UNIVERSITY OF COPENHAGEN

Evaluation of an Acacia and Prosopis trial at Jodhpur, India

Trial no. 16 in the Arid Zone Series

Ræbild, Anders; Graudal, Lars; Harsh, L.N.

Publication date:
2004

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Ræbild, A., Graudal, L., & Harsh, L. N. (2004). *Evaluation of an Acacia and Prosopis trial at Jodhpur, India: Trial no. 16 in the Arid Zone Series*. Danida Forest Seed Centre. Results and Documentation, No. 31

Evaluation of an *Acacia* and *Prosopis* provenance trial at Jodhpur, India

Trial no. 16 in the Arid Zone Series

by

Anders Ræbild[1], Lars Graudal[1] and L.N. Harsh[2]

Central Arid Zone Research Institute[2], Jodhpur, India

Forest Research Institute and Colleges, Dehra Dun, India

Food and Agriculture Organization, Rome

Danida Forest Seed Centre[1], Denmark

Results and Documentation no. 31

Danida Forest Seed Centre

2004

Citation:
A. Ræbild, Lars Graudal and L.N. Harsh. 2004. Evaluation of an *Acacia* and *Prosopis* provenance trial at Jodhpur, India. Trial no. 16 in the Arid Zone Series. Results and Documentation No. 31. Danida Forest Seed Centre, Humlebaek, Denmark.

ISSN 0902-3224

Cover photo: Diagram showing total basal area of the *Acacia* provenances in the trial (fig. 11).

This publication can be requested from:

Forest & Landscape Denmark
Hørsholm Kongevej 11, DK-2970 Hørsholm, Denmark
Phone: +45-35281503 Fax: +45-35281517
Email: sl@kvl.dk
Web Site: www.SL.kvl.dk

and/or be downloaded from the DFSC homepage:
www.dfsc.dk/publications/

Technical Editor: Melita Jørgensen

Print:
Toptryk A/S, Graasten

From 1st January 2004, Danida Forest Seed Centre (DFSC) is part of the Danish Centre for Forest, Landscape and Planning, which is an independent centre under the Royal Veterinary and Agricultural University (KVL), in short *Forest & Landscape Denmark.*

Forest & Landscape is a merger between DFSC, the Danish Forestry College, the Danish Forest and Landscape Research Institute and the Department of Economics and Natural Resources at the Royal Veterinary and Agricultural University of Copenhagen (KVL).

Results and documentations are publications of analyses of e.g. provenance trials, carried out between DFSC and other institutions. DFSC publications are distributed free of charge.

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 originally published by the Danida Forest Seed Centre. The series has served as a place for publication of trial results for the Centre itself as well as for our collaborators. With the integration of DFSC into the Danish Centre for Forest, Landscape and Planning, the series will be taken over by *Forest & Landscape* publication series.

The reports are available from the *Forest & Landscape* 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 reports will allow a more detailed documentation than is possible in scientific journals.

This report presents results 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 was responsible for the reporting of this assessment.

This trial was established and maintained by the Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan in collaboration with Forest Research Institute & Colleges (FRI), Dehra Dun, U.P. under the auspices of Indian Council of Forestry Research and Education (ICFRE). The assessment team consisted of B. S. Beniwal (FRI), G.L. Meena (CAZRI), Hans Roulund, Lars Ravensbech and Lars Graudal (DFSC).

The authors wish to acknowledge the help of the personnel at CAZRI/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.

Abstract

This report describes results from a trial with 16 provenances of the species *Acacia nilotica*, *A. senegal*, *A. tortilis* and *Prosopis cineraria*. The trial was established with a spacing of 3 x 3 metres at Jodhpur, India, in 1984 and assessed after 7 years in 1991. Different growth parameters were measured and subjected to analyses of variance and multivariate analyses.

The fastest growing provenances of *A. tortilis* had increment rates of 0.3 m^2 ha^{-1} y^{-1}, corresponding to a dry weight production of up to 1.0 t ha^{-1} y^{-1}. Growth was slower for *A. nilotica* and *A. senegal.* For *A. nilotica* this was primarily due to a low survival. The provenances of *P. cineraria* had a very poor survival even though the species is native to the area.

All species were represented by more than one provenance. Within *A. nilotica* and *A. tortilis* there were large and significant differences between the provenances, while the two provenances of *A. senegal* could not be separated statistically. Due to the low survival, no tests were made of *P. cineraria*.

Contents

1. Introduction

This report describes the results from trial no. 16 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 more detailed introduction to the series is given by DFSC (Graudal *et al.* 2003).

This trial includes provenances of four species of the dry tropics: *Acacia nilotica*, *A. senegal*, *A. tortilis* and *Prosopis cineraria*.

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.

Acacia senegal is found in most of the Sahel, in Eastern and Southern Africa, and in Pakistan and India (Brenan 1983). The species produces excellent firewood and a gum traded as gum arabic. The species is considered quite variable, and some authors distinguish four varieties, although this is subject to debate (Ross 1979, Fagg & Barnes 1990). The varieties of the provenances in this trial have not been specified, but according to the origin must be of the variety *senegal.*

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

P. cineraria is a species native to the arid zones of the Arabian Gulf, Pakistan and parts of India (Pedersen 1980, Brown no date). Despite its many potentials as producer of wood and fodder and use in soil amelioration and cultivation of saline soils, little is known on the genetic variation within the species (Leakey & Last 1978).

2. Materials and methods

2.1 Site and establishment of the trial

The trial is located at Jodhpur (26°18′N, 73°40′E) in Karnataka, India at an altitude of 224 m. The mean annual temperature is 27.4 °C, and the mean annual rainfall is 373 mm (DFSC 1994). The dry period is approximately 9 months. The site is flat with a gentle slope, and the soil is a sandy loam. 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 1984. For calculation of annual increments it is assumed that the seed were sown in March 1984.

2.2 Species and provenances

The trial includes 16 provenances of the species *Acacia nilotica*, *A. senegal*, *A. tortilis* and *P. cineraria* (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.

The eight provenances of *A. nilotica* are all from India, the exception being a provenance from Sudan. Four different varieties are included, and it is worth noting that the provenances Maharashtra1, Maharashtra2 and Maharashtra4, and the provenances Maharashtra5 and Maharashtra6, represent different varieties collected at the same sites. These provenances are therefore well apt to compare properties of the different varieties.

The two provenances of *A. senegal* are from Senegal, as are two of the provenances of *A. tortilis*. The last provenance of *A. tortilis* is from Israel. All provenances of this species are of the subspecies *raddiana*. For *P. cineraria*, two provenances from India are compared with a provenance from Yemen.

2.3 The experimental design

The experimental design is a randomised complete block design with four blocks. Within each replicate, the provenance is represented by 49 trees in a plot, planted in a square of 7×7 trees. The trees are placed with a spacing of 3×3 m. Only the 25 trees in the centre were assessed. The layout of the trial is shown in annex 3, and further details are given in DFSC (1994).

2.4 Assessment of the trial

In March 1991 CAZRI, FRI 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 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 variables.

Table 1. Provenances of *Acacia* and *Prosopis* tested in trial no. 16 at Jodhpur, India.

Provenance identification	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
Haryana1	*A. nilotica* subsp. *indica* var. *cupressiformis*	Nornaul Singhana Road, Bhiwani (Hissar)	India	28° 03' N	76° 07' E	250	714	4
Maharashtra1	*A. nilotica* subsp. *indica* var. *jaquemontii*	Pune	India	18°32' N	73° 51' E	559	715	25
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 Forest Block, Etawah (Mainpuri)	India	26° 45' N	79° 00' E	157	762	26
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
Israel2	*A. tortilis* subsp. *raddiana*	Ein-Hazeva, Arava	Israel	30° 47' N	35° 12' W	100	40	
Senegal33	*A. tortilis* subsp. *raddiana*	F. C. Rao	Senegal	15° 56' N	16° 23' W	8		30
Senegal34	*A. tortilis* subsp. *raddiana*	F. C. Keur-Mbaye	Senegal	16° 29' N	15° 35' W	6		30
Haryana2	*P. cineraria*	Khora-Ahamad, Bhiwani (Hissar)	India	28° 45' N	76° 10' E	250	446	5
Tamil Nadu3	*P. cineraria*	Krishnapuram, Trichy	India	10° 46' N	78° 43'E	88	876	27
Yemen4	*P. cineraria*	Khanfar (Aden)	Yemen	13° 00' N	45° 10' E	15	50	20

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 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 small trees with heights below 1 m, no assessment of diameter, crown area and/or number of stems was made. For crown area, this was the case for 34 trees, whereas registration of diameter and number of stems were missing for 37 trees. As only 533 trees of the 1600 trees planted were alive at the assessment, this constitutes a significant proportion of the data. Ignoring these data will produce biased results and result in overestimation of the provenances in question, and the crown areas, basal areas and dry weights for these trees were therefore set to zero in the analysis. For number of stems, it is not possible to make this type of correction. Irrespective of the corrections, estimates for the variables crown area, basal area and dry weight of the mean tree and number of stems will be biased.

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

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

3.2 Statistical model and estimates

The statistical analysis of the trial was based on a two-step approach. The first step involved a test of species differences, whereas the second step was performed separately for each species and tested whether there were significant differences between the provenances within the species in question.

The test of species differences was based on the model:

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

where X_{ijk} is the value of the trait (e.g. height) in plot *ijk*, 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 σpr2, $block_j$ is the effect of block (replication) *k* in the trial, assumed to be a random effect (or, in the case of calculating least square means, a fixed effect), and ε_{ijk} is the residual of plot *ijk*, and is assumed to follow the normal distribution N(0, σ_e^2). The test of species differences was performed using the Satterthwaite method for calculation of the degrees of freedom (SAS 1988b).

The test of significant differences between provenances was performed separately for each species. These analyses were based on the model:

$$X_{jk} = \mu + provenance_j + block_k + \varepsilon_{jk}$$

where X_{jk} is the value of the trait in plot *jk*, μ is the grand mean, $provenance_j$ is the fixed effect of provenance number *j*, $block_k$ is the fixed effect of block *k*, and ε_{jk} is the residual of plot *jk* and is assumed to follow a normal distribution N(0, σ_e^2).

As the survival of *P. cineraria* was very low and the growth of the surviving trees was poor, this species was excluded in all but the analyses of survival and height.

To complement blocks in adjusting for uneven environments, co-variates related to the plot position were included in the initial model. In the initial models, the co-variates were distances along the two axes of the trial, plotx and ploty, and squared values of these, 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, transformations or weighting of data as well as omission of outliers were performed to fulfil basic model assumptions (ibid., Afifi & Clark 1996). 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. Where large provenances tended to have larger variances than small provenances (the case for crown area), a square root transformation was used to stabilise variance.

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 'table-wide' 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 *indica*ted 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 *indica*tion of the range of variation within the species. As 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. nilotica*, since this is the only species with a larger number of provenances, even though it may be debated whether the provenances of *A. nilotica* really represent a random selection. The selection of varieties and origins of the provenances *indica*te that the provenances are chosen deliberately rather than randomly. Note that in some cases the ranking of provenances between the LS-mean values and the BLUP values may be different.

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

A more detailed description of the methods used for the analyses of variance is given in Ræbild *et al.* (2002), and a short description of the analysis of each variable is included 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 *indica*tes the adaptability of the provenance to the environment at the trial site. It should be noted that survival reflects only the conditions experienced during the first years 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

The analysis *indica*ted that there was variance heterogeneity in the data, and a weight statement was applied to solve the problem. This was done in the analysis of species differences and in the analysis of provenance differences within *A. nilotica*. The co-variate plotx was significant in the analysis of species differences and in the analyses of provenance differences within *A. nilotica* and *P. cineraria*.

Results

The overall survival in the trial was low. At the time of the assessment, only a third of the 1600 trees originally planted were alive. However, there was a clear variation between the provenances, some having survivals in the range of 60 to 70 % while in others no trees had survived. The analysis of variance demonstrated that the differences between species were highly significant (Table 2). Within *A. nilotica* and *P. cineraria*, the differences between provenances were significant, but in *A. senegal* and *A. tortilis* this was not the case.

Fig. 1 demonstrates that the species with the lowest survival was *P. cineraria*, the survival being below 10 % for all provenances. The provenances of *A. nilotica* had survivals ranging from 10 to 35 %, whereas the provenances of *A. senegal* and *A. tortilis* had considerably higher survivals.

In *A. nilotica*, the provenance Maharashtra4 was clearly inferior to the rest. Sudan08 also had a poor survival, but within this provenance the variation was too big to separate it from the other provenances. The predicted gains by selection of provenances for this species range from -12 to +7 percentage point (Fig. 2), again with Maharashtra4 as the low extreme. In *P. cineraria* the best provenance was Haryana2, but still the survival was below 10 %.

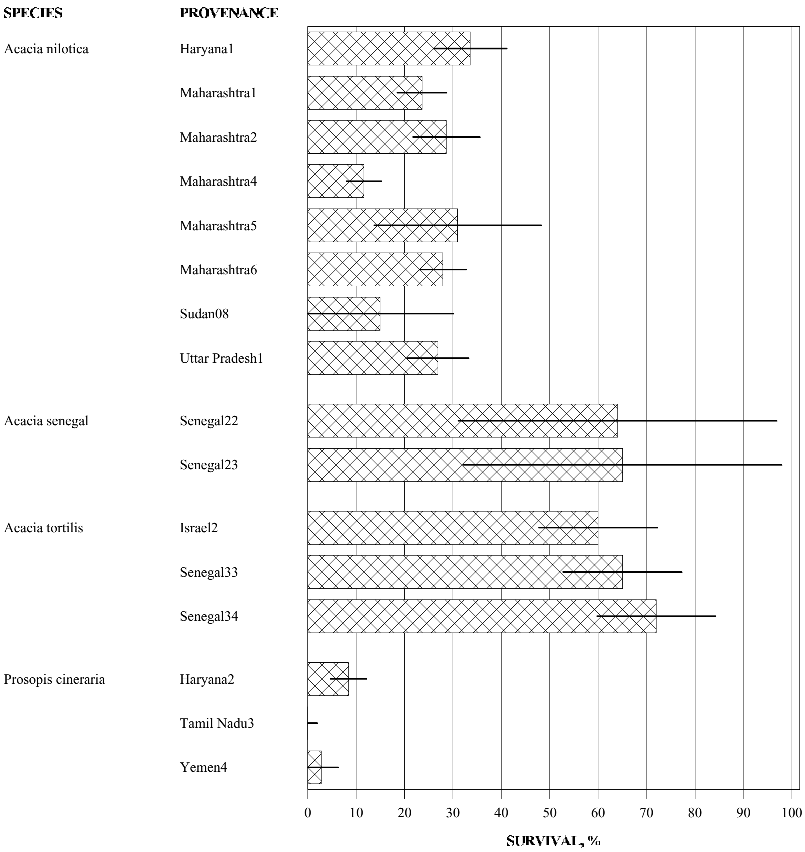


Figure 1. Survival in the *Acacia* and *Prosopis* species and provenance trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analysis of *A. nilotica* the data were weighted with the inverse of the variance for the provenances, and the error bars therefore have different lengths.

Table 2. Results from analysis of variance of species and provenance differences of survival in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	3; 20.7	121.6	52.7	<0.0001	***
Provenance(species)	12; 44	3.8	3.6	0.001	
Block	3; 44	6.2	5.8	0.002	
Plotx	1; 44	23.1	21.7	<0.0001	
Error	44	1.1			
A. nilotica					
Provenance	7; 20	10.0	8.8	<0.0001	***
Block	3; 20	6.7	5.6	0.005	
Plotx	1; 20	58.2	51.2	<0.0001	
Error	20	1.1			
A. senegal					
Provenance	1; 3	0.0002	0.005	0.95	n.s.
Block	3; 3	0.0055	0.13	0.94	
Error	3	0.0429			
A. tortilis					
Provenance	2; 6	0.014	1.4	0.31	n.s.
Block	3; 6	0.027	2.7	0.14	
Error	6	0.010			
P. cineraria					
Provenance	2; 5	0.0072	10.2	0.02	-
Block	3; 5	0.0048	6.8	0.03	
Plotx	1; 5	0.0042	5.8	0.06	
Error	5	0.0007			

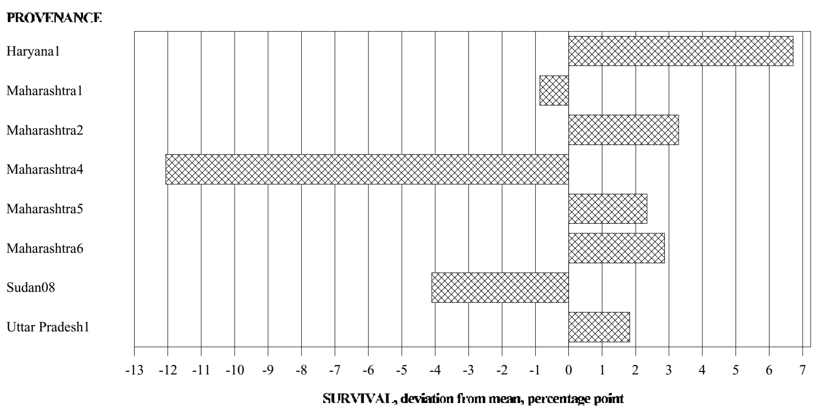


Figure 2. Best linear unbiased predictors (BLUPs) for survival in the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are deviations from the mean value in percentage points.

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 *indica*ting 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 subsequent die-off.

Statistical analysis

The analyses proceeded without problems, and no transformations or weights were used. No covariates were significant. The number of surviving trees was not sufficient to allow an analysis of differences within *P. cineraria*.

Results

The average heights varied from below 1 m for the provenances of *P. cineraria* to around 3 m for the best provenances of *A. nilotica* and *A. tortilis*. The difference between species was significant (Table 3), but depended on the presence of *P. cineraria*. When this species was excluded, the P-value for the species effect decreased to 0.15 (analysis not shown).

Within the species there were significant differences between the provenances of each of the species *A. nilotica*, *A. senegal* and *A. tortilis*. As mentioned above, the data for *P. cineraria* were not sufficient to allow for a test, and no estimates were obtained. Therefore *P. cineraria* is not represented in Fig. 3.

The overall highest provenances were Haryana1 and Uttar Pradesh1 of *A. nilotica* and Senegal33 and Senegal34 of *A. tortilis*. In these species the provenances Sudan08 and Israel2 had the slowest height growth. The provenances of *A. senegal* were much smaller than any of the other provenances (when *P. cineraria* is excluded). In *A. nilotica*, the BLUP estimates varied between -30 and +40 % (Fig. 4). The best provenance was again Haryana1.

Table 3. Results from analysis of variance of species and provenance differences of height in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	3; 11.4	5.07	5.4	0.01	(*)
Provenance(species)	12; 38	1.09	10.2	<0.0001	
Block	3; 38	0.14	1.4	0.26	
Error	38	0.11			
A. nilotica					
Provenance	7; 21	24.3	25.3	<0.0001	***
Block	3; 21	13.4	14.0	<0.0001	
Error	21	1.0			
A. senegal					
Provenance	1; 3	0.120	70.8	0.004	*
Block	3; 3	0.114	67.5	0.003	
Error	3	0.002			
A. tortilis					
Provenance	2; 6	1.21	19.4	0.002	*
Block	3; 6	0.09	1.5	0.32	
Error	6	0.06			

Figure 3. Vertical height in the provenances of *Acacia* in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits.

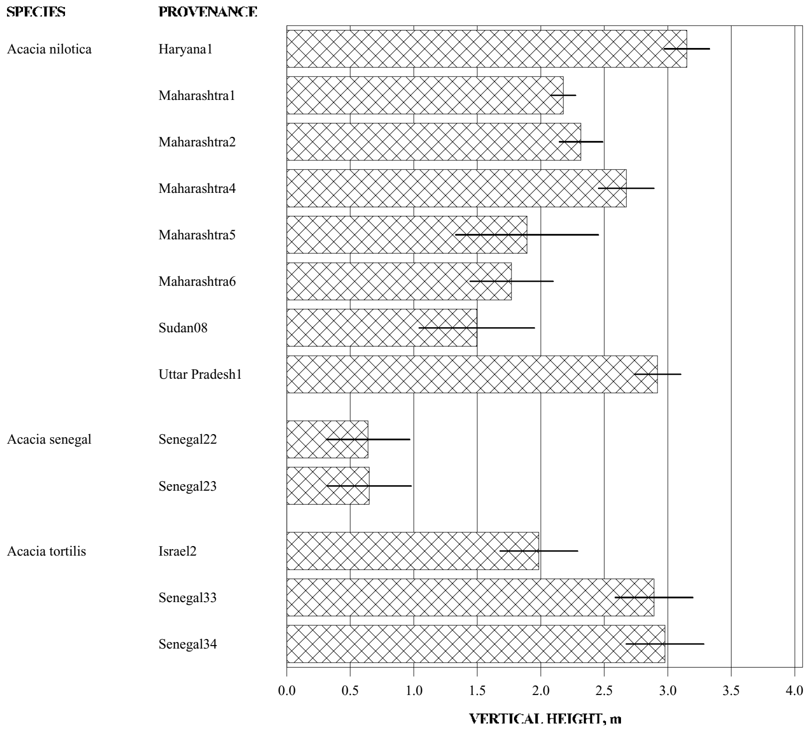
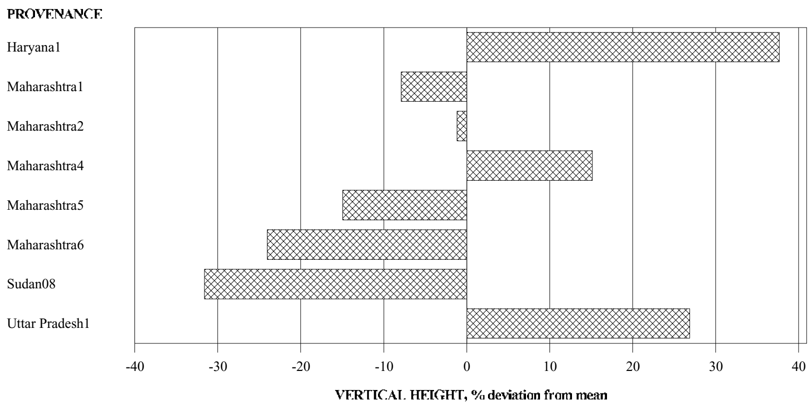


Figure 4. Best linear unbiased predictors (BLUPs) for vertical height in the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations in percent of the mean value.



4.3 Crown area

The crown area variable *indica*tes the ability of the trees to cover the ground. The character is of importance in shading for agricultural crops, in evaluating the production of fodder and in protection of the soil against erosion.

Statistical analysis

P. cineraria was not included in these analyses and those that follows. The preliminary analysis demonstrated that the variance was increasing with the size of the trees, and the subsequent analyses were performed on data transformed with the square root. The estimates presented are back-transformed least square means. Compared to estimates based on data without transformation, back-transformed least square means are always smaller, but give a better description of the differences between the provenances. The co-variates ploty and level were significant in the analysis of species differences, but in the analyses of provenance differences, the only significant co-variate was ploty in the analysis of differences in *A. senegal*.

It should be noted that for several small trees the crown area was not registered and that the crown areas for these trees have been set to zero. This will introduce a bias in the analyses and estimates (section 3.1).

Results

The average crown area for the provenances varied between 2.8 and 8.9 m^2 $tree^{-1}$. The differences between the back-transformed means and the raw means were minute, being only 0.05 m^2 $tree^{-1}$ for the largest provenance. As the growth space was only 9 m^2 $tree^{-1}$, the trees in the largest provenances had more or less closed the canopy above the ground. According to the analyses of variance there were no significant differences between the species, but in all three species the differences between provenances within the species were significant (Table 4). In *A. tortilis* and especially *A. senegal*, however, the correction for multiple comparisons (the Bonferroni test) *indica*ted that this was due to random variation.

In *A. nilotica* the provenances Haryana1, Maharashtra2 and Uttar Pradesh1 all had crown areas of approximately 8 m^2 $tree^{-1}$, whereas Maharashtra5, Maharashtra6 and Sudan08 had values of 4 m^2 $tree^{-1}$ (Fig. 5). In the two provenances of *A. senegal*, the crown areas were even smaller, only 3 m^2 $tree^{-1}$. In *A. tortilis* the provenances Senegal33 and Senegal34 were again the best, having crown areas comparable to the best provenances of *A. nilotica*. The expected gains by provenance selection of *A. nilotica* varied between -30 to +30% of the mean value (Fig. 6).

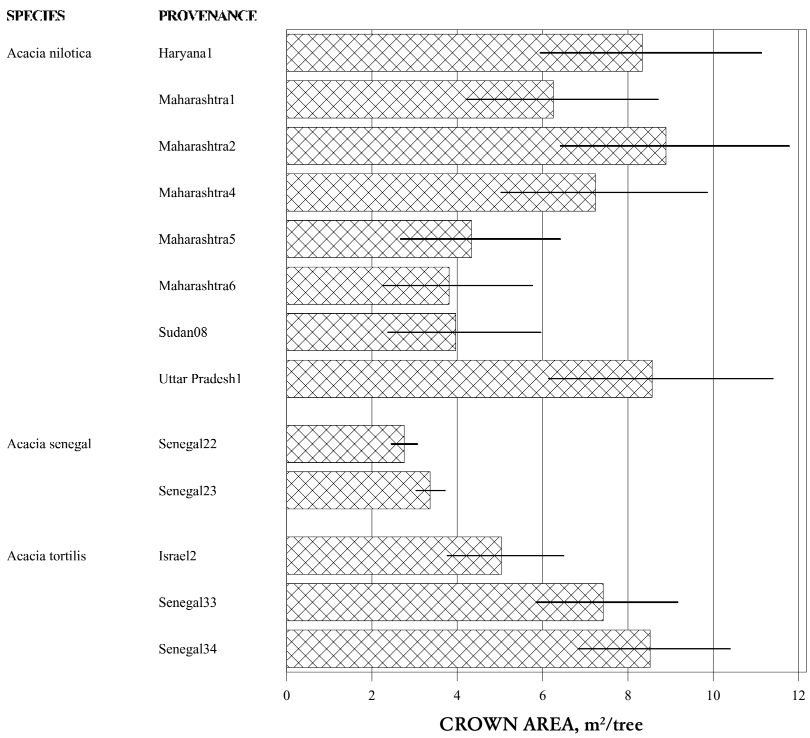


Figure 5. Crown area in the *Acacia* provenance in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). The analysis was performed on data transformed with the square root, and the estimates are back-transformed least square means with 95 % confidence limits. Due to the transformation, the upper and lower confidence intervals have different lengths.

Table 4. Results from analysis of variance of species and provenance differences of crown area in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 10.1	1.78	2.8	0.11	n.s.
Provenance(species)	10; 34	0.65	4.1	0.0009	
Block	3; 34	0.45	2.9	0.05	
Ploty	1; 34	0.84	5.3	0.03	
Level	1; 34	0.48	3.0	0.09	
Error	38	0.16			
A. nilotica					
Provenance	7; 21	0.76	4.1	0.006	*
Block	3; 21	0.48	2.5	0.08	
Error	21	0.19			
A. senegal					
Provenance	1; 2	0.052	30.8	0.03	n.s.
Block	3; 2	0.269	157.7	0.006	
Ploty	1; 2	0.037	21.5	0.04	
Error	2	0.002			
A. tortilis					
Provenance	2; 6	0.48	7.8	0.02	(*)
Block	3; 6	0.06	0.9	0.50	
Error	6	0.06			

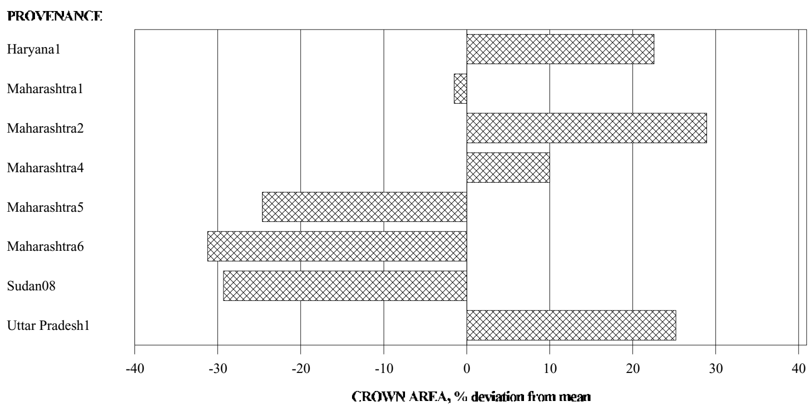


Figure 6. Best linear unbiased predictors (BLUPs) for crown area in the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.4 Number of stems

The number of stems gives an *indica*tion 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 plots of residuals *indica*ted that the value for the plot of Maharashtra5 in block 4 was an outlier, having a larger number of stems than other plots of this provenance. As only two trees were remaining on the plot, it seems justified to exclude the observation from the analysis - solitary trees typically have more stems than trees in competition with others. Therefore the analyses and estimates are without this observation. Apart from this the analyses were without problems.

The co-variates plotx, plotx2 and level were significant in the analysis of species differences, and in the analysis of provenance differences within *A. nilotica*, plotx and plotx2 were significant. No co-variates were significant in the other analyses.

For a number of small trees, the number of stems was not registered, which introduces a bias in the analyses. It was not possible to make a correction for this (section 3.1).

Results

The differences in number of stems were moderate, the values varying from 1 to 2 number of stems per tree. There were no significant differences between the three species, but within *A. nilotica* and perhaps also *A. tortilis* there were significant differences between the provenances (Table 5).

In *A. nilotica*, the provenance Sudan08 had the largest number of stems with 2 stems tree^{-1} (Fig. 7). The other provenances had 1.4 stem tree^{-1} or less, the smallest being Maharashtra4. It should be noted that the least square mean for Maharashtra4 is less than 1, which is of course not possible (should be 1 or more). This is due to imbalance in the model, but as it gives the best picture of differences between the provenances, the value has not been corrected. The number of stems for the provenances for the two other species were all in the intermediate range compared to the variation in *A. nilotica*.

For *A. nilotica* the predicted values by selection of provenances varied between -25 and +45 % of the mean value (Fig. 8).

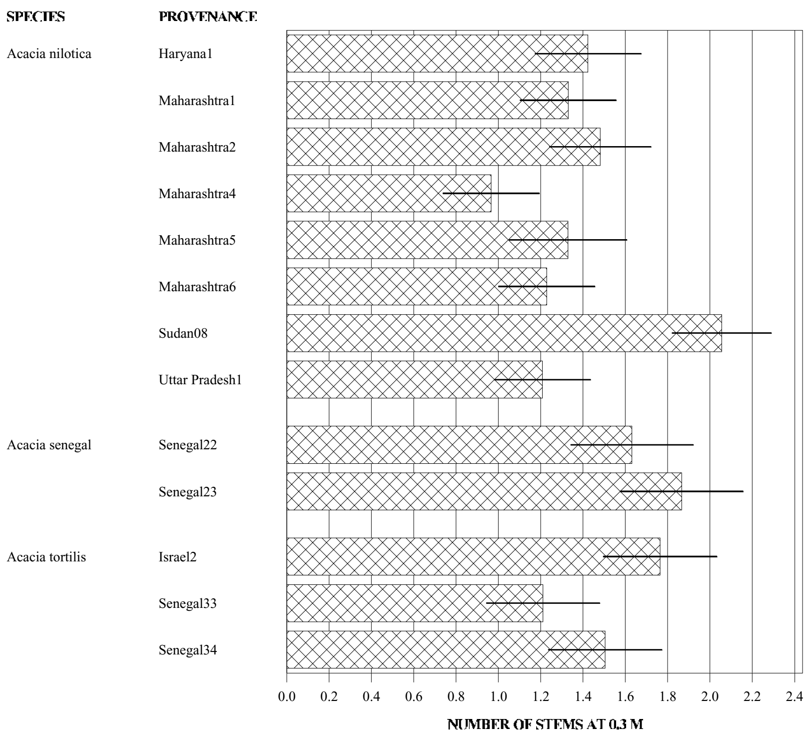


Figure 7. Number of stems in the *Acacia* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 5. Results from analysis of variance of species and provenance differences of number of stems in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 10.0	0.49	1.3	0.31	n.s.
Provenance(species)	10; 32	0.38	7.1	<0.0001	
Block	3; 32	0.17	3.1	0.04	
Plotx	1; 32	0.49	9.2	0.005	
Plotx2	1; 32	0.17	3.2	0.08	
Level	1; 32	0.19	3.5	0.07	
Error	32	0.05			
A. nilotica					
Provenance	7; 18	0.40	8.6	<0.0001	***
Block	3; 18	0.18	4.0	0.02	
Plotx	1; 18	0.54	11.8	0.003	
Plotx2	1; 18	0.21	4.6	0.05	
Error	18	0.05			
A. senegal					
Provenance	1; 3	0.11	3.3	0.17	n.s.
Block	3; 3	0.11	3.4	0.17	
Error	3	0.03			
A. tortilis					
Provenance	2; 6	0.31	6.4	0.03	(*)
Block	3; 6	0.07	1.4	0.33	
Error	6	0.05			

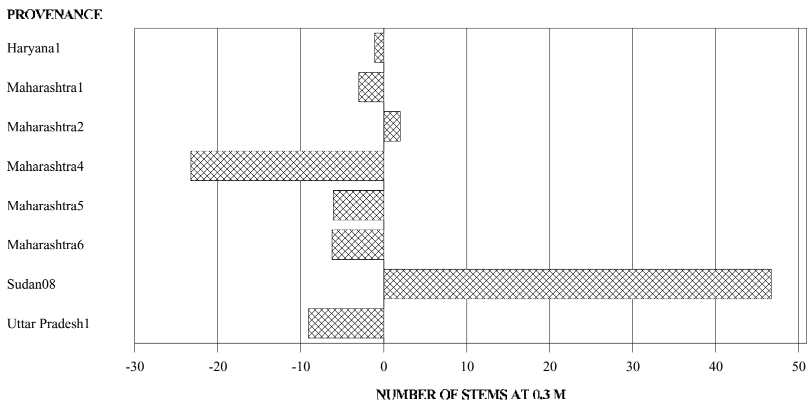


Figure 8. Best linear unbiased predictors (BLUPs) for number of stems in the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations in percent of the mean value.

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 the potential basal area production of the provenances or rather the production if all trees had survived.

Statistical analysis

The provenances had different variances, and in the analysis of species differences the data were weighted to solve the problem. This was also necessary in the analysis of differences within *A. nilotica*. The co-variate ploty2 was significant in all analyses except the analysis of provenance differences within *A. nilotica*.

As the diameters were not measured on a number of small trees, the basal areas for these trees were set to zero (section 3.1). This introduces a bias in the analysis, which should be borne in mind when interpreting the results.

Results

The basal area of the mean tree was highly variable for the different provenances, varying from 8 to 28 cm^2 $tree^{-1}$. The differences between species were not significant, but in *A. nilotica* and *A. tortilis* there were highly significant differences between the provenances (Table 6). Even in *A. senegal* the provenance effect was at the limit of significance, but following the correction for multiple comparisons, there were no signs of significance.

The largest values were found in the provenances Haryana1, Maharashtra2, Maharashtra4 and Uttar Pradesh1 of *A. nilotica*, and in the provenances Senegal33 and Senegal34 of *A. tortilis* (Fig. 9). The smallest trees were in the provenances Sudan08 (*A. nilotica*), Senegal22 and Senegal23 (*A. senegal*) and Israel2 (*A. tortilis*). In *A. nilotica*, the predicted values (BLUPs) varied from -30 to +30 % of the mean value (Fig. 10).

Table 6. Results from analysis of variance of species and provenance differences of basal area of the mean tree in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 11.2	13.5	2.9	0.10	n.s.
Provenance(species)	10; 35	5.6	5.2	<0.0001	
Block	3; 35	5.4	5.0	0.005	
Ploty2	1; 35	5.3	4.9	0.03	
Error	35	1.1			
A. nilotica					
Provenance	7; 21	12.8	12.6	<0.0001	***
Block	3; 21	20.2	19.9	<0.0001	
Error	21	1.0			
A. senegal					
Provenance	1; 2	24.4	18.5	0.05	n.s.
Block	3; 2	22.7	17.2	0.06	
Ploty2	1; 2	15.8	12.0	0.07	
Error	2	1.3			
A. tortilis					
Provenance	2; 5	269	31.8	0.001	*
Block	3; 5	4	0.5	0.69	
Ploty2	1; 5	38	4.5	0.09	
Error	5	8			

Figure 9. The basal area of the mean tree in the *Acacia* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analysis of *A. nilotica* the data were weighted to compensate for variance heterogeneity, and the error bars therefore have different lengths.

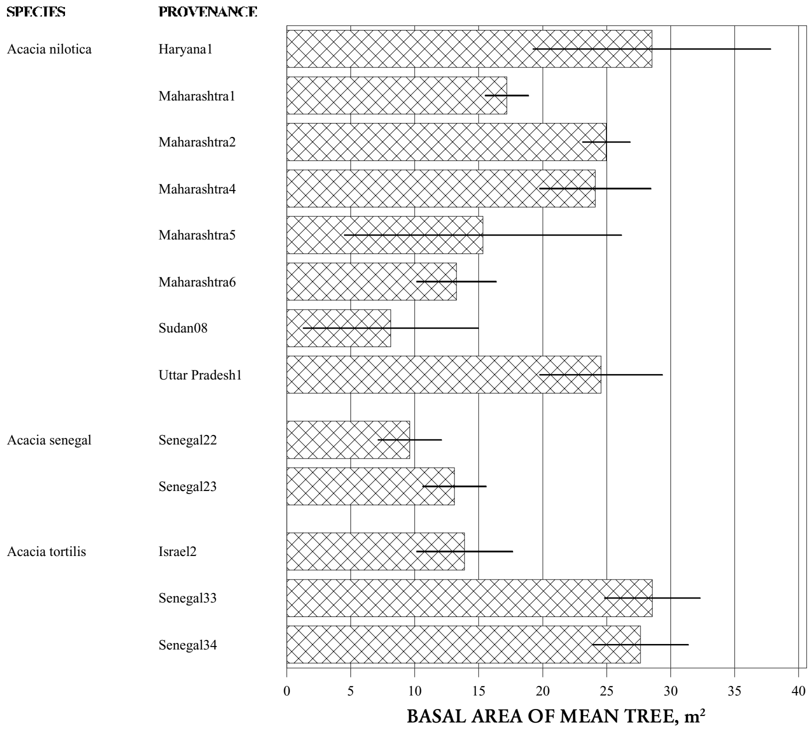


Figure 10. Best linear unbiased predictors (BLUPs) for basal area of the mean tree in the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations in percent of the mean value.

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 on the site.

Statistical analysis

Again there was variance heterogeneity in the data set, and a weight statement was applied in the test of species differences to fulfil the assumptions of the model. This was not necessary in the tests of differences within the species. The co-variate plotx was significant in the analysis of species differences and in the analysis of provenance differences within *A. nilotica*.

Results

The total basal area was varying by a factor 10, ranging from 0.2 m^2 ha^{-1} to more than 2 m^2 ha^{-1}. Thus the average annual increment was approximately 0.3 m^2 ha^{-1} y^{-1} for trees in the largest provenances. The differences between the species were highly significant, and in both *A. nilotica* and *A. tortilis* the differences between provenances were significant (Table 7). In *A. senegal*, the difference between the two provenances were only at the limit of significance and after the correction for multiple tests there were no signs of significance.

A. tortilis was clearly the fastest growing species, and especially the provenances Senegal33 and Senegal34 had large basal areas (Fig. 11). The provenance Israel2 was inferior and at the level of the *A. nilotica* and *A. senegal* provenances. The provenances Haryana1, Maharashtra2 and Uttar Pradesh1 were the best of the *A. nilotica* provenances. In this species the predicted values *indica*ted large gains by selection of provenances, ranging from -55 to +55 % of the mean value (Fig. 12).

Table 7. Results from analysis of variance of species and provenance differences of total basal area in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 20.9	57.2	21.8	<0.0001	***
Provenance(species)	10; 35	9.6	9.1	<0.0001	
Block	3; 35	2.3	2.1	0.11	
Plotx	1; 35	54.3	51.3	<0.0001	
Error	35	1.1			
A. nilotica					
Provenance	7; 20	0.21	6.4	0.0005	**
Block	3; 20	0.04	1.1	0.36	
Plotx	1; 20	0.74	22.5	<0.0001	
Error	20	0.03			
A. senegal					
Provenance	1; 3	0.13	6.7	0.08	n.s.
Block	3; 3	0.20	10.2	0.04	
Error	3	0.02			
A. tortilis					
Provenance	2; 6	1.82	12.1	0.008	*
Block	3; 6	0.31	2.1	0.21	
Error	6	0.15			

Figure 11. Total basal area of the *Acacia* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits.

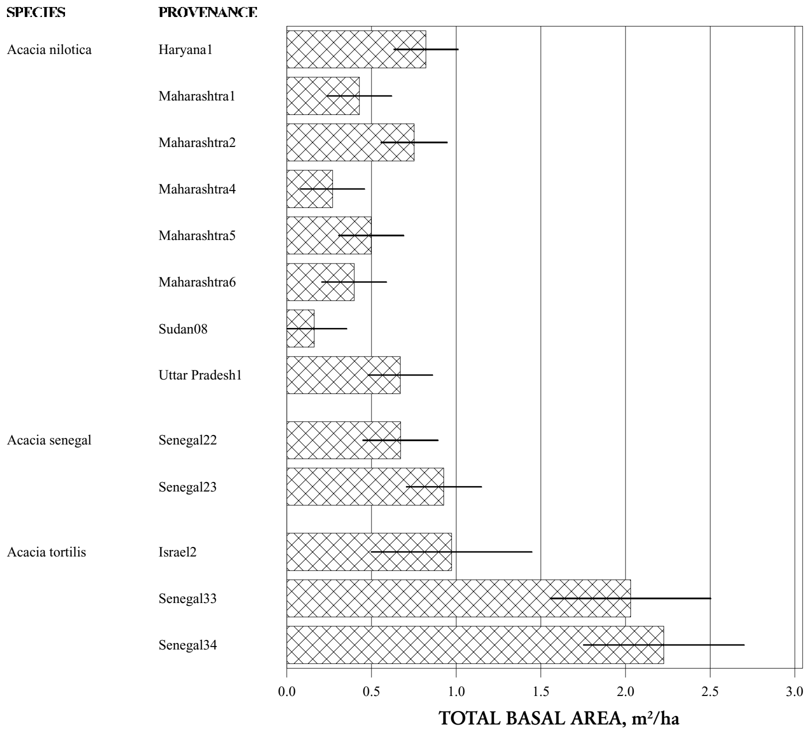
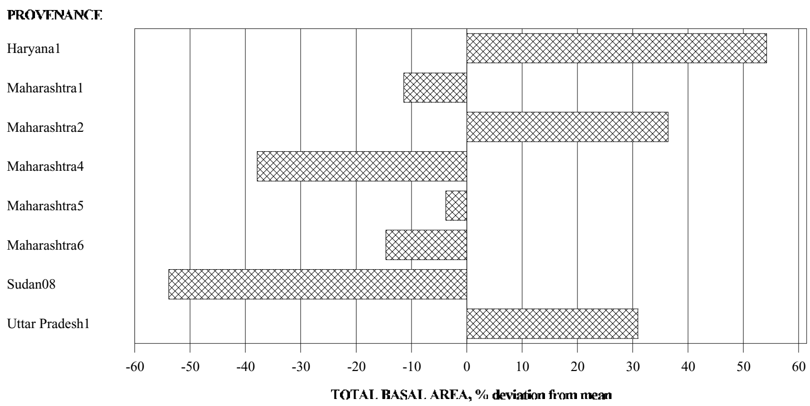


Figure 12. Best linear unbiased predictors (BLUPs) for total basal area in the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations in percent of the mean value.



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 can be interpreted as 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 production of biomass at the site.

Statistical analysis

As there was variance heterogeneity between the provenances, weight statements were applied in the analysis of species differences and in the analysis of differences between the provenances of *A. nilotica*. The co-variate ploty2 was significant in all analyses except for the analysis of *A. nilotica* provenances. Again it should be noted that diameter was not measured for a number of small trees, and that the dry weights have been set to zero for these trees (section 3.1). This introduces a bias in the analysis and estimates.

Results

In the three species the dry weights of the mean tree varied from 1.3 to 10 kg tree^{-1}. The differences between species were significant, and the differences between the provenances of *A. nilotica* and of *A. tortilis* were highly significant (Table 8). Again the differences between the provenances of *A. senegal* were on the limit of significance.

A. tortilis had the largest basal areas of the mean tree, whereas *A. senegal* had the smallest (Fig. 13). In between the two other species was *A. nilotica*. The overall best provenances were Senegal33 and Senegal34 of *A. tortilis*, whereas Israel2 had a poorer performance. In *A. nilotica* the fastest growing trees were found in the provenances Haryana1, Maharashtra2, Maharashtra4 and Uttar Pradesh1. The provenances of *A. senegal* were at the low end together with the provenances Sudan08, Maharashtra5 and Maharashtra6 of *A. nilotica*.

Within *A. nilotica*, the BLUPs *indica*ted that there were gains of ±25 % of the mean value by selection of provenances (Fig. 14).

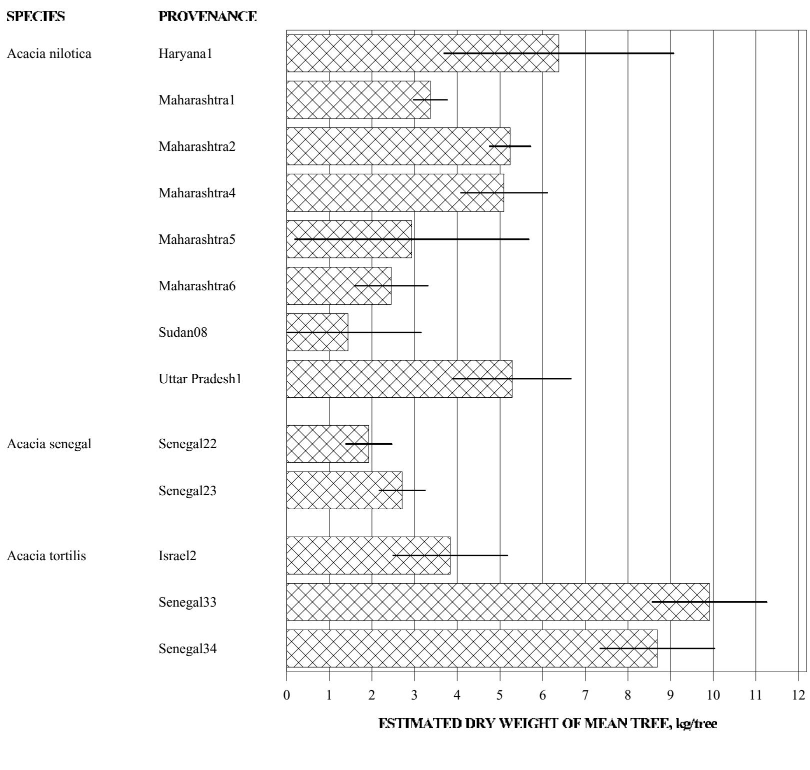


Figure 13. Dry weight of the mean tree in the *Acacia* species and provenance trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analysis of *A. nilotica*, the data were weighted to compensate for variance heterogeneity, and the confidence intervals are therefore of different lengths.

Table 8. Results from analysis of variance of species and provenance differences of dry weight of the mean tree in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 10.7	40.2	7.8	0.008	*
Provenance(species)	10; 35	5.9	5.4	<0.0001	
Block	3; 35	4.6	4.2	0.01	
Ploty2	1; 35	6.0	5.5	0.03	
Error	35	1.1			
A. nilotica					
Provenance	7; 21	10.5	10.8	<0.0001	***
Block	3; 21	20.3	20.8	<0.0001	
Error	21	1.0			
A. senegal					
Provenance	1; 2	1.22	19.2	0.05	n.s.
Block	3; 2	1.27	20.1	0.05	
Ploty2	1; 2	1.03	16.3	0.06	
Error	2	0.06			
A. tortilis					
Provenance	2; 5	41.2	37.7	0.001	**
Block	3; 5	0.4	0.4	0.75	
Ploty2	1; 5	5.5	5.0	0.08	
Error	5	1.1			

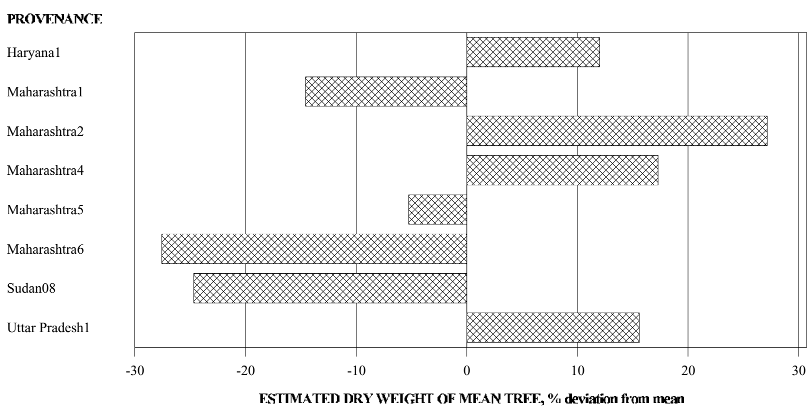


Figure 14. Best linear unbiased predictors (BLUPs) for dry weight of the mean tree of the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.8 Total dry weight

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

Statistical analysis

Since the plots of residuals *indica*ted that there was variance heterogeneity in the data, weight statements were applied in the analyses of species differences and of differences between the provenances of *A. nilotica*. The co-variate plotx was significant in the same two analyses.

Results

The variation in total dry weight was large, ranging from below 0.5 t ha^{-1} to 7 t ha^{-1}. For the largest provenances the average annual increment was 1 t ha^{-1}. The differences between species were highly significant, and also the provenance differences within *A. nilotica* and *A. tortilis* were significant (Table 9). Only in *A. senegal* there were no clear differences between the provenances.

A. tortilis was again the species with the largest production. The best provenances of *A. nilotica* and *A. senegal* produced but a fraction of the dry weight produced by Senegal33 and Senegal34, and even Israel2, the slow-growing provenance of *A. tortilis*, had a larger dry weight than any of the provenances in the other two species (Fig. 15).

Though the growth was slow in *A. nilotica*, there were considerable differences between the provenances, with Haryana1, Maharashtra2 and Uttar Pradesh1 being the best. The gains by provenance selection varied between -50 and +60 % of the mean value (Fig. 16).

Table 9. Results from analysis of variance of species and provenance differences of total dry weight in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 22.7	78.9	33.7	<0.0001	***
Provenance(species)	10; 35	10.8	10.9	<0.0001	
Block	3; 35	2.8	2.8	0.05	
Plotx	1; 35	48.4	48.8	<0.0001	
Error	35	1.0			
A. nilotica					
Provenance	7; 20	10.3	9.0	<0.0001	***
Block	3; 20	3.0	2.6	0.08	
Plotx	1; 20	45.2	39.3	<0.0001	
Error	20	1.1			
A. senegal					
Provenance	1; 3	0.65	7.3	0.07	n.s.
Block	3; 3	1.10	12.3	0.03	
Error	3	0.09			
A. tortilis					
Provenance	2; 6	24.4	15.6	0.004	*
Block	3; 6	3.0	1.9	0.22	
Error	6	1.6			

Figure 15. Total dry weight of the *Acacia* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits.

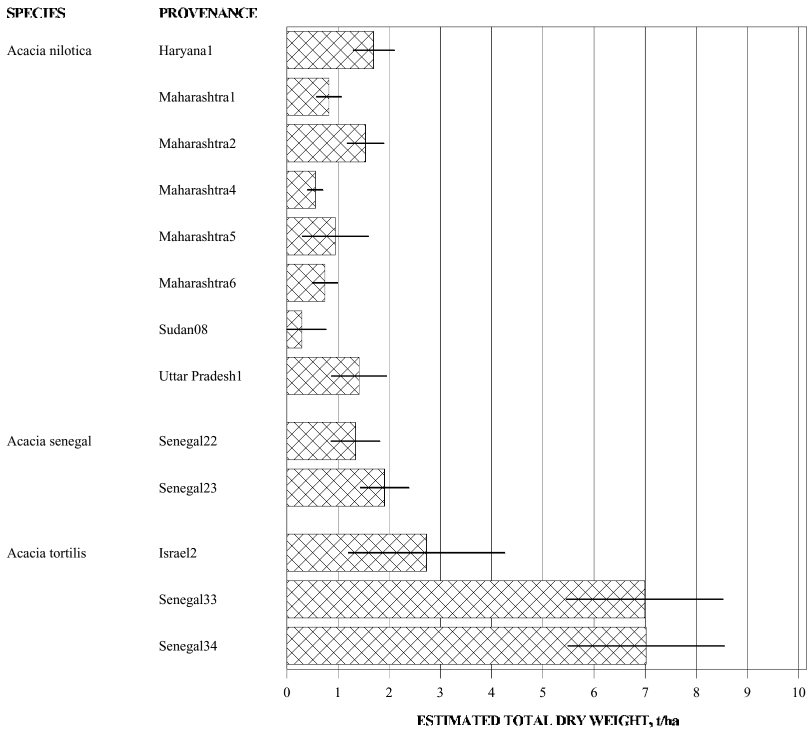
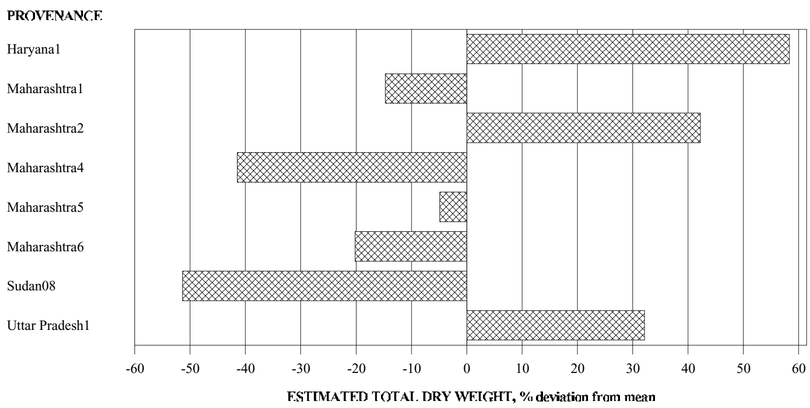


Figure 16. Best linear unbiased predictors (BLUPs) for total dry weight in the *A. nilotica* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations in percent of the mean value.



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 to trees in the trial was primarily due to low temperatures or frost.

Statistical analyses

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 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. This problem is aggravated by the fact that the scale has not been applied in full. The trees have received the scores 0, 1 or 3, but 2 (moderate damage) was not applied in any case.

The provenances had different variances, and a weight statement was used in the analysis of differences between species. This was not needed in the analyses of provenance differences within species. The co-variate level was significant in the analysis of species differences and in the test of differences between the *A. nilotica* provenances.

Results

Only a small proportion of the trees was damaged, and on average the damage score was not high. All provenances had mean scores between 0 and 1, *indica*ting no damage or only light damage. According to the analysis of variance the difference between species was at the limit of significance, but the significance disappeared when the correction for multiple comparisons was made (Table 10). The same occurred in the test of differences between the provenances of *A. nilotica*, while there were no signs at all of differences between the provenances of *A. senegal* and *A. tortilis*. An extra test was performed, in which only the effects of provenances and blocks were included, thus comparing provenances across species. This test demonstrated that the differences between provenances were highly significant (F=3.6, P=0.001).

Certain provenances of *A. nilotica* had relatively high damage scores, while the provenances of *A. senegal* and *A. tortilis* all had little or no damage (Fig. 17). The provenances having the highest damage scores were Maharashtra5 and Maharashtra6. The BLUPs for *A. nilotica indica*ted that selection of provenances could improve the damage score with ±0.25 score units (Fig. 18). Note that in the figure negative values denote healthier trees.

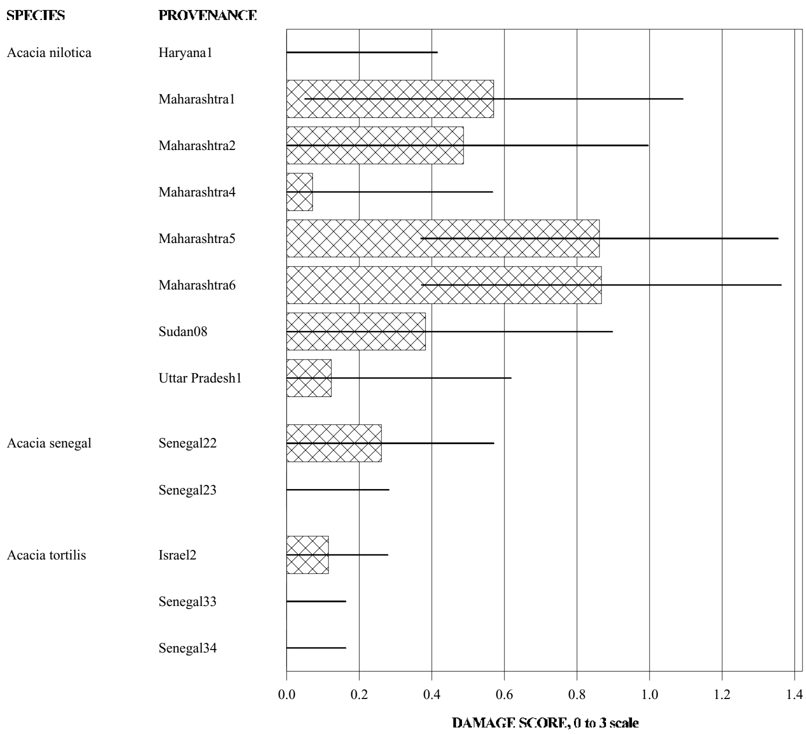


Figure 17. Damage score of the *Acacia* provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Values presented are least square means with 95 % confidence limits. Note that some provenances were not damaged at all, giving an average score of zero.

Table 10. Results from analysis of variance of species and provenance differences of damage score in trial 16.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 11.6	6.4	3.1	0.08	n.s.
Provenance(species)	10; 35	2.3	2.8	0.01	
Block	3; 35	0.8	1.0	0.40	
Level	1; 35	2.4	2.9	0.10	
Error	35	0.8			
A. nilotica					
Provenance	7; 20	0.51	2.3	0.07	(*)
Block	3; 20	0.34	1.5	0.24	
Level	1; 20	0.71	3.2	0.09	
Error	20	0.22			
A. senegal					
Provenance	1; 2	0.15	7.8	0.11	n.s.
Block	3; 2	0.17	8.8	0.10	
Level	1; 2	0.20	10.0	0.09	
Error	2	0.02			
A. tortilis					
Provenance	2; 6	0.017	1	0.42	n.s.
Block	3; 6	0.017	1	0.45	
Error	6	0.017			

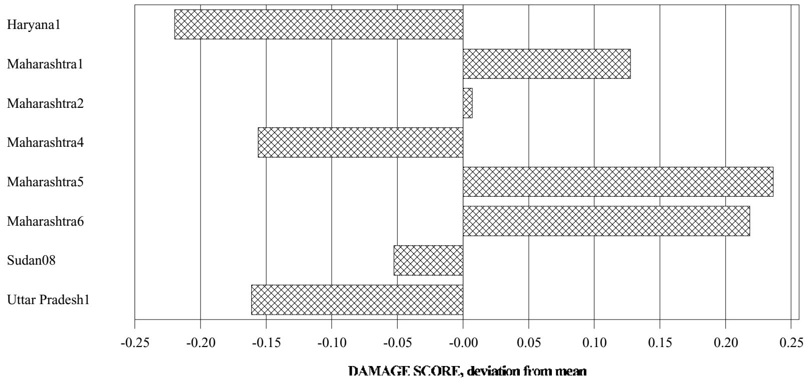


Figure 18. Best linear unbiased predictors (BLUPs) for damage score in the *A. nilotica* provenances in the trial Jodhpur, India (Trial no. 16 in the arid zone series). Values are presented as deviations from the mean value on the scale of the damage score. Note that negative deviations from the mean denote a better health status.

4.10 Multivariate analysis of all provenances

The multivariate analysis included all the variables analysed in the univariate analyses. Crown area was again transformed with the square root, but the analyses did not account for the variance heterogeneity that was observed in the data. The results should therefore be interpreted cautiously. The provenances of *P. cineraria* were not included. No co-variates were included in the analysis.

Of the nine canonical variates, four were significant (Table 11). This means that the variation between the provenances is in several dimensions at the same time. However, even though the significance levels *indica*ted that there was some information in the fourth canonical variate, the plots of scores of this variable did not give substantial new information. Therefore only results for the three first canonical variates are presented. In total, these variates accounted for 95 % of the variation, whereas the fourth contributed with only two percent. The test demonstrated that the provenance effect was highly significant (P-values for Wilk's lambda and Pillai's trace below 0.0001).

The plot of scores for the first three canonical variates is given in Fig. 19. Apart from the scores, the mean values for the provenances are given together with their approximate 95 % confidence regions. Provenances that are far apart in the diagram are interpreted as being different, and if the confidence regions do not overlap, it is likely that the provenances have different properties.

From the figure it appears that the provenances of *A. nilotica* are located in a cluster in the multivariate space. Although there seem to be differences between the provenances, the scatter between the provenances of this species is limited, and the differences between provenances of this species will be analysed separately in the next section.

The two provenances of *A. senegal*, Senegal22 and Senegal23, almost overlap each other, not giving much evidence for the hypothesis of differences between the provenances. However, from the upper figure it appears that the provenances are located a bit at a distance compared to the provenances of *A. nilotica*, thus pointing to a possible (significant) difference between the two species.

The provenances of *A. tortilis*, Israel2, Senegal33 and Senegal34, are located quite far from the two other species. Also another interesting aspect occurs: the variation within *A. tortilis* seems to be larger than in the two other species. However, as the multivariate analysis does not allow for a correction for variance heterogeneity, such conclusions should be treated cautiously.

Table 11. Results from the canonical variate analyses for the first canonical variates in the multivariate analysis of all provenances in trial 16.

Canonical variate no.	**1**	**2**	**3**	**4**
Proportion of variation	0.76	0.14	0.05	0.02
Significance, P-value	<0.0001	<0.0001	<0.0001	0.02

	Raw canonical coefficients			**Standardised canonical coefficients**			**Canonical directions**		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	2.1	-9.1	-5.9	0.5	-2.2	-1.5	1.0	-1.5	-2.2
Height	0.60	5.1	-2.1	0.4	3.3	-1.4	1.2	7.3	-5.5
Crown area	0.70	0.52	3.9	0.4	0.3	2.3	0.6	5.6	-1.2
Number of stems	0.13	-0.41	0.45	0.05	-0.2	0.2	0.01	-3.1	2.6
Basal area of mean tree	-0.92	-0.53	-0.22	-8.6	-4.9	-2.1	15.8	83.3	-63.6
Total basal area	-5.0	4.9	-2.8	-3.3	3.3	-1.9	3.6	0.8	-3.9
Dry weight, mean tree	3.1	1.3	0.007	9.1	3.7	0.02	11.4	21.7	-16.5
Total dry weight	2.2	-1.5	1.5	5.2	-3.5	3.4	13.5	4.0	-8.2
Damage score	-0.061	0.95	0.64	-0.03	0.5	0.3	-0.9	-0.4	3.6

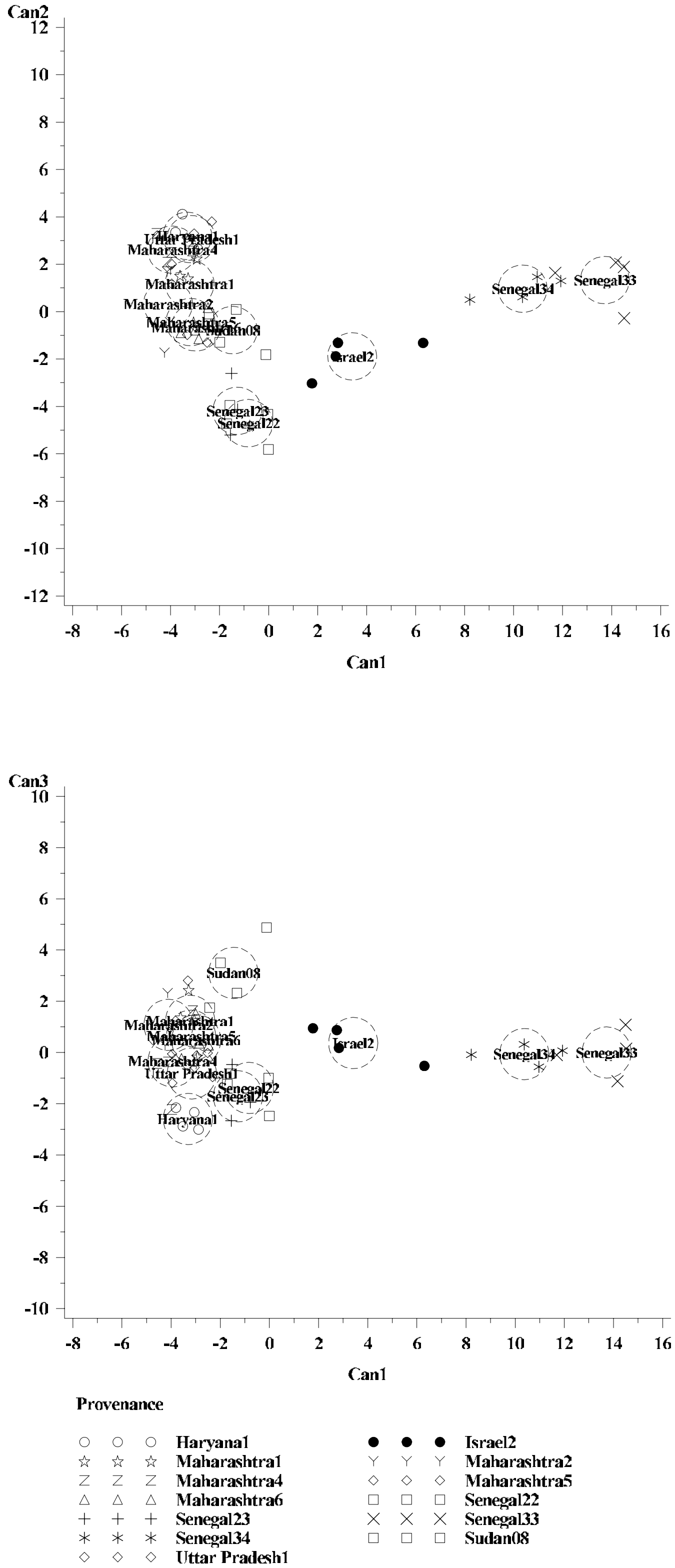


Figure 19. Score plot of the first and the second canonical variate (upper diagram) and of the first and the third canonical variate (lower diagram) from the analysis for all provenances in the trial at Jodhpur, India (Trial no. 16 in the arid zone series). Nine variables were included (see text). Each provenance is marked at the mean value and surrounded by a 95 % confidence region. The provenances Israel2, Senegal33 and Senegal34 are *A. tortilis*, and Senegal22 and Senegal23 are *A. senegal*. The rest are *A. nilotica*.

4.11 Multivariate analysis of *A. nilotica*

The multivariate analysis of the provenances of *A. nilotica* followed the same path as the multivariate analysis of all provenances (section 4.10). 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). Three of the canonical variates were significant, accounting for 90 % of the variation (Table 12).

The plot of scores in Fig. 20 showed some interesting patterns of variation. The provenances Maharashtra1, Maharashtra2, Maharashtra5 and Maharashtra6 were situated closely together. Although no clear grouping of the provenances occurred, the other provenances were more or less separated from the first group. The two provenances from Northern India, Uttar Pradesh1 and Haryana1, were separated from the group in the first canonical direction, and the provenance from Sudan was separated in the second canonical direction (upper diagram). Although the separation from the first group was less clear-cut for Maharashtra4, the combination of the first and the third canonical variate (lower diagram) *indicat*ed that it could be different from the other Maharashtra provenances. There were no clear patterns in the organisation of the different varieties of the species.

Table 12. Results from the canonical variate analyses for the first canonical variates in the multivariate analysis of the *A. nilotica* provenances in trial 16.

Canonical variate no.	1	2	3
Proportion of variation	0.58	0.21	0.11
Significance, P-value	<0.0001	0.003	0.05

	Raw canonical coefficients			Standardised canonical coefficients			Canonical directions		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	-22.7	-19.7	-37.7	-3.5	-3.0	-5.8	0.13	0.22	0.66
Height	8.4	-1.9	0.009	5.4	-1.2	0.006	3.4	3.8	-1.1
Crown area	-2.8	1.4	3.8	-1.7	0.8	2.2	1.7	3.6	0.17
Number of stems	1.9	-2.7	-1.2	0.9	-1.3	-0.6	-0.69	-3.5	1.8
Basal area of mean tree	-2.2	0.53	-2.5	-21.1	5.2	-24.5	31.7	60.9	-17.4
Total basal area	54.5	51.9	96.9	17.4	16.5	30.9	0.84	1.4	1.5
Dry weight, mean tree	8.2	-1.8	8.6	20.4	-4.6	21.4	8.2	13.9	-3.8
Total dry weight	-22.4	-20.1	-36.7	-14.8	-13.3	-24.2	1.9	3.2	3.0
Damage score	0.33	1.2	2.7	0.2	0.7	1.5	-1.9	0.07	0.66

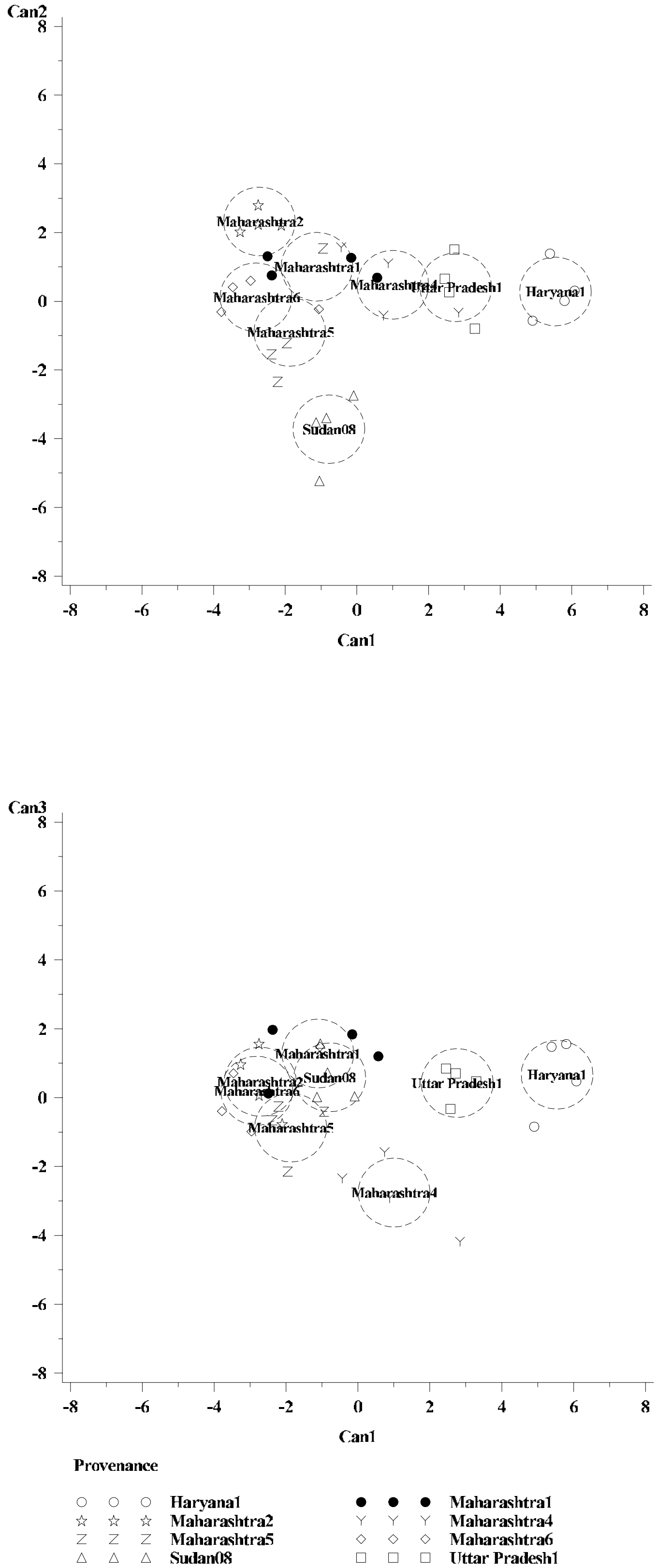


Figure 20. Score plot of the first and the second canonical variate (upper diagram) and of the first and the third canonical variate (lower diagram) from the analysis of *A. nilotica* provenances in the trial at Jodhpur (Trial no. 16 in the arid zone series). Nine variables were included (see text). Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

5. Discussion and conclusions

Productivity
The fastest growing provenances in this trial were of *A. tortilis* and had an average production of 1 t dry weight ha^{-1} y^{-1}. Compared to a trial in B.G. Kere in Karnataka where the largest production was 2.6 t dry weight ha^{-1} y^{-1} (trial no. 15 in the arid zone series), this is a much lower production. The two trials included many of the same provenances. The height growth of the trees at the two sites was comparable, but survival was much better in the trial at B. G. Kere. The rainfall in Jodhpur is only about half of the rainfall in B.G. Kere, and it would be natural to assume that this is the reason for the poor growth. However, the fastest growing provenance of *P. pallida* in another trial in Jodhpur (trial no. 17 in this series) had an annual growth of 1.7 t dry weight ha^{-1} y^{-1}, *indica*ting that these conclusions should not be taken too far.

Species differences
There were clear differences between the species in the trial in both the univariate and the multivariate analyses, and it is rather obvious that the most productive species in the trial is *A. tortilis*.

The poor survival of *P. cineraria* is strange, as this species is occurring naturally at the site. No local provenance was included in the trial, and it may be that none of the three provenances are suitable for the site. Another explanation could be difficulties during the establishment phase, either because of difficulties in transplanting the trees from the nursery to the trial, or because the climatic conditions during the first phase of the trial was extremely adverse. It would seem a dubious conclusion to discard of *P. cineraria* on the basis of this trial.

Except for the variables survival, number of stems and damage score, the provenances of *A. senegal* were always among the poorest provenances. Other provenances may behave differently, but as *A. senegal* is in general considered frost sensitive it may not be worth the effort to test other provenances. In its natural distribution the species is essentially limited to between 11° and 16° northern latitude, thus being outside the "natural" latitudes in this trial (von Maydell 1986).

Considering *A. nilotica*, it appeared that the main differences between this species and *A. tortilis* were caused by differences in survival. The differences in height, crown area and in basal area and dry weight of the mean tree were much less than the differences in total basal area and total dry weight. This *indica*tes that the growth potential in the trees of the two species is more or less the same, but that a factor is stressing the trees of *A. nilotica* and causing die-off of the trees. It appears from the damage scores that some trees of the species are damaged by frost, but problems during the establishment phase could also be the cause.

Provenance differences
Despite the poor survival of *A. nilotica*, there were important differences between the provenances that warrant some conclusions. The provenances Haryana1, Maharashtra2 and Uttar Pradesh1 had the largest production of dry weight, and were also among the best in the other variables. Haryana1 and Uttar Pradesh1 are the northern-most provenances and have an origin closest to the site, and seem to be the most qualified provenances for plantations at the site. The multivariate analysis gave weak *indica*tions of difference between northern and southern provenances from India. The single provenance from Sudan had the poorest performance of them all. However, as there may be a large variability within the African provenances, further tests are needed before provenances with African origin are discarded completely. The multivariate test gave no solid evidence of differences between the varieties. It seems that even though there may be differences between varieties collected at the same site, the growth characteristics are not consistently different between varieties and may vary from site to site.

Although the differences between the two provenances of *A. senegal* were at the limit of significance in some variables, the correction for multiple comparisons in all cases *indica*ted that the significance could be due to random variation. In the multivariate analysis the two provenances were overlapping, meaning that also in this analysis there were no statistically valid differences.

The two *A. tortilis* provenances from Senegal grew significantly faster than the provenance from Israel, and their good performance *indica*tes that they can be recommended for testing on a larger scale. Even though the two provenances separated in the multivariate analysis, there were no clear differences in the univariate tests, and it would be hard to recommend one provenance in favour of another.

In *P. cineraria* the poor survival makes it impossible to give recommendations on the choice of provenances.

Comparison between Jodhpur and B.G. Kere

Most of the provenances of *A. nilotica* and the provenances Senegal22 and Senegal23 of *A. senegal* were also present in the trial at B.G. Kere referred to above. A comparison of the performance of the seed sources at the two sites shows that the ranking of the provenances is almost completely reversed. The two provenances of *A. senegal* had the largest total dry weights in the trial at B.G. Kere, whereas they were among the poorest at Jodhpur.

In *A. nilotica* at B.G. Kere, the southern provenances Maharashtra2, Maharashtra5 and Maharashtra6 had the largest dry weights, whereas the provenances from the North, Haryana1 and Uttar Pradesh1 were more slow-growing. In the present trial it was opposite (see above). This is a strong argument for the recommendation of southern provenances at southern sites and of northern provenances at northern sites. Unfortunately the local provenance at B.G. Kere, Haryana1, also had a meagre performance, somewhat distorting the picture. Sudan08 had a poor performance in both trials. The overall pattern of genetic variation within the species was the same at the two sites. In both multivariate analyses the provenances Maharashtra2, Maharashtra5 and Maharashtra6 formed a group with the provenances from the north and Sudan08 at a distance from of this group. Furthermore, the provenance Maharashtra4 was discernible from the other Maharashtra provenances in both analyses. This information may be useful in planning of genetic conservation of the species.

6. References

Afifi, A.A. and V. Clark. 1996. Computer-aided multivariate analysis. Chapman & Hall, London, 3rd ed., 455 pp.

Brenan, J.P.M. 1983. Manual on taxonomy of *Acacia* species. Food and Agriculture Organisation of the United Nations, Rome, 47 pp.

Brown, K. (no date). An ecophysiological study of *Prosopis cineraria* in the Wahiba Sands, with reference to its suitability as a multi-purpose tree for reafforestation in Oman. Unpublished report, University of Durham.

Chatfield, C. and A.J. Collins. 1980. Introduction to multivariate analysis. Chapman and Hall, London.

DFSC 1994. Preliminary assessment report – trial no. 16. *Acacia* and *Prosopis* species and provenance trial, Jodhpur, India, joint assessment, March 1991 by CAZRI, FRI, FAO and DFSC. Danida Forest Seed Centre, Humlebaek, Denmark.

Draper, N. and H. Smith. 1981. Applied regression analysis, second edition. John Wiley & Sons, New York, 709 pp.

Fagg, C.W. and R.D. Barnes. 1990. African *Acacias*: Study and acquisition of the genetic resources. Final report, ODA Research Scheme R.4348, Oxford Forestry Institute, UK. 170 pp.

Graudal, L. *et al.* 2003. Introduction to the Evaluation of an International Series of Field Trials of Arid and Semi-arid Zone Arboreal Species'. Danida Forest Seed Centre, Humlebæk, Denmark.

Graudal, L. *et al.* (in prep.). Biomass regressions for some species of *Acacia* and *Prosopis*.

Holm, S. 1979. A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6: 65-70.

Kjaer, E.D. and H.R. Siegismund. 1996 Allozyme diversity in two Tanzanian and two Nicaraguan landraces of teak (*Tectona grandis* L.). Forest Genetics 3: 45-52.

Leakey, R.R.B. and F.T. Last. 1978. Biology and potential of *Prosopis* species in areid environments, with particula reference to *P. cineraria*. Unpublished review, Institute of Terrestrial Ecology, Midlothian, Scotland, 43 pp.

Littell, R.C., G.A. Milliken, W.W. Stroup and R.D. Wolfinger. 1996. SAS® System for mixed models. SAS Institute Inc., Cary, NC, 633 pp.

Pedersen, B.O. 1980. A note on the genus *Prosopis*. The International Tree Crops Journal 1: 113-123.

Ross, J.H. 1979. A conspectus of the African *Acacia* species. Memoirs of the Botanical Survey of South Africa, 44, 155 pp.

Ræbild, A., C.P. Hansen and E.D. Kjaer. 2002 Statistical analysis of data from provenance trials. DFSC Guidelines and Technical Notes 63. Danida Forest Seed Centre, Humlebæk, Denmark

SAS 1988a. SAS® Procedures Guide, Release 6.03 Edition. SAS Institute Inc., Cary, NC, 441 pp.

SAS 1988b. SAS/STAT® Users Guide, Release 6.03 Edition. SAS Institute Inc., Cary, NC, 1028 pp.

SAS 1991. SAS® System for Statistical Graphics, First Edition. SAS Institute Inc., Cary, NC, 697 pp.

Skovgaard, I.M. and P. Brockhoff. 1998. Multivariate analysis and variance components. Lecture notes, Dept. of Mathematics and Physics, The Royal Veterinary and Agricultural University, Copenhagen, 41 pp.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical methods. Iowa State University Press, 7th ed., 507 pp.

von Maydell, H.-J. 1986. Trees and shrubs of the Sahel, Their characteristics and uses. TZ-Verlagsgesellschaft, Rossdorf, Germany. 525 pp.

White, T.L. and G.R. Hodge. 1989. Predicting breeding values with applications in forest tree improvement. Kluwer Academic Publishers, Dordrecht, 367 pp.

Annex 1. Description of the trial site

Name of site:	Jodhpur Latitude: 26°18'N Longitude: 73°40'E Altitude: 224 m
Meteorological stations:	Jodhpur (26°18'N, 73°01'E, 224 m (FAO 1987))
Rainfall:	Annual mean (period): 373 mm/year (FAO 1987) 317 mm/year Yearly registrations: 1984: app. 240 1985: app. 210 1986: app. 250 1988: app. 240 Month of establishment (August 1984): app. 100 mm
Rainy season:	7-9 (July-September) Type: Intermediate (FAO 1987) Length (days): 60 (FAO 1987)
Dry months/year:	No. of dry months (< 50 mm): 9 No. of dry periods: 1
Temperature:	Annual mean: 27.4 Coldest month: 9.5 Hottest month: 41.6
Wind:	Speed: 2.1 m/s (FAO 1987)
Topography:	Flat, gentle.
Soil:	Type: Sandy loam Depth: 1 m
Climatic/agroecological zone:	Semi-arid (Thar desert)
Koeppen classification:	BSh
Dominant natural vegetation:	*Capparis decidua*, *Prosopis cineraria*, *Zizyphus nummularia* (?), *Calotropis procera*, *Salvadora oleoides*, *Balanites aegyptiaca*.

Annex 2. Seedlot numbers

Species and provenances of *Prosopis* tested in trial no. 16 at Jodhpur, India. 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	Provenance name	Country of origin	Latitude	Longi-tude	Altitude (m)	Rainfall (mm)	No. of mother trees
Haryana1	1081/82		1	*A. nilotica* subsp. *indica var. cupressiformis*	Nornaul Singhana Road, Bhiwani (Hissar)	India	28 03 N	76 07 E	250	714	4
Maharashtra1	1070/82		4	*A. nilotica* subsp. *indica* var. *jaquemontii*	Pune	India	18 32 N	73 51 E	559	715	25
Maharashtra2	1071/82		7	*A. nilotica* subsp. *indica* var. *vediana*	Pune	India	18 32 N	73 51 E	559	715	25
Maharashtra4	1082/82		8	*A. nilotica* subsp. *indica* var. *cupressiformis*	Pune	India	18 32 N	73 51 E	559	714	25
Maharashtra5	1083/82		2	*A. nilotica* subsp. *indica* var. *cupressiformis*	Akola	India	20 42 N	77 02 E	282	877	
Maharashtra6	1084/82		3	*A. nilotica* subsp. *indica* var. *vediana*	Akola	India	20 42 N	77 02 E	282	877	
Sudan08	1068/82	7/1982	6	*A. nilotica* subsp. *nilotica*	Khartoum Forest	Sudan	15 36 N	32 33 E	330	165	25
Uttar Pradesh1	1069/82		5	*A. nilotica* subsp. *indica* var. *jaquemontii*	Bawain Forest Block, Etawah (Mainpuri)	India	26 45 N	79 00 E	157	762	26
Senegal22	1035/82	82/559	13	*A. senegal*	Namarel	Senegal	14 46 N	16 01 W	50	332	33
Senegal23	1036/82	82/558	12	*A. senegal*	Windou Tiengoly	Senegal	15 59 N	15 20 W	39	350	32
Israel2	1013/81		11	*A. tortilis* subsp. *raddiana*	Ein-Hazeva, Arava	Israel	30 47 N	35 12 W	100	40	
Senegal33	1040/82	82/622	9	*A. tortilis* subsp. *raddiana*	F. C. Rao	Senegal	15 56 N	16 23 W	8		30
Senegal34	1041/82	82/621	10	*A. tortilis* subsp. *raddiana*	F. C. Keur-Mbaye	Senegal	16 29 N	15 35 W	6		30
Yemen4	1062/82	(1)	14	*P. cineraria*	Khanfar (Aden)	Yemen	13 00 N	45 10 E	15	50	20
Haryana2	1087/82		15	*P. cineraria*	Khora-Ahamad, Bhiwani (Hissar)	India	28 45 N	76 10 E	250	446	5
Tamil Nadu3	1089/82		16	*P. cineraria*	Krishnapuram, Trichy	India	10 46 N	78 43 E	88	876	27

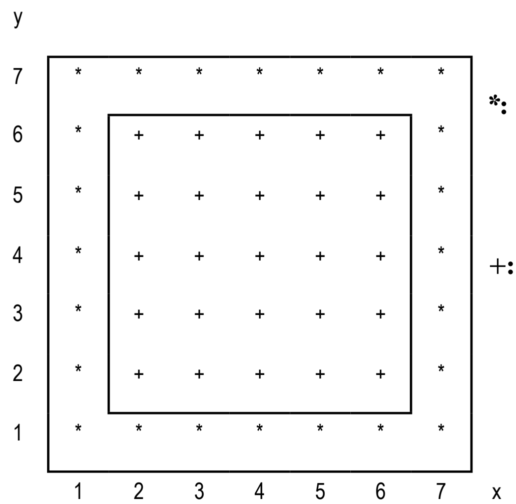
Annex 3. Layout of the trial

Layout of blocks and plots in the field. The numbers correspond to the seedlots given in annex 2:

N

y									
12		7	10	3	1	13	6	11	
11		12	4	2	2	7	5	15	Block 1
10		11	14	9	9	14	10	3	
9		13	5	6	16	8	12	4	
8	16	1	15	8	9	2	6	8	
7	Block 4				16	5	7	14	Block 2
6					4	11	13	10	
5					3	12	15	1	
4					7	15	11	10	
3					8	6	16	5	Block 3
2					13	14	3	1	
1					9	2	4	12	
	1	2	3	4	5	6	7	8	x

Individual tree positions in each plot:



*: plot border trees

+: plot core trees

Annex 4. Plot data set

The plot numbers correspond to the seedlots in the layout of the trial, see annex 3.

Provenance	Species	Block	Plot	Plotx	Ploty	Level	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
Haryana1	*A. nilotica* var. *indica cupressiformis*	1	1	5	12	8.65	0.28	2.96	5.7	1.71	25.1	0.78	5.2	1.63	0.14
Maharashtra4	*A. nilotica* var. *indica cupressiformis*	1	8	6	9	8.53	0.08	2.71	6.5	1.00	26.6	0.24	5.6	0.49	0.50
Maharashtra5	*A. nilotica* var. *indica cupressiformis*	1	2	5	11	8.53	0.20	1.63	2.0	1.20	10.4	0.23	1.7	0.37	0.00
Maharashtra1	*A. nilotica* var. *indica jaquemontii*	1	4	8	9	8.68	0.36	2.04	6.6	1.67	18.1	0.72	3.5	1.40	0.00
Uttar Pradesh1	*A. nilotica* var. *indica jaquemontii*	1	5	7	11	8.85	0.28	2.73	6.4	1.29	20.4	0.63	4.0	1.25	0.00
Maharashtra2	*A. nilotica* var. *indica vediana*	1	7	6	11	8.63	0.32	2.21	7.8	1.63	24.5	0.87	5.0	1.79	0.00
Maharashtra6	*A. nilotica* var. *indica vediana*	1	3	8	10	8.82	0.40	2.10	5.1	1.40	14.4	0.64	2.7	1.19	0.00
Sudan08	*A. nilotica* var.. *nilotica*	1	6	7	12	8.91	0.32	2.05	5.8	2.38	15.4	0.55	2.9	1.05	0.00
Senegal22	*A. senegal*	1	13	6	12	8.73	0.92	1.51	2.8	1.63	9.1	0.93	1.8	1.83	0.00
Senegal23	*A. senegal*	1	12	7	9	8.67	0.52	1.82	4.4	1.92	17.8	1.03	3.9	2.23	0.00
Israel2	*A. tortilis* var. *raddiana*	1	11	8	12	9.05	0.56	1.47	3.5	1.46	8.4	0.52	2.1	1.30	0.00
Senegal33	*A. tortilis* var. *raddiana*	1	9	5	10	8.48	0.68	2.98	8.4	1.31	30.0	2.27	10.2	7.73	0.00
Senegal34	*A. tortilis* var. *raddiana*	1	10	7	10	8.79	0.76	3.05	7.9	1.74	29.7	2.51	9.4	7.97	0.00
Haryana2	*P. cineraria*	1	15	8	11	8.88	0.04	0.20	0.0		0.0	0.00	0.0	0.00	0.00
Tamil Nadu3	*P. cineraria*	1	16	5	9	8.38	0.00								
Yemen4	*P. cineraria*	1	14	6	10	8.59	0.00								
Haryana1	*A. nilotica* var. *indica cupressiformis*	2	1	8	5	8.31	0.52	3.04	6.4	1.46	18.5	1.07	3.6	2.07	0.00
Maharashtra4	*A. nilotica* var. *indica cupressiformis*	2	8	8	8	8.53	0.20	2.82	5.8	1.00	22.6	0.50	4.6	1.03	0.00
Maharashtra5	*A. nilotica* var. *indica cupressiformis*	2	2	6	8	8.47	0.24	2.53	8.5	1.17	27.8	0.74	6.1	1.62	1.00
Maharashtra1	*A. nilotica* var. *indica jaquemontii*	2	4	5	6	8.23	0.16	2.13	7.2	1.00	15.4	0.27	2.8	0.50	0.75
Uttar Pradesh1	*A. nilotica* var. *indica jaquemontii*	2	5	6	7	8.40	0.28	2.86	7.8	1.00	20.4	0.64	4.2	1.29	0.29
Maharashtra2	*A. nilotica* var. *indica vediana*	2	7	7	7	8.39	0.36	2.05	7.3	1.78	24.9	1.00	5.2	2.09	1.00
Maharashtra6	*A. nilotica* var. *indica vediana*	2	3	5	5	8.22	0.12	1.22	1.6	1.00	7.9	0.11	1.2	0.16	2.00
Sudan08	*A. nilotica* var. *nilotica*	2	6	7	8	8.54	0.04	0.95	3.0	2.00	1.8	0.01	0.2	0.01	0.00
Senegal22	*A. senegal*	2	13	7	6	8.34	0.52	1.71	4.3	2.08	15.2	0.88	3.2	1.86	0.00

Provenance	Species	Block	Plot	Plotx	Ploty	Level	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	*A. senegal*	2	12	6	5	8.17	0.72	1.95	5.4	2.06	17.7	1.42	3.8	3.06	0.00
Israel2	*A. tortilis* var. *raddiana*	2	11	6	6	8.18	0.52	2.16	5.8	2.08	16.5	0.96	4.5	2.59	0.00
Senegal33	*A. tortilis* var. *raddiana*	2	9	5	8	8.33	0.44	2.73	5.9	1.20	30.1	1.47	11.0	5.39	0.00
Senegal34	*A. tortilis* var. *raddiana*	2	10	8	6	8.42	0.76	3.04	9.7	1.74	26.5	2.24	8.3	7.01	0.00
Haryana2	*P. cineraria*	2	15	7	5	8.23	0.08	0.53	0.0		0.0	0.00	0.0	0.00	0.00
Tamil Nadu3	*P. cineraria*	2	16	5	7	8.33	0.00								
Yemen4	*P. cineraria*	2	14	8	7	8.43	0.00								
Haryana1	*A. nilotica* var. *indica cupressiformis*	3	1	8	2	7.80	0.52	3.17	7.8	1.08	21.9	1.26	4.5	2.62	0.00
Maharashtra4	*A. nilotica* var. *indica cupressiformis*	3	8	5	3	7.80	0.16	2.19	6.1	1.00	12.8	0.23	2.4	0.42	0.00
Maharashtra5	*A. nilotica* var. *indica cupressiformis*	3	2	6	1	7.80	0.60	1.76	4.5	1.50	9.5	0.63	1.6	1.09	1.00
Maharashtra1	*A. nilotica* var. *indica jaquemontii*	3	4	7	1	7.61	0.32	2.05	5.5	1.57	12.9	0.46	2.3	0.82	1.13
Uttar Pradesh1	*A. nilotica* var. *indica jaquemontii*	3	5	8	3	8.00	0.44	2.63	7.1	1.36	18.8	0.92	3.7	1.80	0.00
Maharashtra2	*A. nilotica* var. *indica vediana*	3	7	5	4	8.07	0.20	2.29	10.0	1.00	20.1	0.45	4.1	0.90	0.00
Maharashtra6	*A. nilotica* var. *indica vediana*	3	3	7	2	7.85	0.48	1.62	4.1	1.13	11.4	0.61	2.1	1.14	1.25
Sudan08	*A. nilotica* var. *nilotica*	3	6	6	3	7.86	0.12	1.02	2.6	2.00	6.2	0.08	1.2	0.16	1.00
Senegal22	*A. senegal*	3	13	5	2	7.73	0.52	1.14	1.8	1.45	6.8	0.39	1.3	0.74	0.00
Senegal23	*A. senegal*	3	12	8	1	7.68	0.76	1.41	2.3	1.56	7.4	0.63	1.3	1.13	0.00
Israel2	*A. tortilis* var. *raddiana*	3	11	7	4	8.16	0.80	2.44	6.6	1.70	20.1	1.78	6.0	5.35	0.00
Senegal33	*A. tortilis* var. *raddiana*	3	9	5	1	7.85	0.80	3.07	8.7	1.00	26.2	2.33	8.6	7.66	0.00
Senegal34	*A. tortilis* var. *raddiana*	3	10	8	4	8.17	0.76	3.05	8.5	1.21	29.0	2.45	9.3	7.87	0.00
Haryana2	*P. cineraria*	3	15	6	4	8.12	0.16	0.35	0.0		0.0	0.00	0.0	0.00	0.00
Tamil Nadu3	*P. cineraria*	3	16	7	3	7.94	0.00								
Yemen4	*P. cineraria*	3	14	6	2	7.76	0.08	0.20	0.0		0.0	0.00	0.0	0.00	0.00

Provenance	Species	Block	Plot	Plotx	Ploty	Level	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
Haryana1	*A. nilotica* var. *indica cupressiformis*	4	1	2	8	8.16	0.04	3.43	14.9	1.00	48.7	0.22	12.2	0.54	0.00
Maharashtra4	*A. nilotica* var. *indica cupressiformis*	4	8	4	8	8.31	0.04	2.98	11.2	1.00	34.5	0.15	7.8	0.35	0.00
Maharashtra5	*A. nilotica* var. *indica cupressiformis*	4	2	4	11	8.49	0.08	1.66	3.5	3.00	13.6	0.12	2.3	0.21	1.50
Maharashtra1	*A. nilotica* var. *indica jaquemontii*	4	4	3	11	8.37	0.12	2.49	5.8	1.00	22.4	0.30	4.8	0.65	1.00
Uttar Pradesh1	*A. nilotica* var. *indica jaquemontii*	4	5	3	9	8.23	0.16	3.45	13.8	1.25	38.6	0.69	9.3	1.65	0.00
Maharashtra2	*A. nilotica* var. *indica vediana*	4	7	2	12	8.57	0.08	2.72	10.7	1.00	30.3	0.27	6.6	0.59	0.50
Maharashtra6	*A. nilotica* var. *indica vediana*	4	3	4	12	8.60	0.20	2.14	5.1	1.60	19.3	0.43	3.8	0.84	0.00
Sudan08	*A. nilotica* var. *nilotica*	4	6	4	9	8.41	0.20	1.97	4.9	2.20	9.1	0.20	1.5	0.33	0.00
Senegal22	*A. senegal*	4	13	2	9	8.18	0.60	1.40	2.2	1.36	7.2	0.48	1.4	0.93	0.87
Senegal23	*A. senegal*	4	12	2	11	8.33	0.60	1.57	2.3	1.93	9.6	0.64	1.8	1.22	0.07
Israel2	*A. tortilis* var. *raddiana*	4	11	2	10	8.23	0.52	1.87	4.5	1.82	10.9	0.63	2.9	1.67	0.46
Senegal33	*A. tortilis* var. *raddiana*	4	9	4	10	8.41	0.68	2.78	6.9	1.33	27.2	2.06	9.5	7.18	0.00
Senegal34	*A. tortilis* var. *raddiana*	4	10	3	12	8.63	0.60	2.77	8.1	1.33	25.6	1.71	7.8	5.22	0.00
Haryana2	*P. cineraria*	4	15	3	8	8.23	0.00								
Tamil Nadu3	*P. cineraria*	4	16	1	8	8.06	0.00								
Yemen4	*P. cineraria*	4	14	3	10	8.28	0.00								