuinea1 (*A. mangium*), Haryana1 (*A. nilotica*), Senegal22 and Senegal23 (*A. senegal*) and India6 (*D. sissoo*) (Fig. 4). Especially the Sudanian provenance of *A. nilotica* (Sudan08) had a poor height growth. For *A. mangium* the expected gains by provenance selection varied from -14 to +19 percent of the mean value (Fig. 5). For *A. nilotica* the gains varied from almost -50 % to +25 % (Fig. 6). Most of this variation was due to the single provenance from Sudan; without this provenance the variation range would have been only ±15 %.

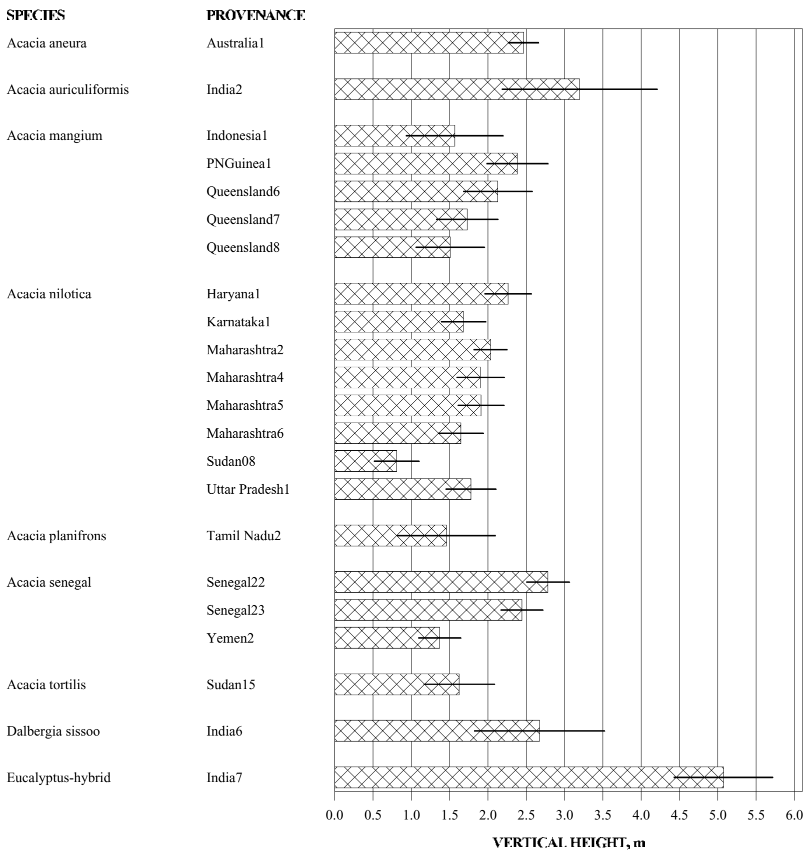


Figure 4. Vertical height in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 3. Results from analysis of variance of species and provenance differences of vertical height in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 13.1	7.40	7.0	0.001	**
Provenance(species)	13; 85	1.07	7.1	<0.0001	
Plotx	1; 85	0.85	5.6	0.02	
Plotx2	1; 85	0.57	3.8	0.06	
Ploty	1; 85	1.82	12.1	0.0008	
Error	85	0.15			
A. mangium					
Provenance	4; 15	0.59	3.3	0.04	n.s.
Error	15	0.18			
A. nilotica					
Provenance	7; 34	0.96	9.5	<0.0001	***
Plotx	1; 34	0.34	3.3	0.08	
Plotx2	1; 34	0.40	4.0	0.05	
Ploty	1; 34	0.59	5.9	0.02	
Error	34	0.10			
A. senegal					
Provenance	2; 11	2.62	33.7	<0.0001	***
Plotx	1; 11	0.35	4.5	0.06	
Error	11	0.08			

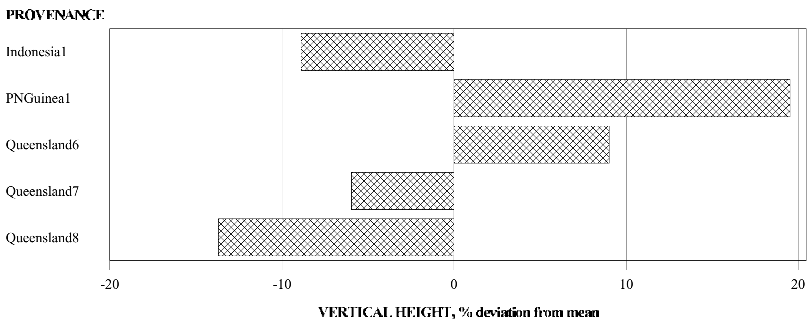


Figure 5. Best linear unbiased predictors (BLUPs) for vertical height in the *A. mangium* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

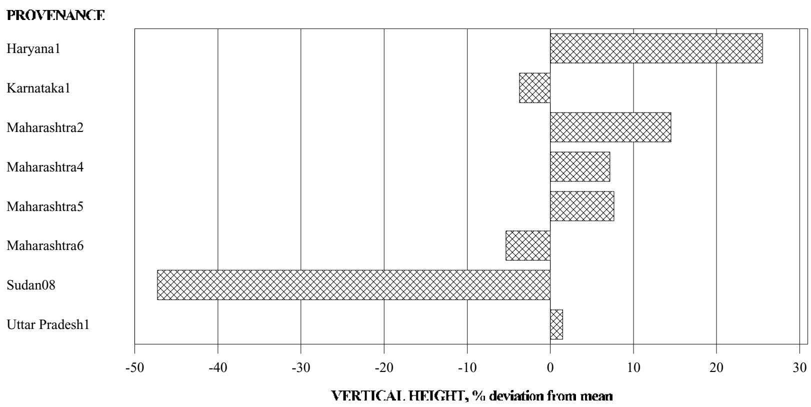


Figure 6. Best linear unbiased predictors (BLUPs) for vertical height in the *A nilotica* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.3 Crown area

This variable indicates the ability of the trees to cover the ground. Crown area is of importance in shading for agricultural crops, in evaluating the production of fodder and in protection of the soil against erosion.

Statistical analysis

In the original data there was clear variance heterogeneity, and the data were transformed with the square root to obtain a proper distribution of the residuals. After transformation, the provenance Maharashtra2 appeared to have one outlier (plotx=1, ploty=4). According to the assessment report there was no apparent reason to justify exclusion of the observation, and since it had no influence on the conclusions from the tests, the results below are based on models with the outlier included. Note that six trees had missing values for crown area. This is believed to have only minor effects (see section 3.1).

For the co-variates, the pattern was exactly the same as for height: In the model with all species, the co-variates plotx, plotx2 and ploty were significant, but in *A. mangium* no co-variates were significant. In *A. senegal* only plotx was significant.

Results

The average crown area for the provenances was varying between 1 and 14 m^2 $tree^{-1}$. As the growth space was only 9 m^2 $tree^{-1}$, trees in the largest provenances had closed the canopy above the ground. The test did not reveal any differences between the species, as there was a large variation between the provenances within the species (Table 4). This was especially the case for *A. nilotica* and *A. senegal*, where the differences between provenances were highly significant. In *A. mangium*, the differences between provenances were not significant.

The largest crown areas were found in the provenances Senegal22 and Senegal23 of *A. senegal* and *Maharashtra2* and *Maharashtra6* of *A. nilotica* (Fig. 7). Most of the other provenances had crown areas in the order of half the crown areas of these provenances, and especially the provenances of *A. mangium* and Sudan08 and Uttar Pradesh1 (both of *A. nilotica*) had small crown areas. It is also noteworthy that the *Eucalyptus* hybrid that had by far the largest height growth was at the low end with regard to crown area.

For *A. mangium*, the gains by provenance selection were modest as would be expected from the lack of significance in the test of provenance differences, but still the largest provenance (PNGuinea1) had a crown area 20 % larger than the average (Fig. 8). In *A. nilotica*, on the other hand, the largest provenance (Maharashtra2) was more than 100 % better than the mean value for the provenances in this species, indicating an enormous gain by selection of the proper provenances (Fig. 9).

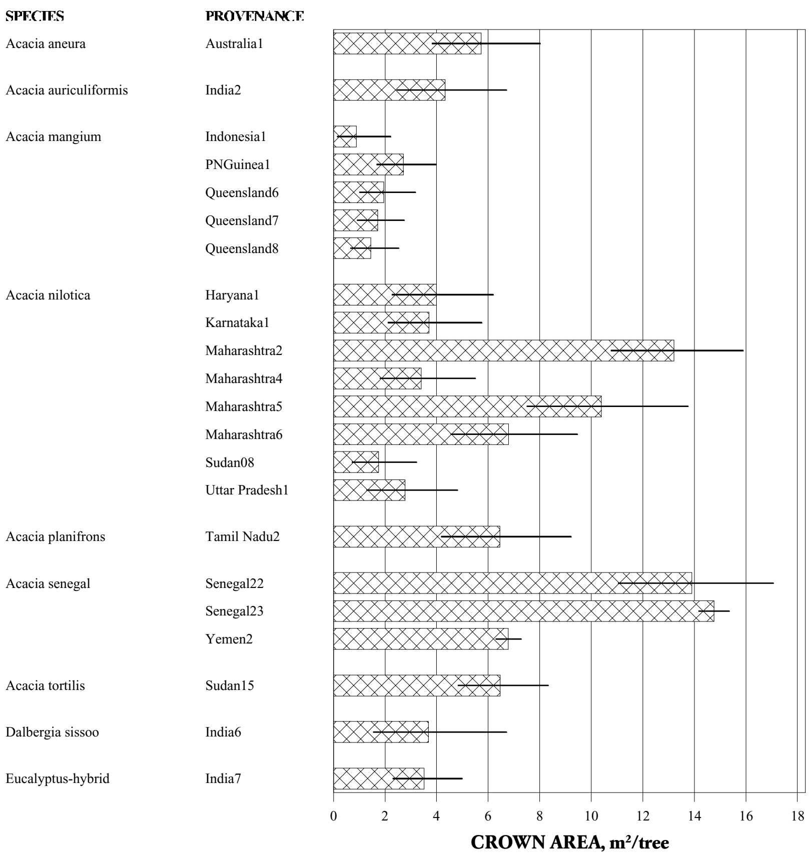


Figure 7. Crown area in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 4. Results from analysis of variance of species and provenance differences of crown area in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 13.0	4.75	1.8	0.17	n.s.
Provenance(species)	13; 85	2.71	15.4	<0.0001	
Plotx	1; 85	2.32	13.2	0.0005	
Plotx2	1; 85	2.33	13.3	0.0005	
Ploty	1; 85	1.68	9.6	0.0027	
Error	85	0.176			
A. mangium					
Provenance	4; 15	0.219	1.7	0.21	n.s.
Error	15	0.133			
A. nilotica					
Provenance	7; 34	3.91	14.8	<0.0001	***
Plotx	1; 34	1.66	6.3	0.02	
Plotx2	1; 34	2.01	7.6	0.009	
Ploty	1; 34	1.30	4.9	0.03	
Error	34	0.263			
A. senegal					
Provenance	2; 11	234	260.6	<0.0001	***
Plotx	1, 11	15.7	17.5	0.002	
Error	11	0.897			

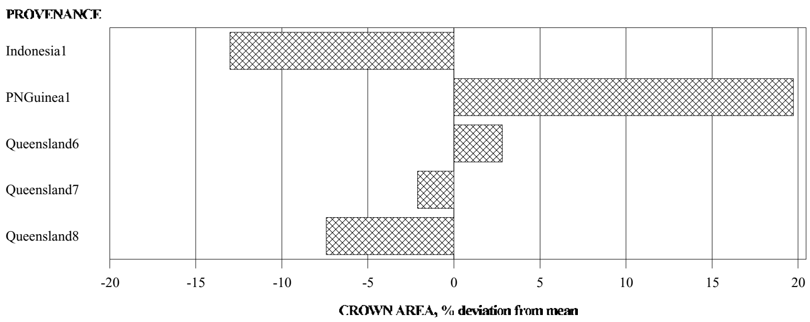


Figure 8. Best linear unbiased predictors (BLUPs) for crown area in the *A. mangium* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

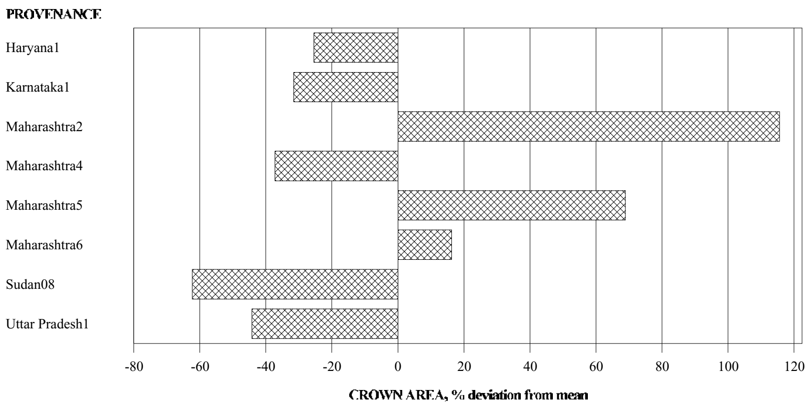


Figure 9. Best linear unbiased predictors (BLUPs) for crown area in the *A. nilotica* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.4 Number of stems

The number of stems gives an indication of the growth habit of the species. Trees with a large number of stems are bushy, whereas trees with only one stem have a more tree-like growth.

Statistical analysis

The residuals from the first analysis indicated that there was variance heterogeneity, and the data was weighted to fulfil assumptions of the model. In the tests of differences between provenances within the species, the weighting was only necessary for *A. senegal*. No co-variates were significant.

Three trees had no records of number of stems, but this is believed to be of minor importance (see 3.1).

Results

A few provenances had very high numbers of stems, meaning that there was a wide range in this character. While most provenances had between one and two stems per tree, the provenance Yemen2 of *A. senegal* had more than 10 stems per tree. The differences between species were significant (Table 5), and within the species *A. nilotica* and *A. senegal* had highly significant differences between the provenances. In *A. mangium*, the provenances were not significantly different.

The largest numbers of stems were found in Australia1 (*A. aneura*), Yemen2 (*A. senegal*) and Sudan15 (*A. tortilis*), all having more than 7 stems per tree (Fig. 10). All other provenances had below three stems per tree, and as mentioned above most of them even had less than two stems per tree.

Since the variation within *A. mangium* was very far from being significant, the calculation of BLUP values gave the same values for all provenances, and drawing a bar chart would have no meaning. Therefore no graph is presented for this species. In *A. nilotica* the predicted values varied from -18 to +32 %, the lowest values being in the provenances Maharashtra2, Maharashtra5 and Maharasthra6, and the highest in Sudan08 (Fig. 11).

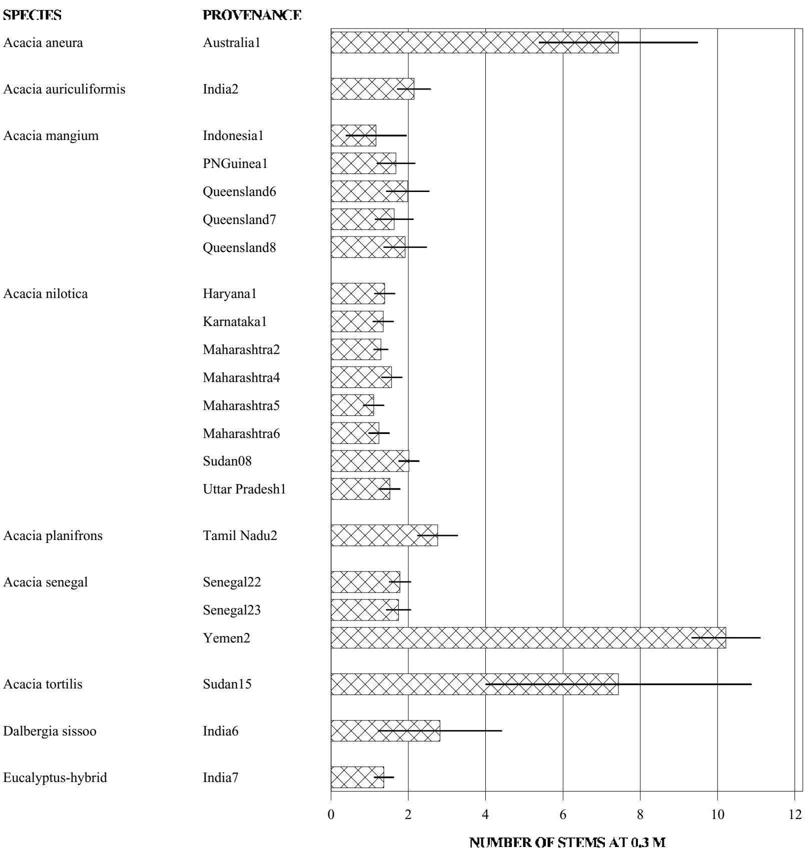


Figure 10. Number of stems in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 5. Results from analysis of variance of species and provenance differences of number of stems in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 14.1	68.1	4.6	0.006	*
Provenance(species)	13; 88	35.2	35.2	<0.0001	
Error	88	1			
A. mangium					
Provenance	4; 15	0.273	1.0	0.43	n.s.
Error	15	0.267			
A. nilotica					
Provenance	7; 37	0.399	4.7	0.0007	***
Error	37	0.0843			
A. senegal					
Provenance	2; 12	205	205.1	<0.0001	***
Error	12	1			

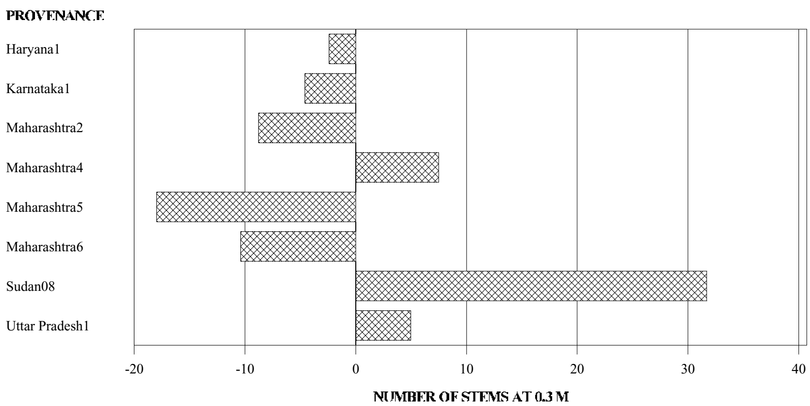


Figure 11. Best linear unbiased predictors (BLUPs) for number of stems in the *A. nilotica* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.5 Basal area of the mean tree

The basal area is often used as a measure of the productivity of stands, since it is correlated with the production of wood. The basal area of the mean tree is calculated on the live trees only and can be interpreted as a measure of the potential basal area production of the provenances if all trees had survived.

Statistical analysis

There were clear signs of variance heterogeneity in the data, and it was first tried to solve the problem with a logarithmic transformation. However, this seemed to increase the difference in variance between the provenances instead of decreasing it, and a weight statement was applied to the untransformed data. This gave a much better distribution of the residuals. Weight statements were also applied in the tests of provenance differences within *A. nilotica* and *A. senegal*.

The co-variates plotx and plotx2 were significant in the test of species differences and of provenance differences within *A. nilotica*, but not in the tests of provenance differences within *A. mangium* and *A. senegal*.

Results

The differences in basal area of the mean tree were less conspicuous than the differences in the two previous variables, but the mean values of the provenances were still varying widely. Sudan08 (*A. nilotica*) had a basal area of only 5 cm^2 $tree^{-1}$, whereas the trees of the *Eucalyptus* hybrid had basal areas of almost 70 cm^2 $tree^{-1}$, corresponding to a growth of ca. 10 cm^2 y^{-1}. The analysis did not point to species differences, but within the species *A. nilotica* and *A. senegal* there were highly significant differences between the provenances (Table 6). In *A. mangium*, the differences between provenances were at the limit of significance and disappeared when the Bonferroni correction for multiple comparisons was made.

The largest basal areas of the mean tree was found in India7 (the *Eucalyptus* hybrid), Senegal22 and Senegal23 (*A. senegal*) and India2 (*A. aneura*) (Fig. 12). Within *A. mangium* the provenance PNGuinea1 had a relatively large mean basal area, while the best provenances of *A. nilotica* were Maharashtra2, Maharashtra5 and Maharashtra6.

That PNGuinea1 seems better than the rest of the *A. mangium* provenances is indicated from the high predicted gain from selection this provenance, amounting to more than 40 % compared to the mean value for the species (Fig. 13). In *A. nilotica*, the predicted gains were even higher, varying between ±60 %. Again the best provenances were Maharashtra2, Maharashtra5 and Maharashtra6 (Fig. 14).

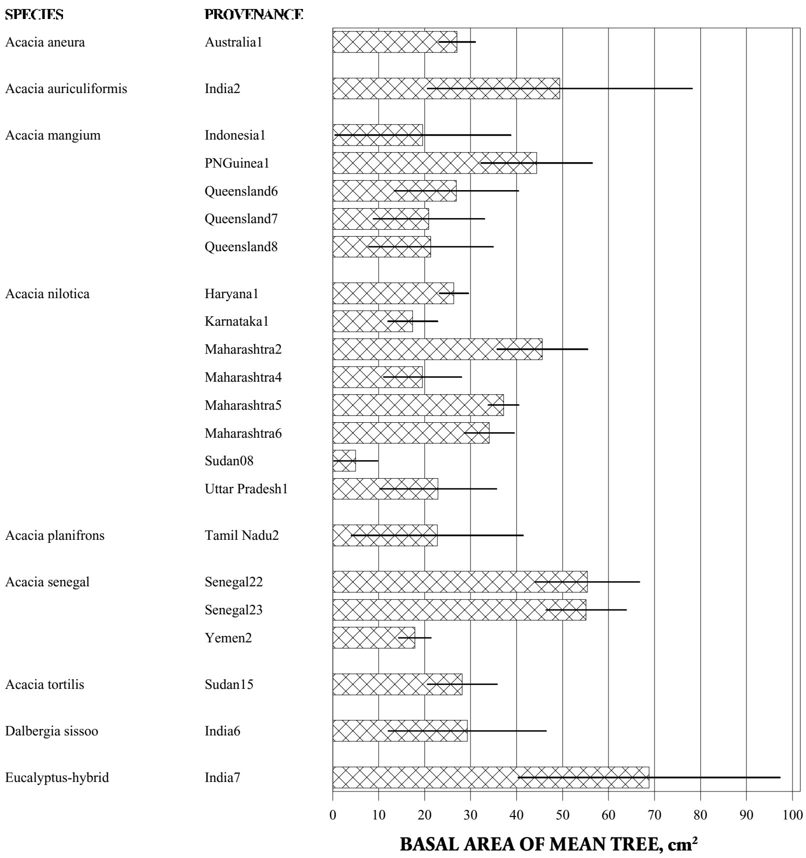


Figure 12. The basal area of the mean tree in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 6. Results from analysis of species and provenance differences of basal area of the mean tree in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 13.3	8.40	0.49	0.84	n.s.
Provenance(species)	13; 86	20.4	20.1	<0.0001	
Plotx	1; 86	16.7	16.5	<0.0001	
Plotx2	1, 86	12.9	12.7	0.0006	
Error	86	1.02			
A. mangium					
Provenance	4; 15	479	3.0	0.05	n.s.
Error	15	162			
A. nilotica					
Provenance	7; 35	22.1	23.3	<0.0001	***
Plotx	1; 35	2.87	3.0	0.09	
Plotx2	1; 35	2.98	3.2	0.08	
Error	35	0.946			
A. senegal					
Provenance	2; 12	54.6	54.6	<0.0001	***
Error	12	1			

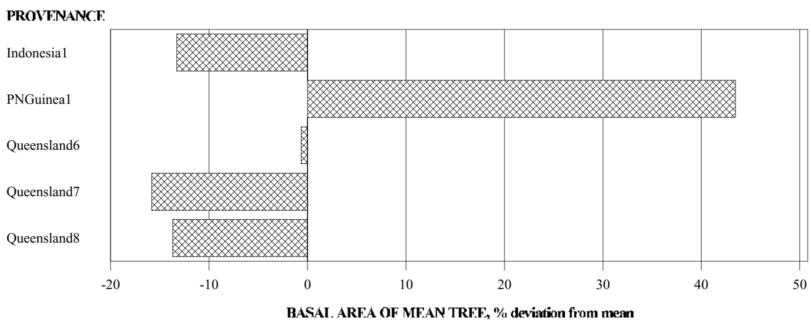


Figure13. Best linear unbiased predictors (BLUPs) for basal area of the mean tree in the *A. mangium* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

Figure 14. Best linear unbiased predictors (BLUPs) for basal area of the mean tree in the *A. nilotica* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.6 Total basal area

In comparison to the basal area of the mean tree, the total basal area is expressed per ha and is thus a better measure of the actual production at the site.

Statistical analysis

The analysis of this variable was quite similar to the analysis of basal area of the mean tree. An attempt was made to remove variance heterogeneity with a logarithmic transformation, but without success. Instead the analysis of species differences was based on a model with weighted data. This was also done with the analysis of provenance differences within *A. nilotica*, but in the analyses of provenance differences in *A. mangium* and *A. senegal* this was not necessary. The co-variate plotx was significant in all analyses except the analysis of provenance differences in *A. nilotica*.

Results

While the smallest provenances had total basal areas of only 0.3 m^2 ha^{-1}, the three largest provenances had had an average growth rate of almost 1 m^2 ha^{-1} y^{-1}, corresponding to 6 m^2 ha^{-1} at the time of measurement. The differences between species were at the limit of significance and disappeared when the correction for multiple comparisons was made (Table 7). In all three species tested the differences between provenances were significant, even though the correction for multiple comparisons took significance away in *A. mangium*.

The three largest provenances in terms of total basal area were Senegal22, Senegal23 (both *A. senegal*) and India7 (the *Eucalyptus* hybrid) (Fig. 15). Small basal areas were found in all provenances of *A. mangium* and in Sudan08 of *A. nilotica*, while the rest of the provenances were intermediate.

Even though the basal areas of *A. mangium* were small and there were no convincing differences between the provenances, the BLUP estimates indicated that there were gains up to 75% by provenance selection within the species (Fig. 16). Also in *A. nilotica* there were large gains, varying between ±60 % of the mean value (Fig. 17).

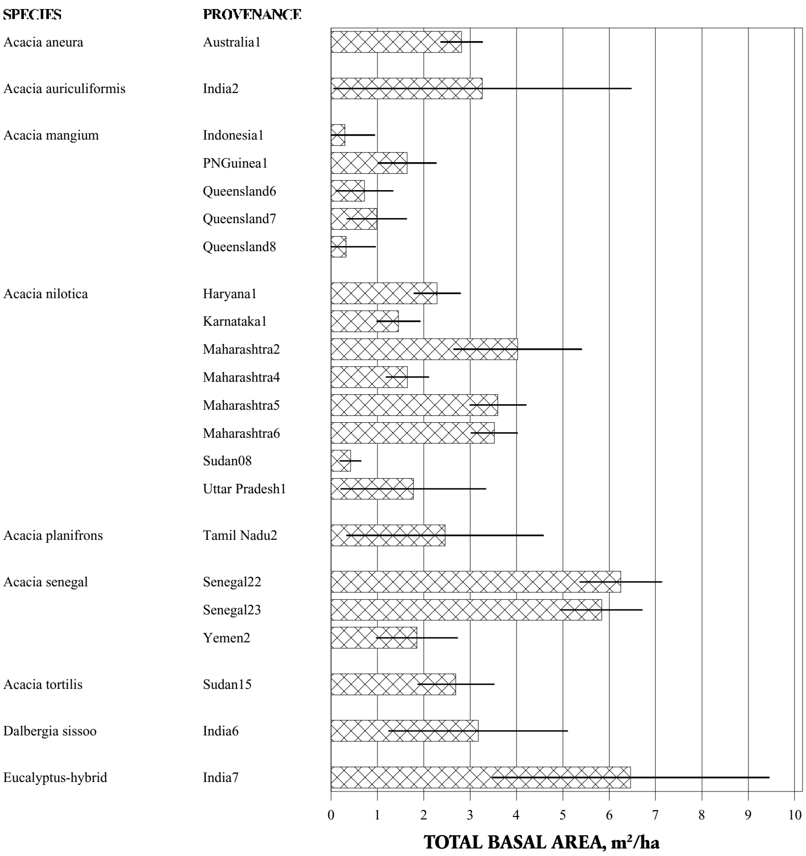


Figure 15. Total basal area in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 7. Results from analysis of variance of species and provenance differences of total basal area in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 14.3	33.0	2.8	0.04	n.s.
Provenance(species)	13; 92	22.6	21.4	<0.0001	
Plotx	1; 92	12.4	18.1	0.0006	
Error	92	1.0			
A. mangium					
Provenance	4; 19	1.5	3.5	0.03	n.s.
Plotx	1; 19	1.7	3.9	0.06	
Error	19	0.4			
A. nilotica					
Provenance	7; 37	33.2	33.2	<0.0001	***
Error	37	1			
A. senegal					
Provenance	2; 11	28.6	36.9	<0.0001	***
Plotx	1; 11	3.31	4.3	0.06	
Error	11	0.776			

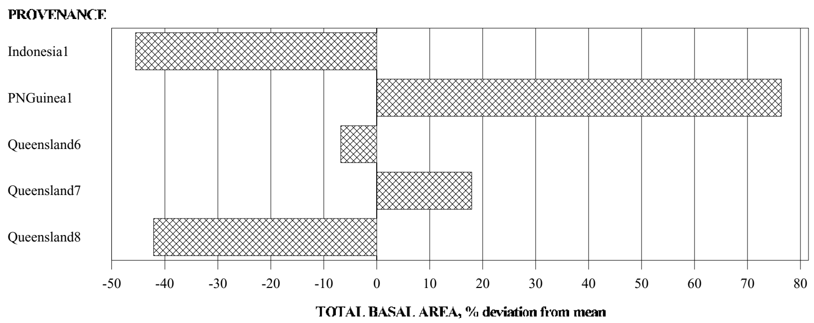


Figure 16. Best linear unbiased predictors (BLUPs) for total basal area in the *A. mangium* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

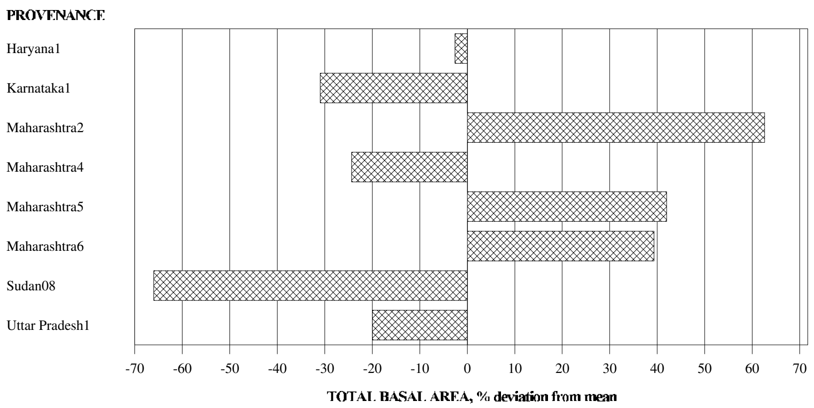


Figure 17. Best linear unbiased predictors (BLUPs) for total basal area in the *A. nilotica* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.7 Dry weight of the mean tree

The dry weight of the mean tree is comparable to the basal area of the mean tree in that they both are calculated on the live trees only and thus serve as a measure of the potential production at the site under the assumption that all trees survive. Furthermore, the two variables are linked closely as the basis for estimation of the dry weight is the basal area. However, an important difference is that the dry weight includes a cubic term (in comparison to basal area having only a square term), meaning that trees with large diameters are weighted more heavily in this variable. The dry weight is thus the best estimate for the potential production of biomass at the site.

Statistical analysis

The dry weight was determined only for the species *A. nilotica*, *A. senegal* and *A. tortilis* as no regressions were available for the other species in the trial. There was variance heterogeneity between the provenances of the trial, which was solved by weighting the data. This was necessary in all the analyses. The co-variate level was significant in the test of species differences, but not in the tests of provenance differences within the species.

Results

In the three species analysed, the dry weights of the mean tree varied from 1 to 16 kg tree^{-1}. For a tree in the largest provenances this corresponds to a growth of 2.3 kg annually. Differences between the species were not significant, but within both *A. nilotica* and *A. senegal* the differences between provenances were highly significant (Table 8).

In *A. nilotica*, the provenances Maharashtra2, Maharashtra5 and Maharashtra6 represented the largest dry weights, while especially Sudan08 had a small dry weight (Fig. 18). The best provenances of *A. senegal* were Senegal22 and Senegal23. These provenances were also the largest when all provenances were compared. The sole provenance of *A. tortilis*, Sudan15, was intermediate in this character.

The expected gains by selection of provenances were large in *A. nilotica*, varying from -70 % in Sudan08 to 90 % in Maharashtra2 (Fig. 19).

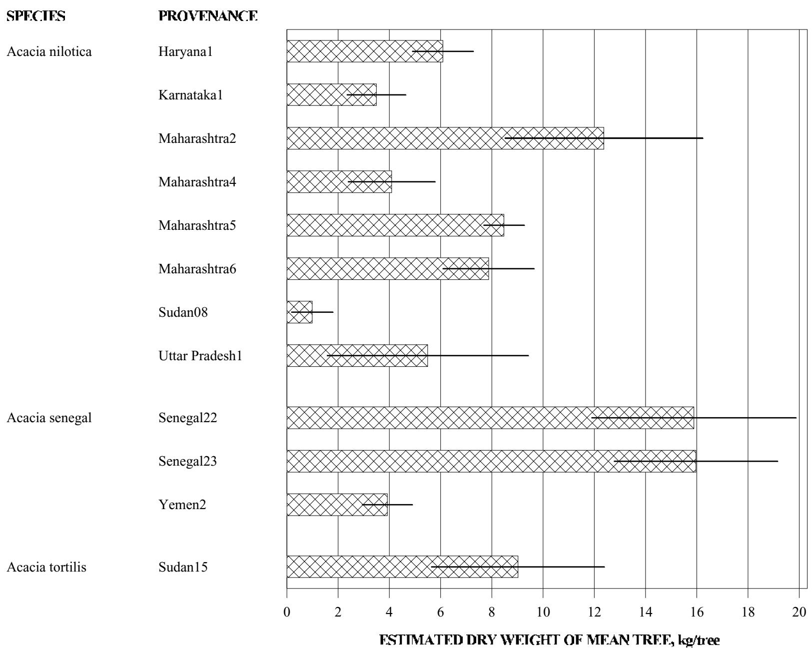


Figure 18. Dry weight of the mean tree in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 8. Results from analysis of variance of dry weight of the mean tree in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	2; 10.3	24.1	2.2	0.16	n.s.
Provenance(species)	9; 52	33.2	32.8	<0.0001	
Level	1; 52	6.47	6.4	0.01	
Error	52	1.01			
A. nilotica					
Provenance	7; 37	31.0	31.0	<0.0001	***
Error	37	1			
A. senegal					
Provenance	2; 12	47.8	47.8	<0.0001	***
Error	12	1			

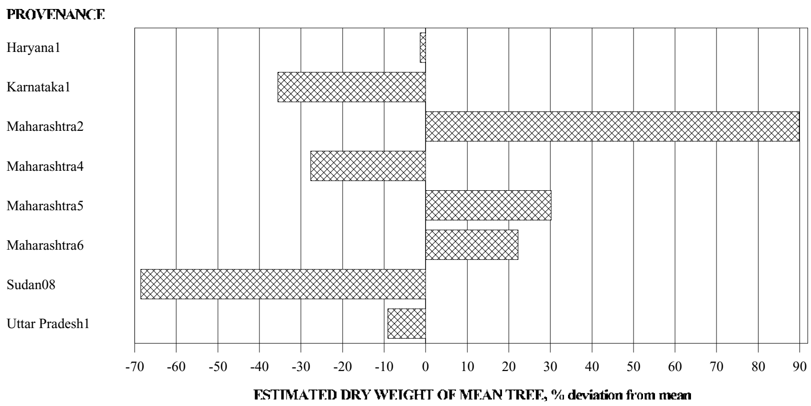


Figure 19. Best linear unbiased predictors (BLUPs) for dry weight of the mean tree of the *A. nilotica* provenances in the trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.8 Total dry weight

As with the total basal area, the total dry weight is expressed on a per-area basis and gives the best estimate of the production of biomass on the site.

Statistical analysis

Again there was variance heterogeneity in the data, and weight statements were applied in the analyses of species differences and of provenance differences within *A. nilotica*. It was not necessary in the analysis of provenance differences within *A. senegal*. The co-variate plotx was significant in the analyses of species differences and of provenance differences within *A. senegal*, but not in the test of provenance differences within *A. nilotica*.

Results

The total dry weight ranged from 1 t ha^{-1} in the provenance Sudan08 to 18 t ha^{-1} in the provenance Senegal22 (Fig. 20). Thus for Senegal22 the average annual increment was 2.6 t ha^{-1}. The three species were not significantly different, but again there were highly significant differences between the provenances of both *A. nilotica* and *A. senegal* (Table 9).

The overall fastest producing provenances were Senegal22 and Senegal23 of *A. senegal* (Fig. 20), while the provenances Maharasthra2, Maharashtra5 and Maharashtra6 of *A. nilotica* and Sudan15 of *A. tortilis* came in the second row. At the bottom was again Sudan08. In *A. nilotica* the expected gains by selection of provenances were high, spanning from -65 % to +78 % (Fig. 21).

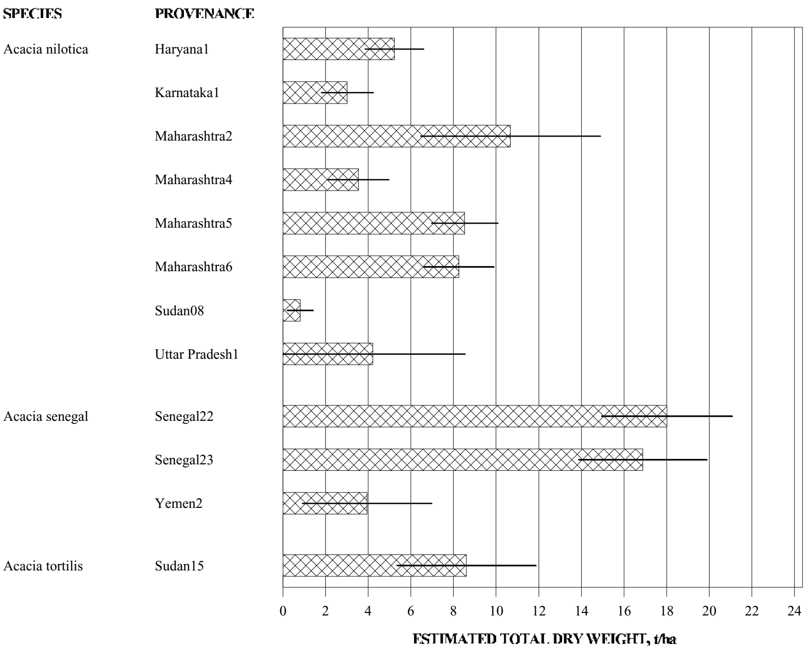


Figure 20. Total dry weight in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 9. Results from analysis of variance of species and provenance differences of total dry weight in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	2; 9.8	34.4	2.7	0.12	n.s.
Provenance(species)	9; 52	26.7	26.9	<0.0001	
Plotx	1; 52	4.96	5.0	0.03	
Error	52	0.994			
A. nilotica					
Provenance	7; 37	24.5	24.5	<0.0001	***
Error	37	1			
A. senegal					
Provenance	2; 11	296	31.6	<0.0001	***
Plotx	1; 11	38.3		0.07	
Error	11	9.36	4.1		

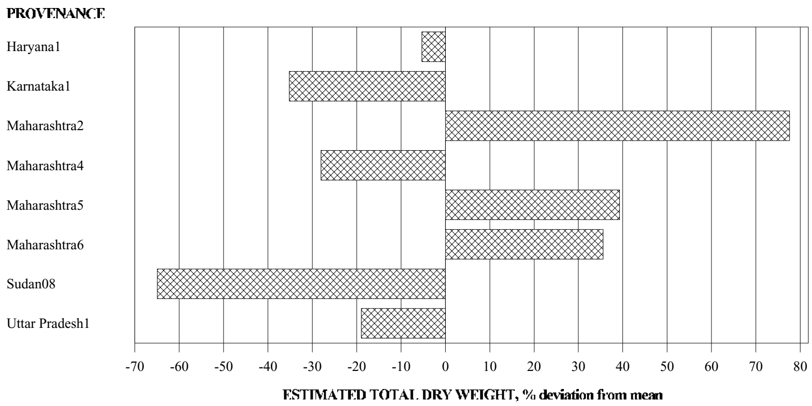


Figure 21. Best linear unbiased predictors (BLUPs) for total dry weight in the *A. nilotica* provenances in the trial at Bebedouro, Brazil (Trial no. 15 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.9 Damage score

The damage score was determined on a scale from 0 to 3, where 0 means no damage, 1 - light damage, 2 - moderate damage and 3 - severe damage. The damage in the trial was believed to be primarily due to drought stress.

Statistical analyses

The plots of residuals from the first model indicated that there was variance heterogeneity, and weight statements were applied in all analysis to fulfil the assumptions of the models. The co-variate ploty2 was significant in all analyses except for the analysis of provenance differences within *A. senegal.*

There are two problems with the scale that should be borne in mind when interpreting the results. First, the scores are subjective and do not necessarily reflect the real damage level of the trees. It may be difficult to give the proper scores to different species or to trees of different sizes, because the damage affects the trees differently. Second, the scores are not necessarily equidistant. For the growth of a tree it may mean less going from a damage score of 0 to 1 than going from a score of 1 to 2. There are ways of taking this into account, but this has not been attempted in the current analyses.

Results

The variation between the provenances in this variable was large, some provenances hardly being damaged at all with average scores of almost zero, while in other provenances nearly all trees were severely damaged and the average score was as high as 2.8. The differences between species were not significant, but there were significant differences between the provenances of both *A. mangium* and *A. nilotica* (Table 10). In *A. senegal*, the provenances were not significantly different.

Even though the differences between species were not significant, all provenances of *A. senegal* had low damage scores, as had the provenance Sudan15 of *A. tortilis* and Australia1 of *A. aneura* (Fig. 22). In *A. mangium* the provenance Queensland6 was severely damaged, while the other provenances were in the category with moderate damage. In *A. nilotica* the smallest damages were found in the provenances Maharashtra2, Maharashtra5 and Maharashtra6, while the other provenances were moderately and, in the case of Sudan08, severely damaged. The provenance India2 of *A. auriculiformis* was moderately damaged, whereas the provenances of *Eucalyptus* and *D. sissoo* were in the category with light damage.

The gains by provenance selection were ranging from -0.4 to 0.8 in *A. mangium* (Fig. 23). Note that in the figure negative values denote healthier trees. For *A. nilotica*, the gains were varying between ±1.2, indicating large improvements by selection of the best provenances (Fig. 24).

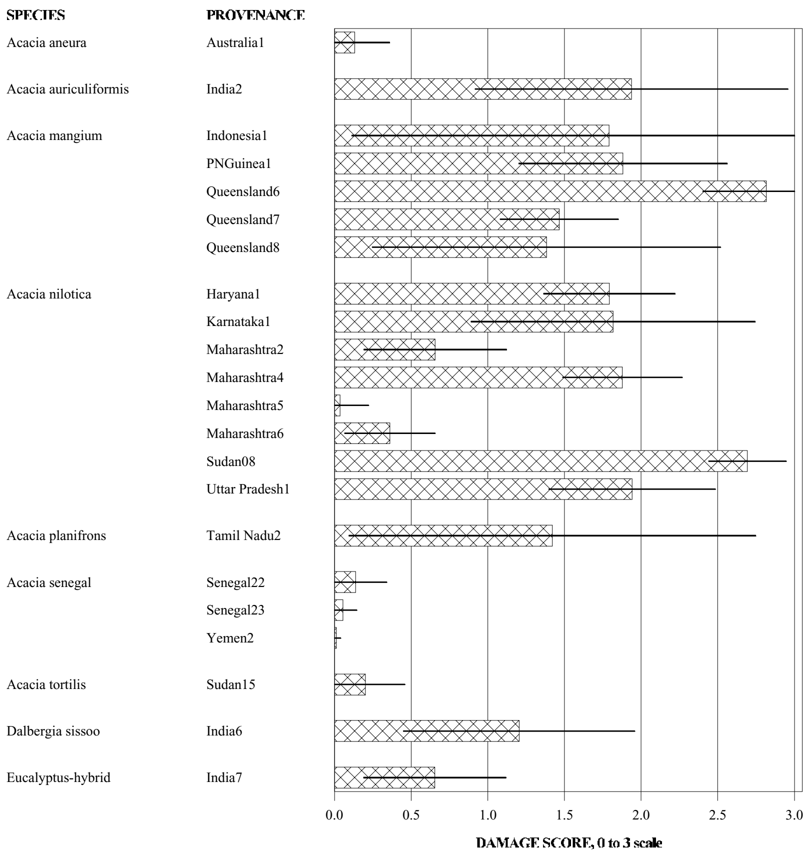


Figure 22. Damage score in the *Acacia* species and provenance trial at B. G. Kere, India (Trial no. 15 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 10. Results from analysis of variance of species and provenance differences of damage score in trial 15.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 12.9	27.5	1.0	0.47	n.s.
Provenance(species)	13; 89	24.6	26.8	<0.0001	
Ploty2	1; 89	9.7	10.6	0.002	
Error	89	0.9			
A. mangium					
Provenance	4; 16	6.6	6.3	0.003	*
Ploty2	1; 16	39.6	37.3	<0.0001	
Error	16	1.1			
A. nilotica					
Provenance	7; 36	52.4	51.9	<0.0001	***
Ploty2	1; 36	5.3	5.3	0.03	
Error	36	1.0			
A. senegal					
Provenance	2; 12	1.3	1.3	0.30	n.s.
Error	12	1.0			

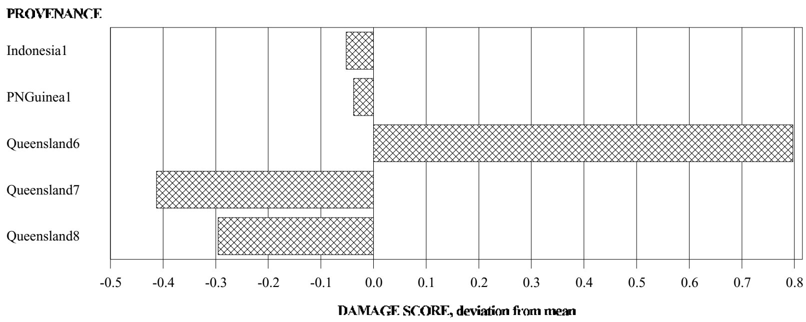


Figure 23. Best linear unbiased predictors (BLUPs) for damage score in the *A. mangium* provenances in the trial B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations from the mean value on the scale of the damage score. Note that negative deviations from the mean denote a better health status.

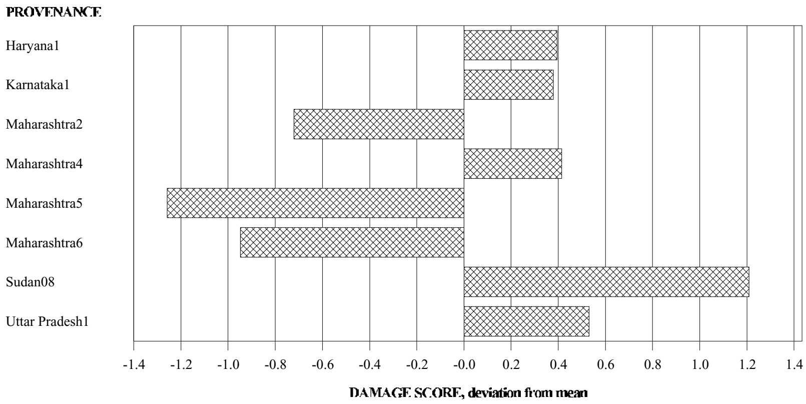


Figure 24. Best linear unbiased predictors (BLUPs) for total dry weight in the *A. nilotica* provenances in the trial B. G. Kere, India (Trial no. 15 in the arid zone series). Values are presented as deviations from the mean value on the scale of the damage score. Note that negative deviations from the mean denote a better health status.

4.10 Multivariate analysis of all provenances

This multivariate analysis included all the variables analysed in the univariate analyses except for the dry weight of the mean tree and the total dry weight, because these were not determined for several of the species. Survival and crown area were transformed with the arcsine transformation and the square root transformation before analysis, respectively. However, the variance heterogeneity observed in several of the other variables could not be accounted for, and the results should therefore be interpreted cautiously. Five of the observations (those that had a survival of zero) were not included in the analysis. No covariates were included in the analysis.

Of the seven canonical variates, no less than five were significant, indicating that the variation between the provenances is in several dimensions at the same time (Table 11). However, even though the significance levels indicated that there was important information in the fourth and the fifth canonical variates, the plots of scores of these variables did not give substantial new information. Therefore only results for the three first canonical variates are presented. In total, these variates accounted for 92 % of the variation. The test did not surprisingly demonstrate that the provenance effect was highly significant (P-values for Wilk's lambda and Pillai's trace below 0.0001). An additional multivariate test of the species effect indicated that there were also significant differences between the species in the trial (not shown, P-value for Wilk's lambda <0.0001, P-value for Pillai's trace =0.01).

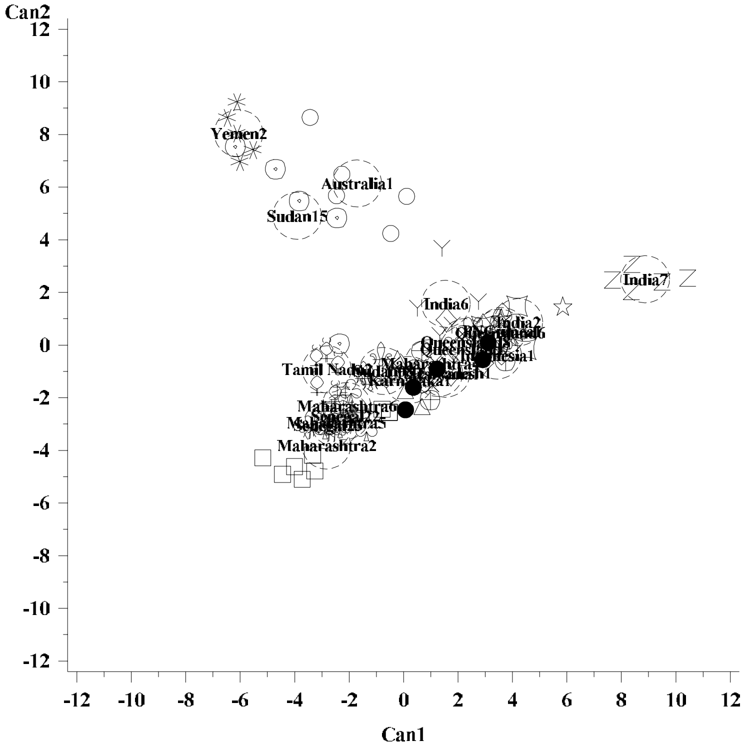
The plot of scores for the first three canonical variates is given in Fig. 25. Apart from the scores, the mean values for the provenances are given together with their approximate 95 % confidence regions. The presentation of the results in three dimensions is justified by the fact that these canonical variates account for 93 % of the variation. In the diagram, provenances that are far apart are interpreted as being different, and if the confidence regions do not overlap, it is likely that the provenances have different properties. The first impression of the score plots is that there is one big cluster of provenances and a number of single provenances which are located at a relatively large distance from this cluster. As would be expected from the univariate analyses the *Eucalyptus* hybrid (India7) is clearly separated from the cluster, but also the provenances of *A. tortilis* (Sudan15) and *A. aneura* (Australia1) diverge from the cluster. It is noteworthy that the provenances in the upper part of the upper diagram all have large numbers of stems; this also includes the provenance Yemen2 of *A. senegal.*

Even though it may be difficult to discern the provenances in the big cluster, going into detail it appears that all the provenances of *A. mangium* are located at the one end (the right side) of the cluster. The provenances of *A. nilotica* are at the middle and the other end of the cluster. Also at the left side are the Senegal22 and Senegal23 of *A. senegal.* Thus there appears to be a pattern of differences between the species even in the relatively compact cluster. The differences between the provenances of *A. mangium* and *A. nilotica* are dealt with in the following section.

Table 11. Results from the canonical variate analyses for the first canonical variates in the multivariate analysis of all provenances in trial 15.

Canonical variate no.	1	2	3	4	5	6	7
Proportion of variation	0.43	0.36	0.14	0.04	0.02	0.01	0.003
Significance, P-value	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.14	0.86

	Raw canonical coefficients			Standardised canonical coefficients			Canonical directions		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	1.6	-0.91	3.2	0.6	-0.3	1.2	5.3	-0.7	10.5
Height	2.5	1.1	-1.9	2.3	1.0	-1.7	13.7	2.6	-28.1
Crown area	-2.1	-1.8	-0.5	-2.0	-1.6	-0.4	-13.8	-7.7	-23.0
Number of stems	-0.33	1.1	0.14	-0.8	2.9	0.4	-29.8	60.3	-1.8
Average basal area	0.011	0.032	0.017	0.2	0.6	0.3	100.8	-100.2	-522.3
Total basal area	-0.027	-0.38	0.15	-0.06	-0.8	0.3	-2.7	-9.9	-72.4
Damage score	0.33	-0.35	0.41	0.3	-0.4	0.4	12.6	-4.3	26.9



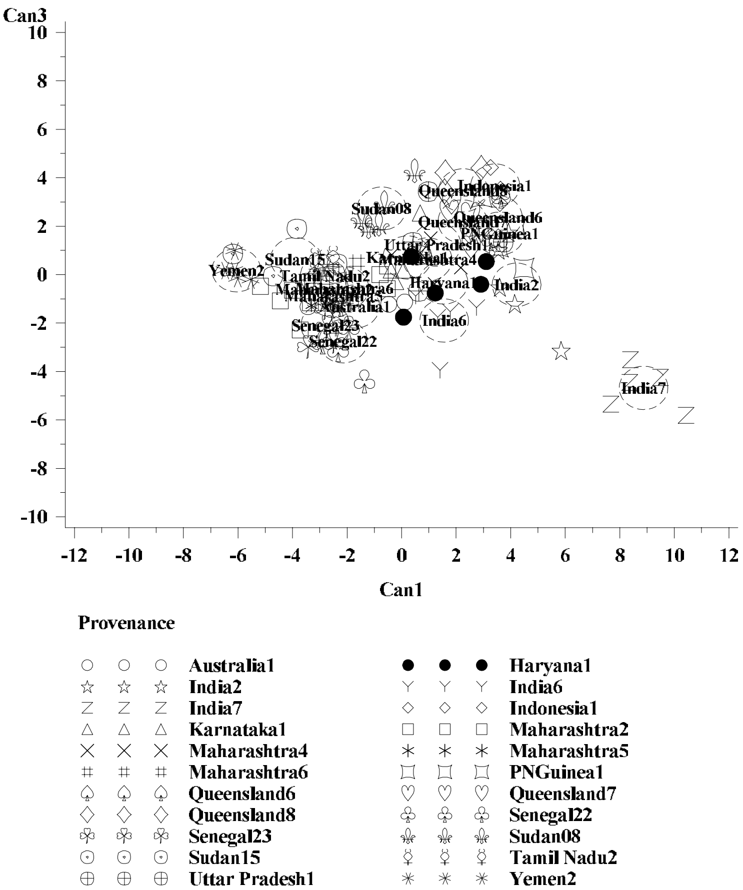


Figure 25. Score plot of the first and the second canonical variate (upper diagram) and of the first and the third canonical variate (lower diagram) from the analysis for all provenances in the trial at B.G. Kere (Trial no. 15 in the arid zone series). The variables survival, height, crown area, number of stems, average basal area, total basal area and damage score were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

4.11 Multivariate analysis of *A. mangium* and *A. nilotica*

A. mangium

In this analysis the same variables as in the previous analysis was included. However, as the provenance differences were not significant (P-value for Wilk‘s lambda=0.10, P-value for Pillai‘s trace=0.05), no further results are presented from this analysis.

A. nilotica

All nine variables analysed in the univariate analyses were included in the multivariate analysis of the *A. nilotica* provenances. The analysis demonstrated that there were highly significant differences between the provenances (P-values for Wilk‘s lambda and Pillai‘s trace both below 0.0001). Two of the canonical variates were significant, accounting for 86 % of the variation (Table 12).

The plot of scores in Fig. 26 confirms patterns found in the univariate analyses. The provenance Sudan08 is distinctly different from the other provenances. The other provenances, which are all from India, tend to group in two clusters, one with the fast-growing Maharashtra2, Maharashtra5 and Maharashtra6, and one with the less productive Haryana1, Karnataka1, Maharashtra4 and Uttar Pradesh1. As regards the different varieties, there were no clear patterns, the subspecies *indica* var. *cupressiformis*, subsp. *indica* var. *jaquemontii* and subsp. *indica* var. *cupressiformis* being mixed in between each others.

Table 12. Results from the canonical variate analyses for the first canonical variates in the multivariate analysis of provenances of *A. nilotica* in trial 15.

Canonical variate no.	1	2	3	4	5	6	7
Proportion of variation	0.67	0.19	0.10	0.02	0.01	0.009	0.0003
Significance, P-value	<0.0001	0.0002	0.10	0.80	0.86	0.87	0.99

	Raw canonical coefficients		Standardised canonical coefficients		Canonical directions	
Canonical variate no.	**1**	**2**	**1**	**2**	**1**	**2**
Survival	3.6	-2.0	1.0	-0.5	1.4	-1.3
Height	0.69	-3.7	0.3	-1.9	-3.2	-6.8
Crown area	-0.90	0.96	-0.9	0.9	-9.1	6.0
Number of stems	2.5	0.34	0.9	0.1	3.3	1.3
Basal area of mean tree	-0.82	0.13	-13.5	2.1	-155.3	27.6
Total basal area	2.65	-3.5	4.5	-6.0	-15.9	4.6
Dry weight, mean tree	2.44	-0.23	11.9	-1.1	-41.4	14.6
Total dry weight	-0.63	1.0	-3.1	5.1	-41.2	16.7
Damage score	0.66	-0.34	0.7	-0.3	11.2	-3.9

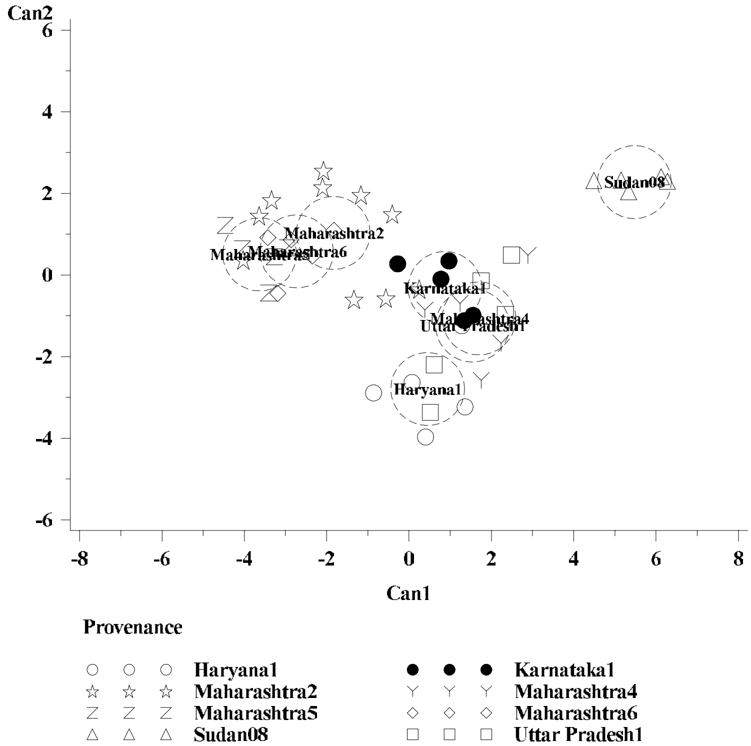


Figure 26. Score plot of the first and the second canonical variate from the analysis of *A. nilotica* provenances in the trial at B.G. Kere (Trial no. 15 in the arid zone series). The variables survival, height, crown area, number of stems, basal area of the mean tree, total basal area, dry weight of the mean tree, total dry weight and damage score were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

5. Discussion and conclusions

Productivity

The productivity of the best provenances in this trial was at the high end compared to trials from Burkina Faso and Brazil, also parts of this series. Senegal22 of *A. senegal* had an average production of 2.6 t ha^{-1} y^{-1}, and one could expect that the *Eucalyptus*-hybrid India7 had an even larger production of biomass. The *Eucalyptus*-hybrid had a slightly larger total basal area than Senegal22, and was also considerably higher.

Species differences

There were important differences between the species of the trial. It was clear that *A. mangium* had poor survival compared to the other species, and in general was poorly adapted to the site. This was reflected in small crown areas and total basal areas, and the species also had high damage scores. It seems that the dry conditions of the site at B.G. Kere are not favourable to the species, which origin in areas with higher rainfalls. The other representative of species from the humid tropics, *A. auriculiformis*, had a better performance in terms of survival, height growth and basal area. Unfortunately, the provenance of this species had a high score on the damage scale, the average score corresponding to moderately damaged.

Many of the species from the dry tropics were represented by only one provenance, and it would be premature to give species recommendations on this basis. In *A. nilotica* and *A. senegal* several provenances were represented, but there were large variations between the provenances. However, it appears from the trial that apart from *A. mangium*, all species had an acceptable survival and growth. Further testing of the species represented by one provenance alone may help in optimising the choice of provenances.

Provenance differences and recommendations

Within *A. mangium*, the differences between provenances were in many variables at the border of significance, either below or above the 5 % level. The multivariate analysis did not give a clear answer as to the presence of provenance differences, and it remains an open question whether the provenances are different or not. Taking into account these reservations and the fact that the species in general does not seem very well adapted to the site, it appears that the provenances PNGuinea1 and Queensland7 are the best choice, having the best survival and the largest production of basal area.

In *A. nilotica*, the three provenances Maharashtra2, Maharashtra5 and Maharashtra6 were clearly better than the rest, having larger crown areas, basal areas and dry weights. These provenances also had the lowest damage scores. Unfortunately, the better growth was not a general trend for the provenances from Maharashtra as the provenance Maharashtra4 had a poor growth. Maharashtra4 (subsp. *indica* var. *cupressiformis*) was collected at the same site as Maharashtra2 (subsp. *indica* var. *vediana*), indicating that the differences between the two provenances are due to variety differences. Unfortunately the variety differences are not consistent either, as indicated by Maharastra5 and Maharashtra6. These provenances represented a parallel sample of the same varieties but on a different site. However, they both had fast growth and could not be separated in the analysis. Finally it should be mentioned that the only provenance from Africa, Sudan08, had an extremely poor growth.

The provenances of *A. senegal* which originated from Senegal were highly different from the provenance from Yemen. The Yemeni provenance had a slow growth and a very bushy growth habit as indicated by the large number of stems, whereas the provenances from Senegal were fast-growing and with a small number of stems.

Overall it seems that the best provenances for production of biomass are the provenances of *A. senegal* from Senegal and the *Eucalyptus*-hybrid. It must be stressed, however, that provenances from the other species do also show good growth, and that it is possible to make a diversified choice of species on the basis of results in the trial. The drought-tolerant species *A. aneura*, *A. tortilis* and the best provenances of *A. nilotica* deserve special mention in this trial.

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Annex 1. Description of the trial site

Name of site:	B.G. Kere Latitude: 14°11'N Longitude: 76°24'E Altitude: 735 m
Meteorological stations:	Chitradurga (14°14'N, 76°26'E, 733 m (FAO 1987))
Rainfall:	Annual mean: 654 mm/year (FAO 1987) 1990: 250-300 mm
Rainy season:	5-10 (May-October) Type: Season with dry period (FAO 1987) Length (days): Intermediate 106, wet 29 (FAO 1987)
Dry months/year:	No. of dry months (< 50 mm): 6 No. of dry periods: 1
Temperature:	Annual mean: 25.8 Coldest month: 16.7 Hottest month: 36.3
Wind:	Speed: 2.0 m/s (FAO 1987)
Topography:	Gentle.
Soil:	Type: Poor, stony Depth: Shallow? (See Myforest 25 (1), 33-35, Studies on the response to regeneration by protection from biotic interference)
Climatic/agroecological zone:	Semi-arid/subhumid
Koeppen classification:	BSh/Aw
Dominant natural vegetation:	*Hardwickia binnata* (?)

Annex 2. Seedlot numbers of the provenances tested in trial no. 15

The plot number refers to the seedlot in the map of the trial, see annex 3.

Seedlot numbers					Provenance information						
Provenance	DFSC	Country of origin	Plot	Species	Origin	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
Australia1		Bgkere3	20	*A. aneura*		Australia					
India2		Bgkere4	21	*A. auriculiformis*	West Bengal	India					
Indonesia1		13621	16	*A. mangium*	Piru Ceram	Indonesia	3°04'S	128°12'E	150	ca. 2800	9
PNGuinea1		13460	13	*A. mangium*	Oriomo R.	Papua New Guinea	8°50'S	143°08'E	10	ca. 2000	33
Queensland6		12992	15	*A. mangium*	Rex Range, Qsl	Australia	16°30'S	145°22'E	30	ca. 2000	8
Queensland7		13233	14	*A. mangium*	Walsh's Pyramid, Qsl	Australia	17°06'S	145°48'E	20	ca. 2000	10
Queensland8		13234	17	*A. mangium*	Trinity Inlet, Qsl	Australia	17°02'S	145°48'E	20	ca. 2000	10
Haryana1	1081/82		8	*A. nilotica* subsp. *indica* var. *cupressiformis*	Nornaul Singhana (Mahandra Gahr) Bhiwani (Hissar)	India	28°03'N	76°07'E	250	714	4
Karnataka1		Bgkere1	18	*A. nilotica*	B.G. Kere	India	14°11'N	76°24'E	735	654	
Maharashtra2	1071/82		2 and 4	*A. nilotica* subsp. *indica* var. *vediana*	Pune	India	18°32'N	73°51'E	559	715	25
Maharashtra4	1082/82		3	*A. nilotica* subsp. *indica* var. *cupressiformis*	Pune	India	18°32'N	73°51'E	559	714	25
Maharashtra5	1083/82		1	*A. nilotica* subsp. *indica* var. *cupressiformis*	Akola	India	20°42'N	77°02'E	282	877	
Maharashtra6	1084/82		5	*A. nilotica* subsp. *indica* var. *vediana*	Akola	India	20°42'N	77°02'E	282	877	
Sudan08	1068/82	7/1982	7	*A. nilotica* subsp. *nilotica*	Khartoum Forest	Sudan	15°36'N	32°33'E	330	165	25
Uttar Pradesh1	1069/82		6	*A. nilotica* subsp. *indica* var. *jaquemontii*	Bawain Forest Block, Etawah (Mainpuri),	India	26°45'N	79°00'E	157	762	26

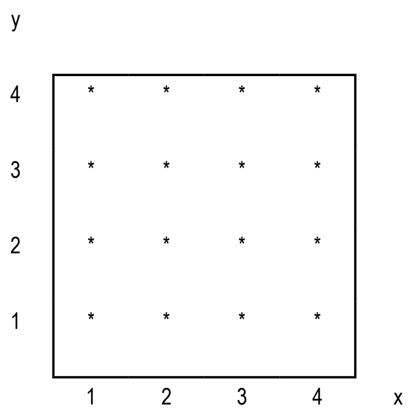
Seedlot numbers					Provenance information						
Provenance	DFSC	Country of origin	Plot	Species	Provenance name	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
Tamil Nadu2		Bgkere2	19	*A. planifrons*	Coimbatore, Tamil Nadu	India	11°00‘N	76°57‘E	314	790	
Senegal22	1035/82	82/559	11	*A. senegal*	Namarel	Senegal	14°46‘N	16°01‘W	50	332	33
Senegal23	1036/82	82/558	10	*A. senegal*	Windou Tiengoly	Senegal	15°59‘N	15°20‘W	39	350	32
Yemen2	1063/82	(2)	12	*A. senegal*	Ahwar	Yemen	13°25‘N	46°40‘E	500	225	20
Sudan15	1045/82	3/82	9	*A. tortilis* subsp. var. *spirocarpa*	Khartoum, West Nile	Sudan	15°36‘N	32°33‘E	330	165	25
India6		Bgkere6	23	*Dalbergia sissoo*	B.G. Kere ?	India					
India7		Bgkere5	22	*Eucalyptus* hybrid	Hosakote	India					

Annex 3. Layout of plots in the field

The numbers correspond to the seedlots given in annex 2.

y					
23	10 D	21 D	3 A	18 B	14 D
22	3 B	4 A	3 C	5 B	14 C
21	12 B	4 D	17 E	10 B	19 D
20	21 B	16 B	13 E	23 E	9 A
19	2 E	1 E	1 A	18 A	2 D
18	19 A	17 C	1 B	19 C	10 E
17	2 B	11 A	19 E	21 E	9 E
16	7 B	4 B	11 B	20 E	2 A
15	18 D	23 D	7 A	5 C	12 A
14	15 C	16 D	14 E	21 C	12 E
13	20 B	21 A	13 C	16 E	23 A
12	16 A	11 E	3 E	22 D	19 B
11	13 D	23 B	12 D	17 A	7 C
10	9 C	22 E	17 D	10 A	6 C
9	5 E	18 C	12 C	15 B	6 D
8	8 D	15 A	8 B	8 C	6 B
7	14 B	1 D	20 D	8 E	8 A
6	3 D	2 C	6 A	7 D	17 B
5	15 E	4 E	22 A	9 D	9 B
4	4 C	13 A	6 E	1 C	22 B
3	16 C	13 B	18 E	14 A	23 C
2	22 C	10 C	5 D	20 C	11 D
1	11 C	5 A	7 E	20 A	15 D
	1	2	3	4	5 x

Individual tree positions in each plot:



Annex 4. Plot data set

The plot numbers correspond to the seedlots given in annex 2 and the location given in annex 3.

Provenance	Plot	Plotx	Ploty	Level	*Species*	Survival	Height	Crown area	Number of stems	Basal area of mean tree	Total basal area	Dry weight of mean tree	Total dry weight	Damage score
						propotion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	0-3 scale
Australia1	20	1	13	93.4	*A. aneura*	0.88	2.53	8.39	7.79	30.5	2.97			0.00
Australia1	20	3	7	91.8	*A. aneura*	0.88	2.65	4.26	6.43	25.3	2.46			0.29
Australia1	20	4	1	94.0	*A. aneura*	0.94	2.39	4.25	5.33	25.6	2.66			0.00
Australia1	20	4	2	93.4	*A. aneura*	1.00	2.53	6.51	7.94	30.4	3.37			0.38
Australia1	20	4	16	94.8	*A. aneura*	1.00	2.23	5.75	9.69	23.4	2.61			0.00
India2	21	1	20	96.9	*A. auriculiformis*	0.31	2.64	3.86	2.00	51.4	1.79			3.00
India2	21	2	13	92.9	*A. auriculiformis*	0.81	4.58	7.53	2.46	85.2	7.70			1.31
India2	21	2	23	99.0	*A. auriculiformis*	0.69	3.27	4.38	1.82	43.2	3.30			1.73
India2	21	4	14	93.4	*A. auriculiformis*	0.56	2.74	2.63	1.89	20.7	1.30			1.08
India2	21	4	17	95.3	*A. auriculiformis*	0.44	2.74	3.91	2.57	46.4	2.26			2.57
Indonesia1	16	1	3	92.2	*A. mangium*	0.00					0.00			0.00
Indonesia1	16	1	12	93.2	*A. mangium*	0.19	1.33	0.64	1.33	23.3	0.48			3.00
Indonesia1	16	2	14	93.2	*A. mangium*	0.13	1.80	1.16	1.00	15.9	0.22			1.67
Indonesia1	16	2	20	97.1	*A. mangium*	0.00					0.00			
Indonesia1	16	4	13	92.8	*A. mangium*	0.00					0.00			
PNGuinea1	13	1	11	93.8	*A. mangium*	0.13	2.40	2.04	1.50	50.0	0.69			0.46
PNGuinea1	13	2	3	92.5	*A. mangium*	0.31	2.28	1.93	1.40	18.3	0.64			1.27
PNGuinea1	13	2	4	92.0	*A. mangium*	0.31	3.16	5.43	1.20	59.9	2.08			2.00
PNGuinea1	13	3	13	93.0	*A. mangium*	0.25	1.85	2.05	1.75	47.5	1.32			2.20
PNGuinea1	13	3	20	97.1	*A. mangium*	0.56	2.23	2.72	2.56	46.2	2.89			3.00
Queensland6	15	1	5	92.2	*A. mangium*	0.19	1.80	1.09	1.67	17.3	0.36			2.67
Queensland6	15	1	14	93.2	*A. mangium*	0.44	2.26	2.48	1.57	27.8	1.35			2.43
Queensland6	15	2	8	92.8	*A. mangium*	0.13	1.90	1.23	2.50	21.0	0.29			2.50
Queensland6	15	4	9	92.0	*A. mangium*	0.00					0.00			
Queensland6	15	5	1	93.9	*A. mangium*	0.31	2.56	3.42	2.20	41.4	1.44			2.20
Queensland7	14	1	7	92.9	*A. mangium*	0.13	1.45	1.42	1.50	11.0	0.15			0.38
Queensland7	14	3	14	93.6	*A. mangium*	0.50	1.84	1.65	1.50	18.3	1.02			1.89
Queensland7	14	4	3	92.6	*A. mangium*	0.44	2.04	1.84	1.86	14.8	0.72			1.09
Queensland7	14	5	22	98.2	*A. mangium*	0.56	1.87	2.04	2.00	38.9	2.43			3.00

Provenance	Plot	Plotx	Ploty	Level	*Species*	Survival	Height	Crown area	Number of stems	Basal area of mean tree	Total basal area	Dry weight of mean tree	Total dry weight	Damage score
						propotion	m	m^2 tree^{-1}	no. tree^{-1}	cm^2 tree^{-1}	m^2 ha^{-1}	kg tree^{-1}	t ha^{-1}	0-3 scale
Queensland7	14	5	23	98.5	*A. mangium*	0.63	1.45	1.64	1.30	21.5	1.49			3.00
Queensland8	17	2	18	95.9	*A. mangium*	0.19	1.53	2.03	2.67	29.0	0.60			1.50
Queensland8	17	3	10	92.6	*A. mangium*	0.13	0.80	0.30	1.00	0.6	0.01			0.38
Queensland8	17	3	21	97.7	*A. mangium*	0.13	1.50	1.10	2.50	22.7	0.32			3.00
Queensland8	17	4	11	92.3	*A. mangium*	0.00					0.00			0.00
Queensland8	17	5	6	91.5	*A. mangium*	0.38	2.20	3.22	1.50	33.1	1.38			2.67
Karnataka1	18	1	15	93.4	*A. nilotica*	0.38	1.52	3.95	1.17	17.0	0.71	3.2	1.34	2.50
Karnataka1	18	2	9	93.1	*A. nilotica*	0.81	1.71	2.69	1.46	18.6	1.68	3.8	3.43	2.08
Karnataka1	18	3	3	92.6	*A. nilotica*	0.81	1.97	5.43	1.54	23.1	2.09	5.5	4.97	1.92
Karnataka1	18	4	19	96.5	*A. nilotica*	0.94	1.51	2.32	1.13	12.1	1.26	2.2	2.34	0.20
Karnataka1	18	4	23	98.7	*A. nilotica*	1.00	1.41	2.59	1.44	13.9	1.54	2.7	3.00	2.63
Haryana1	8	1	8	93.2	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.88	2.65	9.37	1.21	30.2	2.93	7.2	6.98	1.33
Haryana1	8	3	8	92.2	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.81	2.38	4.74	1.38	27.1	2.45	6.2	5.63	1.07
Haryana1	8	4	7	91.6	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.69	2.20	1.71	1.36	20.4	1.56	4.1	3.17	1.92
Haryana1	8	4	8	91.9	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.69	1.98	5.47	1.73	24.9	1.90	5.5	4.23	2.17
Haryana1	8	5	7	91.6	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.75	2.60	3.52	1.25	31.2	2.60	7.4	6.13	1.85
Maharashtra4	3	1	6	92.4	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.56	2.31	3.13	2.00	22.0	1.37	4.5	2.79	1.11
Maharashtra4	3	1	22	98.3	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.94	1.37	2.59	1.87	9.5	0.99	1.6	1.63	2.25
Maharashtra4	3	3	12	92.8	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.69	1.71	3.16	1.18	27.0	2.06	6.3	4.78	2.18
Maharashtra4	3	3	22	98.4	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.94	1.49	2.00	1.33	15.3	1.59	2.9	3.01	2.53
Maharashtra4	3	3	23	98.9	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.94	2.08	3.21	1.47	21.4	2.22	5.3	5.50	2.00

Provenance	Plot	Plotx	Ploty	Level	*Species*	Survival	Height	Crown area	Number of stems	Basal area of mean tree	Total basal area	Dry weight of mean tree	Total dry weight	Damage score
						propo-tion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	0-3 scale
Maharashtra5	1	2	7	92.4	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.81	1.69	7.83	1.08	30.8	2.78	7.1	6.40	0.00
Maharashtra5	1	2	19	96.5	*A. nilotica* subsp. *indica* var. *cupressiformis*	1.00	1.66	9.28	1.00	39.2	4.36	9.5	10.56	0.00
Maharashtra5	1	3	18	95.9	*A. nilotica* subsp. *indica* var. *cupressiformis*	1.00	1.71	7.95	1.00	36.7	4.08	8.7	9.70	0.31
Maharashtra5	1	3	19	96.6	*A. nilotica* subsp. *indica* var. *cupressiformis*	0.94	1.82	9.82	1.27	35.9	3.74	8.4	8.78	0.00
Maharashtra5	1	4	4	91.6	*A. nilotica* ssubsp. *indica* var. *cupressiformis*	0.75	2.16	10.89	1.17	36.7	3.05	8.6	7.20	0.00
Uttar Pradesh1	6	3	4	91.8	*A. nilotica* subsp. *indica* var. *jaquemontii*	0.63	1.88	3.61	2.10	17.6	1.22	3.4	2.38	1.25
Uttar Pradesh1	6	3	6	91.7	*A. nilotica* subsp. *indica* var. *jaquemontii*	0.69	1.61	3.16	1.64	20.8	1.59	4.7	3.56	1.57
Uttar Pradesh1	6	5	8	92.5	*A. nilotica* subsp. *indica* var. *jaquemontii*	0.31	1.16	2.11	1.00	9.6	0.33	1.6	0.57	2.40
Uttar Pradesh1	6	5	9	91.9	*A. nilotica* subsp. *indica* var. *jaquemontii*	0.38	2.35	2.50	1.17	23.7	0.99	4.9	2.03	2.50
Uttar Pradesh1	6	5	10	91.9	*A. nilotica* subsp. *indica* var. *jaquemontii*	0.88	2.54	7.16	1.71	48.8	4.75	12.9	12.55	1.38
Maharashtra2	4	1	4	92.1	*A. nilotica* ssubsp. *indica* var. *vediana*	0.19	2.63	27.37	1.33	66.3	1.38	19.6	4.08	0.43
Maharashtra2	2	1	17	94.9	*A. nilotica* subsp. *indica* var. *vediana*	0.94	1.74	17.17	1.93	54.3	5.66	14.3	14.92	0.13
Maharashtra2	2	1	19	96.1	*A. nilotica* ssubsp. *indica* var. *vediana*	1.00	2.56	19.84	1.06	76.6	8.51	23.0	25.51	0.13
Maharashtra2	4	2	5	91.9	*A. nilotica* ssubsp. *indica* var. *vediana*	0.56	2.56	11.89	1.33	50.2	3.14	13.7	8.55	0.44
Maharashtra2	2	2	6	92.0	*A. nilotica* ssubsp. *indica* var. *vediana*	0.94	1.92	13.10	1.00	37.3	3.89	8.9	9.26	0.38
Maharashtra2	4	2	16	94.6	*A. nilotica* subsp. *indica* var. *vediana*	0.94	1.47	7.54	1.53	22.3	2.16	5.0	4.90	1.40
Maharashtra2	4	2	21	97.6	*A. nilotica* ssubsp. *indica* var. *vediana*	0.88	1.77	5.72	1.14	25.7	2.50	6.2	6.07	2.07

Provenance	Plot	Plotx	Ploty	Level	*Species*	Survival	Height	Crown area	Number of stems	Basal area of mean tree	Total basal area	Dry weight of mean tree	Total dry weight	Damage score
						propo-tion	m	m^2 tree^{-1}	no. tree^{-1}	cm^2 tree^{-1}	m^2 ha^{-1}	kg tree^{-1}	t ha^{-1}	0-3 scale
Maharashtra2	4	2	22	98.3	*A. nilotica* subsp. *indica* var. *vediana*	0.94	1.75	5.71	1.20	24.2	2.52	5.4	5.61	2.00
Maharashtra2	2	5	16	94.8	*A. nilotica* ssubsp. *indica* var. *vediana*	0.88	1.93	16.10	1.21	52.1	5.06	13.6	13.22	0.14
Maharashtra2	2	5	19	97.9	*A. nilotica* ssubsp. *indica* var. *vediana*	0.94	1.94	17.12	1.13	52.2	5.44	14.0	14.62	0.00
Maharashtra6	5	1	9	93.6	*A. nilotica* subsp. *indica* var. *vediana*	0.94	1.96	7.93	1.13	34.2	3.56	7.9	8.25	0.00
Maharashtra6	5	2	1	94.0	*A. nilotica* subsp. *indica* var. *vediana*	1.00	1.49	5.25	1.19	26.4	2.93	5.6	6.24	0.06
Maharashtra6	5	3	2	93.5	*A. nilotica* subsp. *indica* var. *vediana*	0.94	1.53	7.69	1.60	28.8	3.00	6.4	6.68	0.38
Maharashtra6	5	4	15	94.1	*A. nilotica* subsp. *indica* var. *vediana*	0.88	1.66	7.01	1.29	43.0	4.18	10.6	10.28	0.86
Maharashtra6	5	4	22	98.4	*A. nilotica* subsp. *indica* var. *vediana*	1.00	1.69	6.46	1.00	35.4	3.94	8.8	9.83	0.44
Sudan08	7	1	16	94.4	*A. nilotica* subsp. *nilotica*	0.88	0.96	1.94	2.36	5.3	0.48	0.8	0.68	2.60
Sudan08	7	3	1	94.2	*A. nilotica* subsp. *nilotica*	0.88	0.94	2.63	1.92	5.2	0.47	0.9	0.83	2.67
Sudan08	7	3	15	94.2	*A. nilotica* subsp. *nilotica*	0.56	0.52	0.49	1.50	1.1	0.06	0.1	0.06	3.00
Sudan08	7	4	6	91.6	*A. nilotica* subsp. *nilotica*	0.69	1.06	3.71	2.45	9.9	0.75	2.5	1.90	2.14
Sudan08	7	5	11	92.3	*A. nilotica* subsp. *nilotica*	0.75	0.77	1.66	1.83	4.3	0.36	0.7	0.59	2.77
Tamil Nadu2	19	1	18	95.5	*A. planifrons*	0.94	1.25	6.65	2.60	16.4	1.70			1.47
Tamil Nadu2	19	3	17	95.4	*A. planifrons*	1.00	1.15	5.06	2.19	15.7	1.74			3.00
Tamil Nadu2	19	4	18	95.8	*A. planifrons*	1.00	1.15	4.96	2.80	11.8	1.23			1.44
Tamil Nadu2	19	5	12	92.4	*A. planifrons*	0.94	1.39	5.98	3.33	20.7	2.16			1.20
Tamil Nadu2	19	5	21	97.5	*A. planifrons*	1.00	2.36	10.28	2.88	49.1	5.46			0.00
Senegal22	11	1	1	93.1	*A. senegal*	1.00	2.50	14.53	1.56	46.8	5.21	13.0	14.49	0.13
Senegal22	11	2	12	92.8	*A. senegal*	1.00	2.53	11.34	2.25	53.0	5.89	14.9	16.54	0.50
Senegal22	11	2	17	95.4	*A. senegal*	0.94	2.14	10.33	1.73	42.3	4.41	11.2	11.71	0.07
Senegal22	11	3	16	94.9	*A. senegal*	1.00	2.96	16.97	1.81	68.0	7.56	20.5	22.83	0.00
Senegal22	11	5	2	92.8	*A. senegal*	1.00	3.54	19.33	1.56	66.9	7.43	19.7	21.90	0.00
Senegal23	10	1	23	99.0	*A. senegal*	0.88	2.32	13.94	1.64	52.7	5.12	15.4	14.99	0.21

Provenance	Plot	Plotx	Ploty	Level	*Species*	Survival	Height	Crown area	Number of stems	Basal area of mean tree	Total basal area	Dry weight of mean tree	Total dry weight	Damage score
						propotion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	0-3 scale
Senegal23	10	2	2	93.2	*A. senegal*	1.00	2.51	16.14	1.81	45.3	5.03	12.3	13.67	0.00
Senegal23	10	4	10	92.1	*A. senegal*	0.94	2.51	15.50	2.27	68.0	7.08	20.6	21.48	0.00
Senegal23	10	4	21	97.7	*A. senegal*	1.00	2.56	13.61	1.56	49.6	5.51	13.8	15.37	0.06
Senegal23	10	5	18	95.7	*A. senegal*	1.00	2.39	13.41	1.44	60.1	6.68	17.6	19.61	0.00
Yemen2	12	1	21	97.7	*A. senegal*	1.00	1.34	6.33	10.13	18.1	2.01	3.9	4.38	0.00
Yemen2	12	3	9	92.5	*A. senegal*	1.00	1.47	7.49	10.94	24.0	2.67	5.7	6.28	0.06
Yemen2	12	3	11	92.6	*A. senegal*	0.94	1.37	6.52	11.33	15.7	1.64	3.3	3.43	0.00
Yemen2	12	5	14	93.6	*A. senegal*	1.00	1.45	6.10	9.38	15.0	1.66	3.2	3.57	0.00
Yemen2	12	5	15	94.2	*A. senegal*	1.00	1.39	7.00	9.31	16.4	1.83	3.5	3.93	0.00
Sudan15	9	1	10	93.8	*A. tortilis* subsp. *spirocarpa*	0.94	1.41	7.93	10.27	22.9	2.39	6.6	6.90	0.00
Sudan15	9	4	5	91.7	*A. tortilis* subsp. *spirocarpa*	0.69	1.42	5.75	8.00	23.6	1.80	7.0	5.33	0.38
Sudan15	9	5	5	91.4	*A. tortilis* subsp. *spirocarpa*	0.75	2.26	7.94	7.17	37.1	3.09	13.1	10.93	0.00
Sudan15	9	5	17	95.2	*A. tortilis* subsp. *spirocarpa*	1.00	1.66	6.26	8.81	31.8	3.53	10.4	11.52	0.19
Sudan15	9	5	20	97.0	*A. tortilis* subsp. *spirocarpa*	0.94	1.38	4.74	2.93	25.5	2.66	8.0	8.33	0.44
India6	23	2	11	93.2	*Dalbergia sissoo*	0.94	2.73	2.68	2.60	26.1	2.71			1.67
India6	23	2	15	94.1	*Dalbergia sissoo*	1.00	2.33	2.96	1.75	21.7	2.41			1.50
India6	23	4	20	96.9	*Dalbergia sissoo*	1.00	1.96	2.35	2.75	17.1	1.90			1.75
India6	23	5	3	92.4	*Dalbergia sissoo*	1.00	3.78	8.22	5.00	52.7	5.86			0.44
India6	23	5	13	93.3	*Dalbergia sissoo*	0.94	2.56	3.37	2.00	28.8	3.00			0.67
India7	22	1	2	90.6	*Eucalyptus-hybrid*	0.94	4.77	3.31	1.40	45.0	4.68			0.38
India7	22	2	10	93.2	*Eucalyptus-hybrid*	0.69	4.48	2.10	1.64	44.3	3.38			0.88
India7	22	3	5	91.8	*Eucalyptus-hybrid*	0.88	5.86	4.51	1.07	93.7	9.11			0.21
India7	22	4	12	92.7	*Eucalyptus-hybrid*	0.88	5.19	3.31	1.36	85.1	8.27			1.14
India7	22	5	4	91.7	*Eucalyptus-hybrid*	0.81	5.06	4.68	1.38	76.2	6.88			0.67