UNIVERSITY OF COPENHAGEN

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

Trial no. 17 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

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

Trial no. 17 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 & Colleges, Dehra Dun, India

Arid Forest Research Institute, Jodhpur, India

Food and Agriculture Organization, Rome

Danida Forest Seed Centre[1], Denmark

Results and Documentation no. 32

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.17 in the arid zone series. Results and Documentation No. 32.
Danida Forest Seed Centre, Humlebaek, Denmark.

ISSN 0902-3224

Cover photo:

This publication can be requested from:

Forest & Landscape Denmark
Kongevejen 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 represents 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. and the Arid Forest Research Institute (AFRI) under the auspices of Indian Council of Forestry Research and Education (ICFRE). The assessment team consisted of L.N. Harsh and G.L. Meena (CAZRI), N.K. Vasu (AFRI), and Hans Roulund (DFSC).

The authors wish to acknowledge the help of the personnel at CAZRI/FRI/AFRI 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 32 provenances of the species *Acacia albida*, *A. niloticaa*, *A. senegal*, *Prosopis chilensis*, *P. cineraria* and *P. pallida*. The provenances represented a mixture of exotic and autochthonous origins, being from India, Pakistan, Chile and Peru. The trial was established with a spacing of 3 x 3 metres at Jodhpur, India, in 1985 and assessed after 6 years in 1991. Different growth parameters were measured and subjected to analyses of variance and multivariate analyses.

Survival of most provenances was poor, especially for *A. albida* and *P. cineraria*, where only one tree survived despite the fact that *P. cineraria* is native to the area. *P. pallida* had the highest survival with values varying between 30 and 90 %. This was also reflected in the dry weight production, where *P. pallida* took the lead. The best provenance of this species had produced 10 t ha^{-1} at the assessment, corresponding to 1.7 t ha^{-1} y^{-1}. Overall the results indicate that the most promising species is *P. pallida*, with some provenances of *A. niloticaa* and *A. senegal* having a slower but still satisfactory growth.

Within the species there were few significant differences. However, for *A. niloticaa* and *A. senegal* results indicated that the most productive provenances in terms of biomass were the local provenances. For *P. pallida*, two groups of provenances were included, one from northern and one from southern Peru. There was more variation in the northern than in the southern group.

Contents

1. Introduction

This report describes the results from trial no. 17 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.).

Acacia albida is often considered belonging to a separate genus, thus being called *Faidherbia albida* by some authors (von Maydell 1986, Fagg & Barnes 1990). The growth cycle is reversed in comparison to other species in that it drops the leaves during the rainy season and flush in the dry period. The species is widespread in Africa and is an important component of the *Faidherbia* parklands (Boffa 1999). Its importance to agroforestry systems is probably due to its nutrient- and nitrogen-fixing properties, shading for the crops and protection of soils. Furthermore the pods and branches provide an important fodder for the animals (von Maydell 1986). The provenances in this trial are all from Senegal.

Acacia 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 or varieties are recognised (Brenan 1983, Dwivedi 1993, Ross 1979). Among the main products of the tree are firewood, fodder and tannins. In this trial most of the provenances are exotic, being either from Pakistan or from Senegal except one provenance which is local. Unfortunately it is not clear which varieties are represented.

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). In this trial, one of the provenances is local and four are from Pakistan, presumably all of the variety senegal.

Many species of the genus *Prosopis* occur naturally in extremely hot and highly arid environments. Only four *Prosopis* species are native to the Old World, and the largest diversity of species is found in South and Central America. The taxonomy of *Prosopis* is difficult and still debated (Ffolliott & Thames 1983). Early introductions of material from the Americas to India and Pakistan are believed to be of narrow genetic origin, and there is a need to examine the potential of this genus in more detail (Pasiecnik *et al.* 2001). The current trial includes one provenance of *P. chilensis* from Chile and a range of provenances of *P. pallida* from Peru.

The last species included is *P. cineraria*, which is 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 1985. For calculation of annual increments it is assumed that the seed were sown in March 1985.

2.2 Species and provenances

The trial includes 32 provenances of the species mentioned in the introduction (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. One provenance from Pakistan turned out to be a mixture of two species, and is included in neither table 1 nor the analyses. No further reference is made to this seedlot.

2.3 The experimental design

The experimental design is a randomised complete block design with three blocks. Within each replicate, the provenance is represented by 36 trees in a plot, planted in a square of 6×6 trees. The trees are placed with a spacing of 3×3 m. Only the 16 central trees 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, AFRI, 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 values.

Table 1. Species and provenances of *Acacia* and *Prosopis* tested in trial no. 17 at Jodhpur, India.

Provenance	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Annual Rainfall (mm)	No. of mother trees
Senegal06	*Acacia albida*	Kirdiom	Senegal	15° 38' N	16° 12' W	40	450	
Senegal07	*Acacia albida*	Region De Long Nayobe	Senegal	15° 38' N	16° 13' W	50	450	
Senegal11	*Acacia albida*	Bignona	Senegal	12° 45' N	16° 25' W	10	1170	34
Punjab2	*Acacia nilotica*	Patoki, Lahore Punjab	Pakistan	31° 05' N	73° 30' E	200	350	25
Punjab3	*Acacia nilotica*	Fazal Abad Rice Mill, D.I.Khan	Pakistan	31° 15' N	70° 45' E	330	300	25
Punjab4	*Acacia nilotica*	Dargai-Jehangira, Peshawar	Pakistan	33° 50' N	72° 20' E	500	750	25
Punjab5	*Acacia nilotica*	Muzaffar Garh, Punjab	Pakistan	30° 05' N	71° 10' E	170	200	25
Punjab6	*Acacia nilotica*	Nullah, Gujrat	Pakistan	32° 49' N	73° 53' E	220	500	25
Rajasthan11	*Acacia nilotica* subsp. *indica* var. *cupressiformis*	Pali	India	24° N	73° 35' E	382	400	
Senegal17	*Acacia nilotica*	Podor	Senegal	16° 38' N	14° 57' W	50	200	
Senegal20	*Acacia nilotica*	Dinaga, Podor	Senegal	16° 30' N	14° 55' W	50	200	
Sind01	*Acacia nilotica*	Ziala Forest, Thatta, Sind	Pakistan	24° 41' N	67° 57' E	14	204	25
Sind02	*Acacia nilotica*	Sukhur, Sind	Pakistan	27° 42' N	67° 54' E	50	100	25
Rajasthan5	*Acacia senegal*	Jodhpur	India	26°18'N	73°40'E	224	317	
Sind03	*Acacia senegal*	Bourberband, Dadu	Pakistan	25° N	67° E	100	200	25
Sind04	*Acacia senegal*	Dhabiji (Thatta)	Pakistan	24° 49' N	67° 32' E	14	204	25
Sind05	*Acacia senegal*	Loonio, Tharparkar, Sind	Pakistan	24° 38' N	70° 31' E	150	350	25
Sind06	*Acacia senegal*	Nagar-Parkar, Tharparkar, Sind	Pakistan	24° 21' N	70° 47' E	200	350	
Chile5	*Prosopis chilensis*	Lampa	Chile	33° 17' S	70° 53' W	500	306	5
NW Frontier1	*Prosopis cineraria*	Darya Khan, Bhakkar	Pakistan	31° 47' N	71° 10' N	200	200	30
NW Frontier2	*Prosopis cineraria*	Goharwala, Bhakkar	Pakistan	31° 42' N	71° 34' E	200	200	28
Rajasthan10	*Prosopis cineraria*	Jodhpur	India	26°18'N	73°40'E	224	317	
Sind09	*Prosopis cineraria*	Islam-Kot, Tharparkar, Registan (Loonio)	Pakistan	24° 40' N	70° 12' E	50	150	25
Sind10	*Prosopis cineraria*	Saeed-Abad, Hyderabad	Pakistan	25° 25' N	68° 24' E	30	157	25
Peru06	*Prosopis pallida*	Puerte Del Vice, Piura	Peru	05° 25' S	80° 47' W	13	70	18
Peru07	*Prosopis pallida*	Huacachina, Ica	Peru	14° 07' S	76° 45' W	100	1	60
Peru08	*Prosopis pallida*	Rinconada (Piura)	Peru	05° 30' S	80° 35' W	30	60	18
Peru09	*Prosopis pallida*	Cachiche, Ica	Peru	13° 45' S	75° 50' W	0	2	22
Peru10	*Prosopis pallida*	Pueblo De Santa Clara, Piura	Peru	05° 29' S	80° 45' W	7	8.3	10
Peru12	*Prosopis pallida*	Sechura (Piura)	Peru	05° 33' S	80° 48' W	4	25	5
Peru13	*Prosopis pallida*	Ocucaje (Ica), Zona: Tres Esquinas	Peru	14° 20' S	75° 40' W	420	35	

3. Statistical analyses

3.1 Variables

In this report the following nine (eight) 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

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 and number of stems 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 a unit area basis. Note that the calculations of basal area are based on measurements of the three largest stems per tree.

The health characters were not analysed statistically, as there was almost no damage to the trees. Instead a graphical presentation is given in annex 5.

A problem with the assessment data is that for some small trees, no assessment of diameter and number of stems was made. This was the case for 3 trees in the provenance Sind04 and 5 trees in Sind05. All missing observations were in block 1. Omission of these data will produce biased results and lead to an over-estimation of the provenances in question, and ideally a correction should be made. However, since the provenances Sind04 and Sind05 both were slow-growing provenances the impact of a correction would be limited and was omitted.

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.). The regression was of the type

$$TreeDW = e^{(a \times \ln(basalarea) - b)}$$

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. a and b are species specific coefficients given in table 2. No such regression was available for *P. chilensis*, which was therefore omitted in the analyses of the dry weight variables.

Table 2. Coefficients for the dry weight regressions used for calculation of dry weight. Coefficients for *P. chilensis* were not available.

Species	*a*	*b*
Acacia albida	2.055	1.976
Acacia nilotica	2.582	2.518
Acacia senegal	2.474	2.233
Prosopis cineraria	2.395	2.434
Prosopis pallida	2.814	2.765

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 σ_{pr}^2, $block_j$ 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 $N(0, \sigma_e^2)$. In the test of species differences, Satterthwaite's approximation was used for calculating 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 $N(0, \sigma_e^2)$.

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 two axes of the trial, plotx and ploty, and squared values of these, plotx2 and ploty2. The variable level was also included as a co-variate. 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.

In general, the poor survival of most of the species made analyses difficult because of a large number of missing observations. 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 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 variances tended to vary with the size of the variable, an arc sine transformation (survival) or a square root transformation (crown area) 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 eight, 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.

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 present BLUP estimates for *A. niloticaa*, *A. senegal* and *P. pallida* since they are the only species with larger numbers of provenances.

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 short description of the analysis of each variable is given in the result section, and a more detailed description of the statistical methods used is given by Ræbild *et al.* (2002). 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.

Statistical analysis

It was difficult to obtain a model with a satisfactory distribution of the residuals. Analysis on the untransformed data showed signs of variance heterogeneity, and an arc sine function was used to transform the data. Even after this there were signs of variance heterogeneity, but as a visual inspection of the data support the conclusion from the arc sine model, this model is used for providing estimates and tests. The co-variate ploty was significant in the analysis of species differences, and in the analysis of provenance differences within *A. senegal*.

Results

Overall the survival of the trees was poor (Fig.1). Only *P. pallida* had a survival that can be considered acceptable. Senegal11 of *A. albida* had only one surviving tree, the other provenances of this species none, and despite several provenances being represented, none of the trees of *P. cineraria* survived. Therefore the results for *P. cineraria* are not presented in Fig. 1.

The differences between species were highly significant (Table 3). An extra test was made to compare the species without *P. cineraria*, and the species effect was still highly significant (not shown).

Within species, the differences between provenances were significant in *A. senegal*. In *A. niloticaa*, the differences between provenances were balancing on the edge of significance, but significance disappeared when the correction for multiple comparisons was made. In *P. pallida*, the differences were not significant at all.

The best provenance of *P. pallida* was Peru10 with a survival of almost 90 %, and for the other provenances of this species survival varied between 30 and 70 %. In *A. senegal*, Rajasthan5 and Sind05 had the best survivals with approximately 45 %, and in *A. niloticaa*, Rajasthan11 had a survival of 55 %. For all other provenances the survival was below 20 %.

The corresponding BLUP values appear from the figures 2-4. Rajasthan 11 (*A. niloticaa*) was more than 25 % better than the average, but note again that this was not sufficient to give significant differences. For *A. senegal* and *P. pallida* the gains by provenance selection were up to 15 % of the average values.

Table 3. Results from analysis of variance of species and provenance differences of survival in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	5; 25.1	1.75	15.9	<0.0001	***
Provenance(species)	25; 59	0.11	2.5	0.0024	
Block	2; 59	0.005	0.1	0.89	
Ploty	1; 59	0.16	3.5	0.07	
Error	59	0.04			
A. niloticaa					
Provenance	9; 18	0.189	2.6	0.04	n.s.
Block	2, 18	0.016	0.2	0.81	
Error	18	0.073			
A. senegal					
Provenance	4; 7	0.115	11.2	0.004	*
Block	2; 7	0.028	2.8	0.13	
Ploty	1; 7	0.210	20.5	0.003	
Error	7	0.010			
P. pallida					
Provenance	6; 12	0.127	1.9	0.16	n.s.
Block	2, 12	0.150	2.3	0.15	
Error	12	0.066			

Figure 1. Survival in the *Acacia* and *Prosopis* species and provenance trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits.

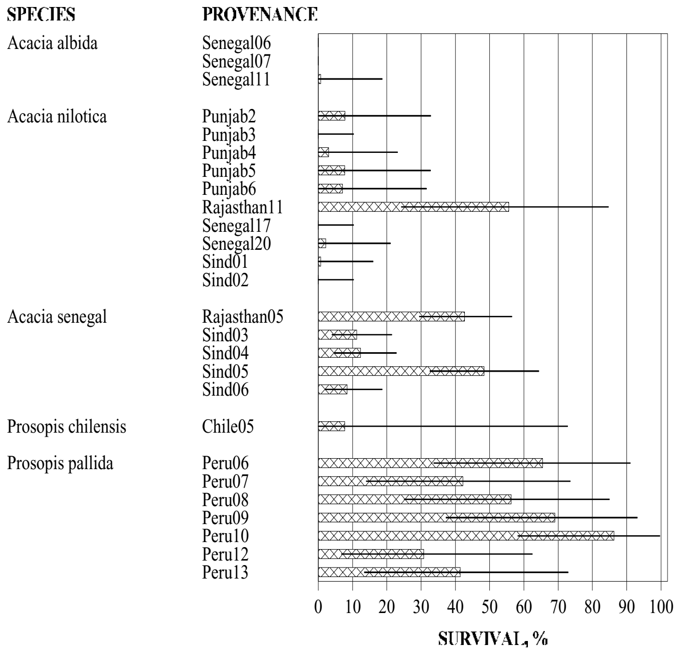


Figure 2. Best linear unbiased predictors (BLUP's) for survival in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are deviations from the mean value in percentage point.

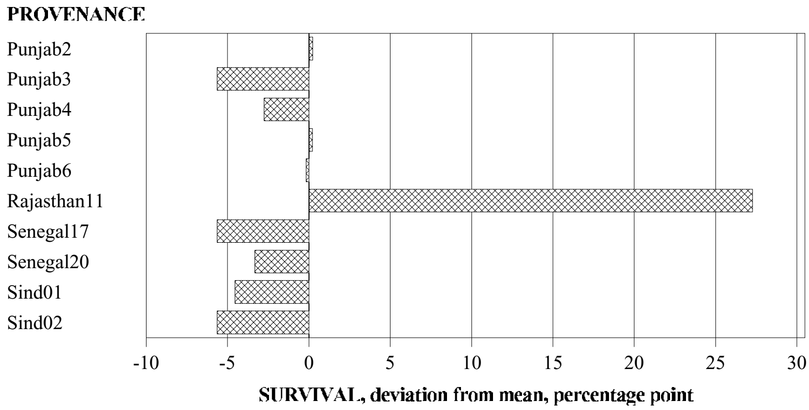


Figure 3. Best linear unbiased predictors (BLUP's) for survival in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are deviations from the mean value in percentage point.

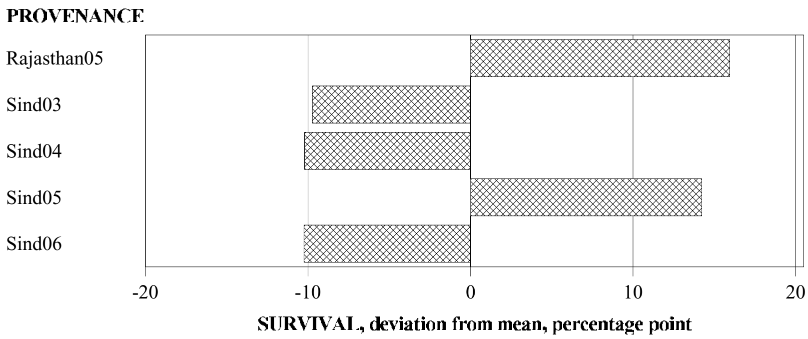
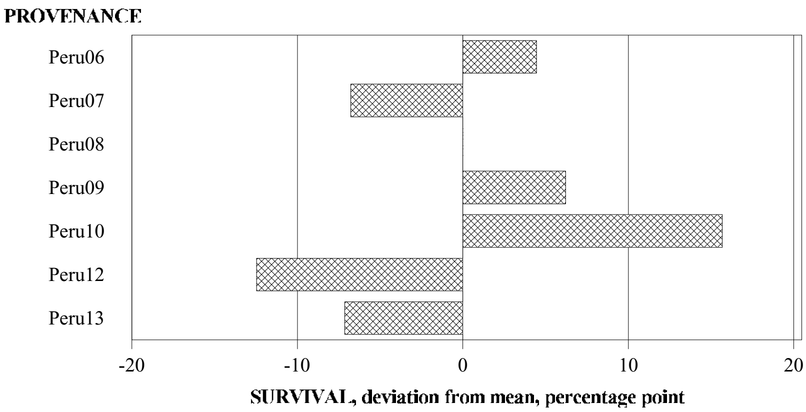


Figure 4. Best linear unbiased predictors (BLUP's) for survival in the *P. pallida* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are deviations from the mean value in percentage point.



4.2 Height

Height is usually considered an important variable in the evaluation of species and provenances. However, this of course 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 provenances/trees usually being better adapted to the site than short provenances/trees. This need not always be true as there have been cases where the tallest provenances are suddenly affected by stress and die-off.

Statistical analysis

Residuals from the initial analysis suggested that there was variance heterogeneity in the data, and a weight statement was applied to fulfil the assumptions of the model. This was not necessary in the analyses of provenance differences within species. The co-variate plotx2 was significant in the analysis of species differences and in the analysis of provenance differences within *P. pallida*.

Results

The height was varying between 1 m and almost 5 m (Fig. 5). The provenances of *A. niloticaa* and *P. pallida* had the fastest height growth, whereas *A. senegal* and *P. chilensis* had a more modest increment. The tallest provenances were Peru06 of *P. pallida* and Sind01 and Punjab5 of *A. niloticaa*, whereas Sind04 of *A. senegal* was the shortest of them all. As there was only one tree left of *A. albida* it is difficult to say something reasonable about the growth of this species.

Looking at Fig. 5 it appears immediately that there are differences between the species, and this is confirmed by the statistical tests of the species effect, being highly significant (Table 4). Within the species, there were signs of significant differences in *A. senegal* and *P. pallida*, but not in *A. niloticaa*.

The BLUP values (Fig. 6 to 8) showed that the gains by provenance selection varied between 10% for *A. niloticaa* and almost 20 % for the best provenances of *A. senegal* and *P. pallida*.

Table 4. Results from analysis of variance of species and provenance differences of vertical height in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	3; 12.2	290	24.3	<0.0001	***
Provenance(species)	12; 25	13.1	14.7	<0.0001	
Block	2; 25	6.1	6.8	0.004	
Plotx2	1; 25	36.4	40.7	<0.0001	
Error	525	0.9			
A. niloticaa					
Provenance	6; 2	0.466	1.0	0.59	n.s.
Block	2; 2	0.525	1.1	0.48	
Error	2	0.478			
A. senegal					
Provenance	4; 8	0.256	6.2	0.01	(*)
Block	2; 8	0.042	1.0	0.40	
Error	8	0.041			
P. pallida					
Provenance	6; 10	0.731	7.5	0.003	*
Block	2, 10	0.106	1.1	0.37	
Plotx2	1; 10	0.436	4.4	0.06	
Error	10	0.098			

Figure 5. Vertical height in the *Acacia* and *Prosopis* species and provenance trial at Jodphur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits. There are no confidence limits for Senegal11 (*A. albida*) as surviving trees were present only on one plot.

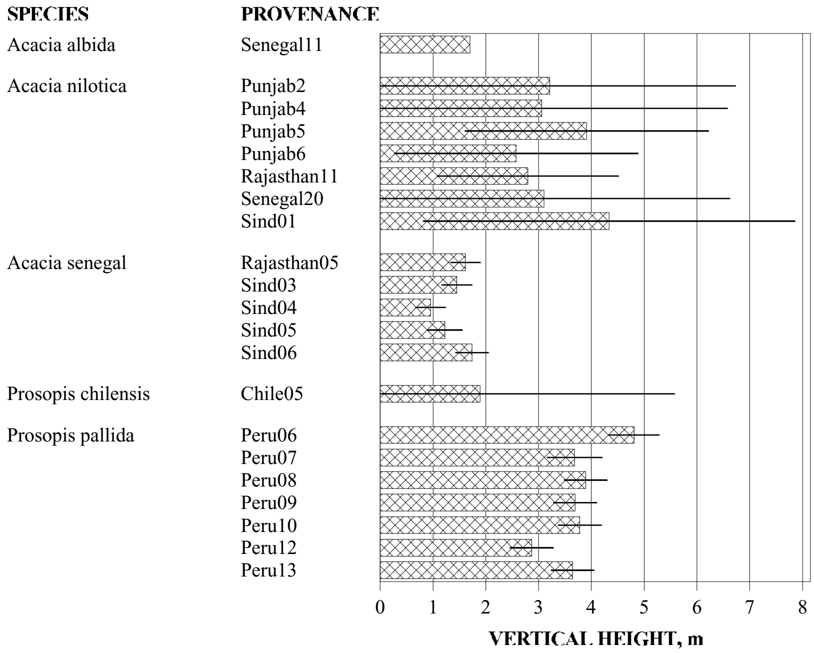


Figure 6. Best linear unbiased predictors (BLUP's) for vertical height in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

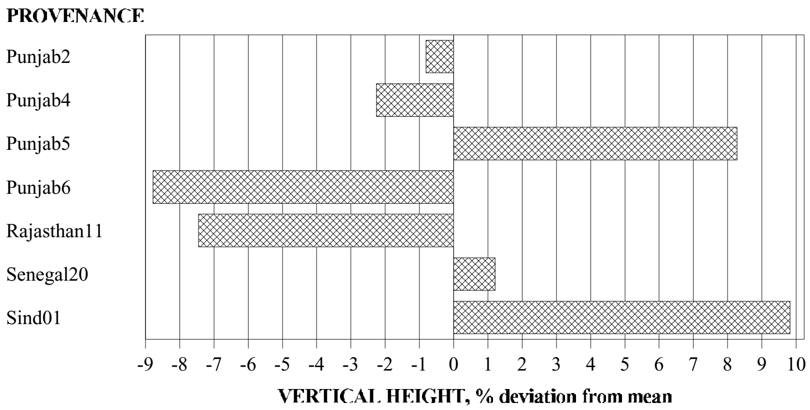


Figure 7. Best linear unbiased predictors (BLUP's) for vertical height in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

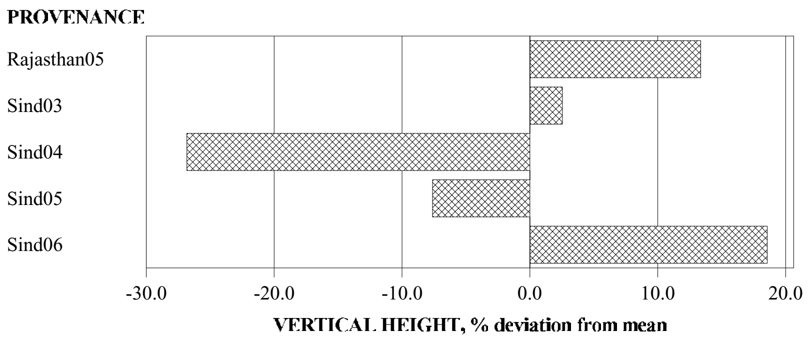
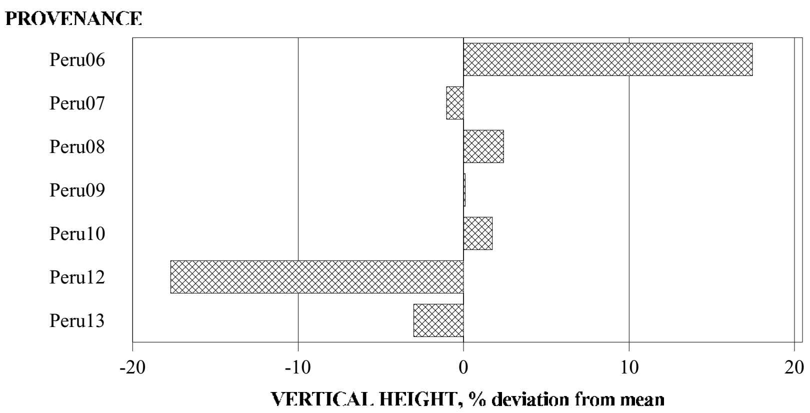


Figure 8. Best linear unbiased predictors (BLUP's) for vertical height in the *P. pallida* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.



4.3 Crown area

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

Statistical analysis

As the variance was larger for provenances with big crowns, the data were transformed with the square root before analysis. The co-variates ploty and ploty2 were significant in the analysis of species differences, but not in any of the other analyses.

Because of the square root transformation the presented least square means are slightly smaller than mean values calculated on the untransformed data. For the largest provenance, Senegal20, the least square mean calculated on data without transformation was 16.8 m^2 $tree^{-1}$, but only 16.6 m^2 $tree^{-1}$ when calculated from square root transformed data. The back-transformed least square means are presented because they give the best illustration of differences between the provenances.

Results

There was a big variation between the crown area of the smallest and the biggest provenances, ranging from 2 to 17 m^2 $tree^{-1}$ (Fig. 9). As for height growth there were highly significant differences between the species (Table 5), the smallest being *A. senegal* and *P. chilensis*, whereas the provenances of *P. pallida* were the largest. *A. niloticaa* was very variable, the best provenances equalling *P. pallida* and the poorest equalling *A. senegal.*

It should be noted that the large error bars for the provenances of *A. niloticaa* are partly due to the fact that there are many missing observations (plots with no surviving trees) for this species. This also explains why such large differences within the species are not significantly different.

Only in *A. senegal* were there weak signs of significant differences between the provenances, but when the correction for multiple comparisons were made, even these signs disappeared. Within the two other species, there were no signs whatsoever of significant differences. However, for *A. niloticaa*, the BLUP values indicated gains of up to 60 % (for Senegal20), and for *A. senegal* above 25 % (Rajasthan05) (Fig. 10 and 11). For *P. pallida* the calculated BLUP deviations from the mean value were all zero, and it has therefore no meaning to make a BLUP graph for this species.

Table 5. Results from analysis of variance of species and provenance differences of crown area in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	4; 18.0	6.07	19.6	<0.0001	***
Provenance(species)	16; 24	0.361	3.8	0.002	
Block	2; 24	0.687	7.3	0.003	
Ploty	1; 24	0.471	5.0	0.04	
Ploty2	1; 24	0.830	8.8	0.007	
Error	24	0.0942			
A. niloticaa					
Provenance	6; 2	0.63	1.9	0.39	n.s.
Block	2; 2	0.16	0.5	0.67	
Error	2				
A. senegal					
Provenance	4; 8	0.30	3.4	0.07	n.s.
Block	2; 8	0.36	4.0	0.06	
Error	8	0.09			
P. pallida					
Provenance	6; 11	0.0699	0.6	0.73	n.s.
Block	2, 11	0.151	1.3	0.32	
Error	11	0.119			

Figure 9. Crown area in the *Acacia* and *Prosopis* species and provenance trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits. The upper confidence limit for some provenances of *A. niloticaa* were larger than illustrated, but was truncated at 25 m in the figure. There are no confidence limits for Senegal11 (*A. albida*) as there was only one surviving tree.

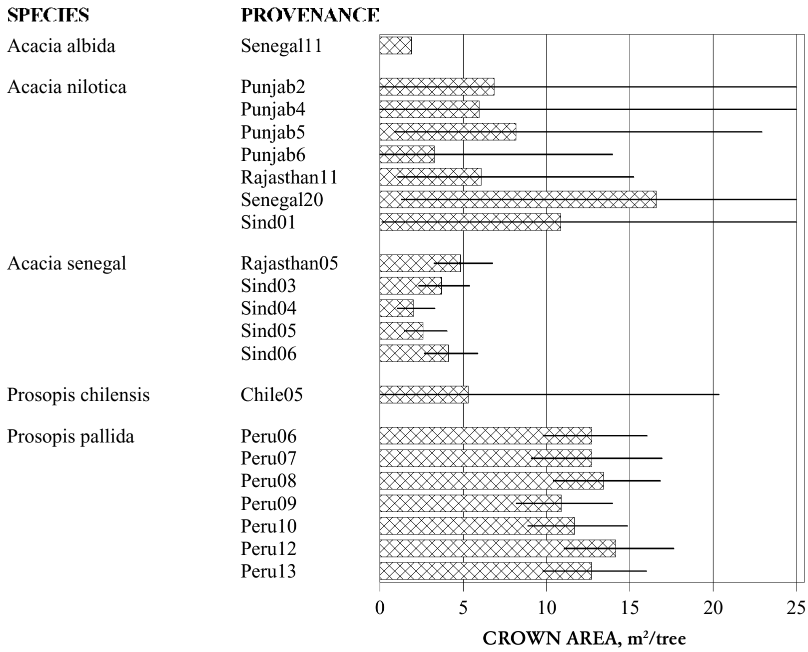


Figure 10. Best linear unbiased predictors (BLUP's) for crown area in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

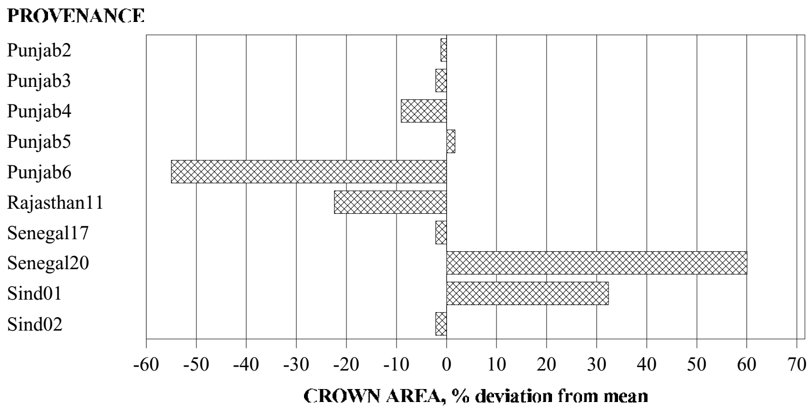
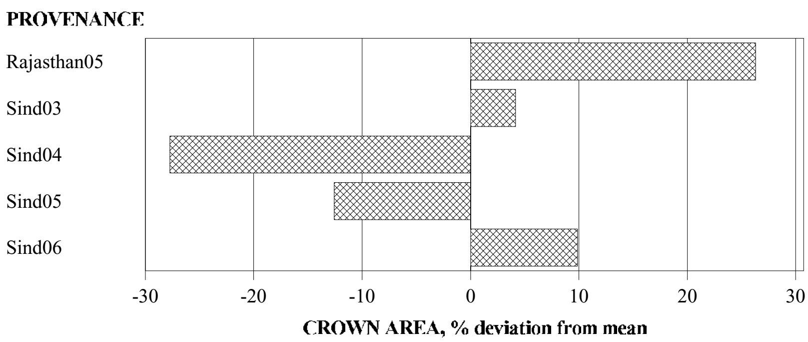


Figure 11. Best linear unbiased predictors (BLUP's) for crown area in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.



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 considered bushy, whereas trees with only one stem have a more tree-like growth.

Statistical analysis

In block 2 the provenance Sind05 was represented by only one tree, which had 4 branches. In the analysis this observation turned out as an outlier, and since it seems well justified to discard this observation (solitary trees often develop large crowns), it was excluded. Apart from this the analyses were without problems. The co-variates ploty and level were significant in the analysis of species differences, and level was almost significant in the analysis of provenance differences in *A. niloticaa*.

The imbalance in this variable (many missing observations) gave strange results, as the number of stem for provenance Sind05 was below 1. Of course it is not possible for (live) trees to have stem numbers below 1, but this reflects the correction that the block effect has on the estimates. For illustration of differences between the provenances the estimates are still the best, but for describing the trees on the site the estimates may be of limited value.

Results

The average number of stems varied from 1 in Sind05 (*A. senegal*) to almost 4 in the provenance of *P. chilensis*. Tests demonstrated that the species differences were highly significant with *P. pallida* and *P. chilensis* having the largest numbers and *A. niloticaa* and *A. senegal* the smallest (Table 6, Fig. 12). Within *A. niloticaa* and *A. senegal*, the differences between provenances were not significant, but in *P. pallida* the differences were significant. Peru12 had the smallest number of stems in *P. pallida*, and Peru10 had the largest.

The BLUP values ranged from only ±1 % in *A. senegal* over −15 to +20 % in *A. niloticaa* to around ±25 % for the extreme provenances of *P. pallida* (Fig. 13 to 15).

Table 6. Results from analysis of variance of species and provenance differences of number of stems in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	4; 21.6	3.58	10.3	<0.0001	***
Provenance(species)	16; 21	0.410	2.2	0.05	
Block	2; 21	0.287	1.5	0.24	
Ploty	1; 21	0.641	3.4	0.08	
Level	1; 21	0.587	3.1	0.09	
Error	21	0.188			
A. niloticaa					
Provenance	6; 2	0.106	3.0	0.27	n.s.
Block	2; 2	0.072	2.0	0.33	
Error	2	0.035			
A. senegal					
Provenance	4; 5	0.353	1.4	0.35	n.s.
Block	2; 5	0.723	2.9	0.14	
Error	5	0.247			
P. pallida					
Provenance	6; 11	0.713	4.9	0.01	(*)
Block	2, 11	0.230	1.6	0.25	
Error	11	0.144			

Figure 12. Number of stems in the *Acacia* and *Prosopis* species and provenance trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits. The upper confidence limit for Chile05 of *P. chilensis* was 14 m, but was truncated at 6 m in the figure.

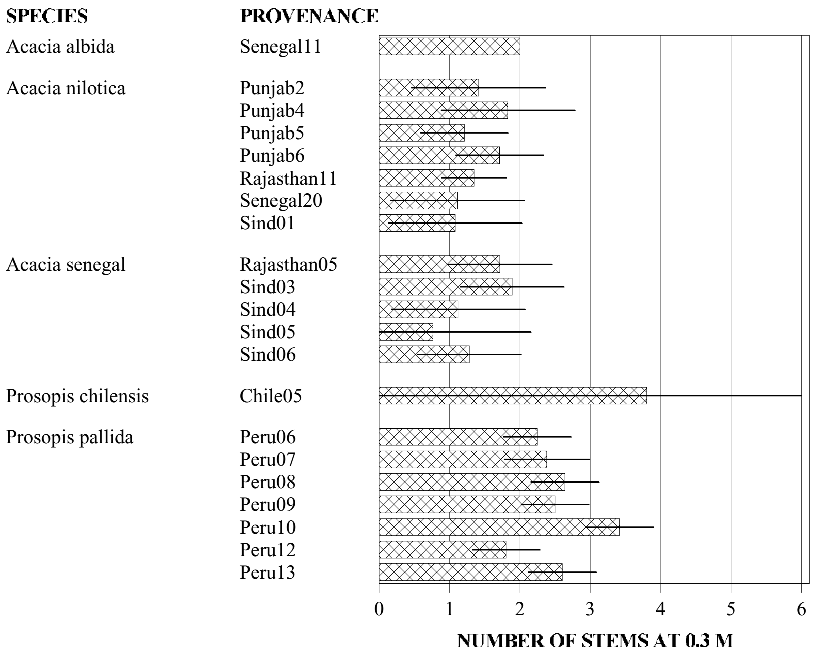


Figure 13. Best linear unbiased predictors (BLUP's) for number of stems in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

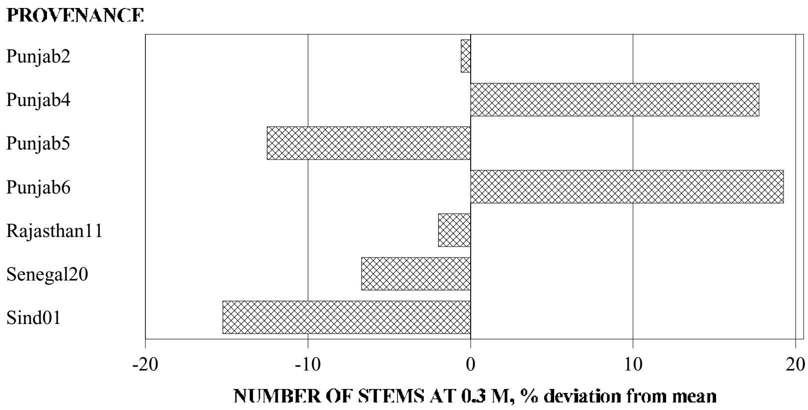


Figure 14. Best linear unbiased predictors (BLUP's) for number of stems in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

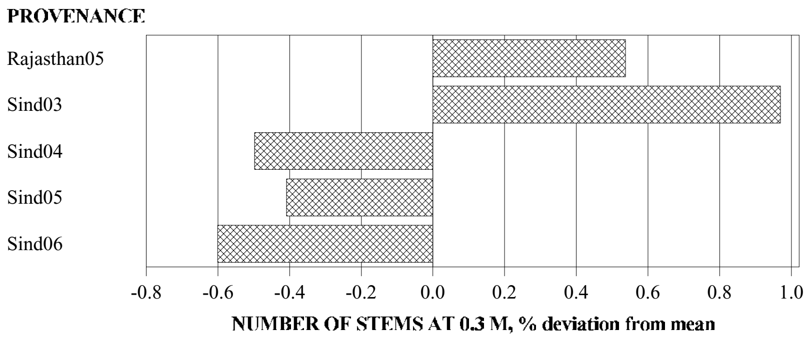
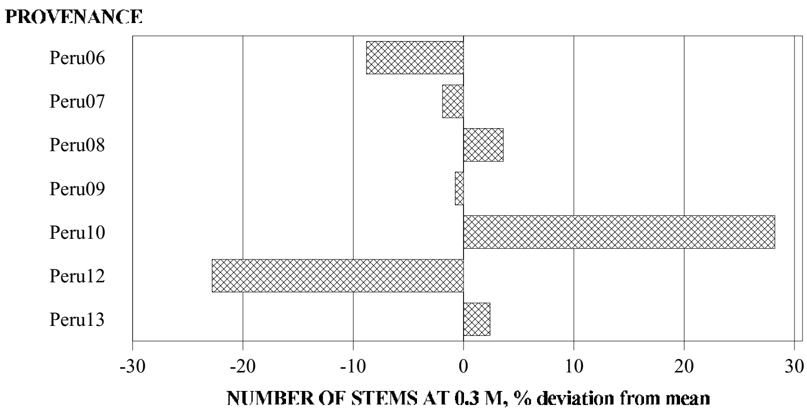


Figure 15. Best linear unbiased predictors (BLUP's) for number of stems in the *P. pallida* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.



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, provided that all trees survive.

Statistical analysis

The assumptions of the statistical models seemed to be fulfilled without transformations or weight statements. The co-variates ploty2 and level were significant in the model for analysis of species effects. In the tests within species, ploty2 was significant in the analysis of *A. senegal*.

Results

The tests demonstrated that there were significant differences between the species (Table 7). The largest trees were found in the provenances of *A. niloticaa* and *P. pallida* with values up to 80 cm^2 $tree^{-1}$ (Sind01), whereas *A. senegal* and *P. cineraria* had the smallest values, all below 15 cm^2 $tree^{-1}$ (Fig. 16).

Within-species-differences were not significant in any of the species. The differences within *A. senegal* were almost significant with a P-value of 0.06, but this disappeared after the correction for multiple comparisons. Nevertheless the BLUP-values indicated substantial gains by selection of the best provenances, especially for *A. niloticaa*. For this species, Sind01 was 120 % better than the average provenance (Fig. 17). For *A. senegal* the best provenance was Sind03 with a performance 20 % better than the average (Fig. 18). For *P. pallida* Peru06 was the fastest growing with 12 % more than the average (Fig. 19).

Table 7. Results from analysis of species and provenance differences of basal area of the mean tree in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	4; 17.2	1500	5.6	0.005	**
Provenance(species)	16, 22	327	7.2	<0.0001	
Block	2; 22	186	4.1	0.03	
Ploty2	1; 22	303	6.7	0.02	
Level	1; 22	423	9.3	0.006	
Error	22	45.4			
A. niloticaa					
Provenance	6; 2	602	6.9	0.13	n.s.
Block	2; 2	133	1.5	0.40	
Error	2	87			
A. senegal					
Provenance	4; 5	13.0	4.5	0.06	n.s.
Block	2; 5	15.9	5.6	0.05	
Ploty2	1; 5	15.5	5.4	0.07	
Error	5	2.87			
P. pallida					
Provenance	6; 11	102	1.9	0.17	n.s.
Block	2; 11	190	3.5	0.07	
Error	11	54			

Figure 16. The basal area of the mean tree in the *Acacia* and *Prosopis* species and provenance trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits.

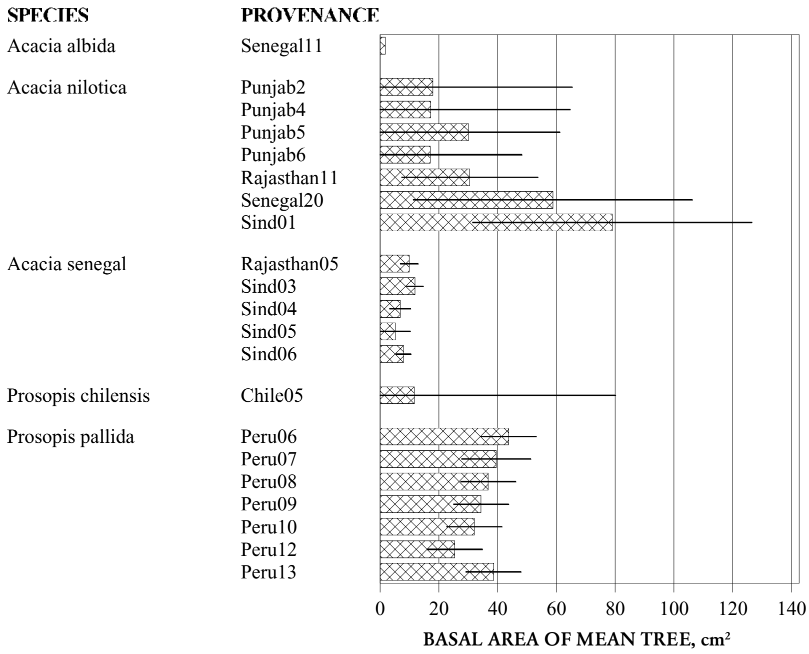


Figure 17. Best linear unbiased predictors (BLUP's) for basal area of the mean tree in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

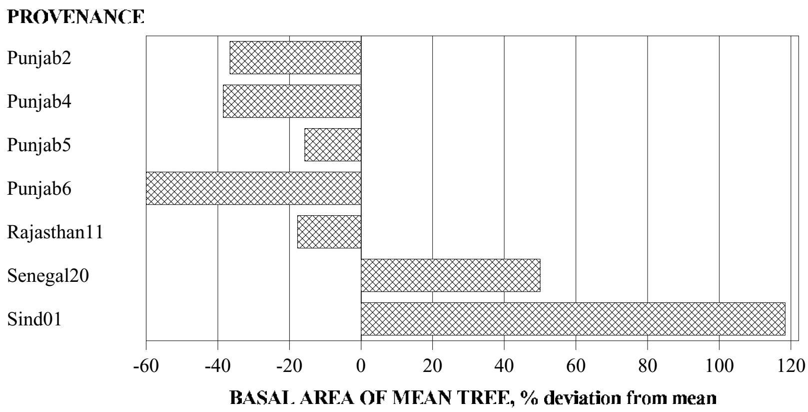


Figure 18. Best linear unbiased predictors (BLUP's) for basal area of the mean tree in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

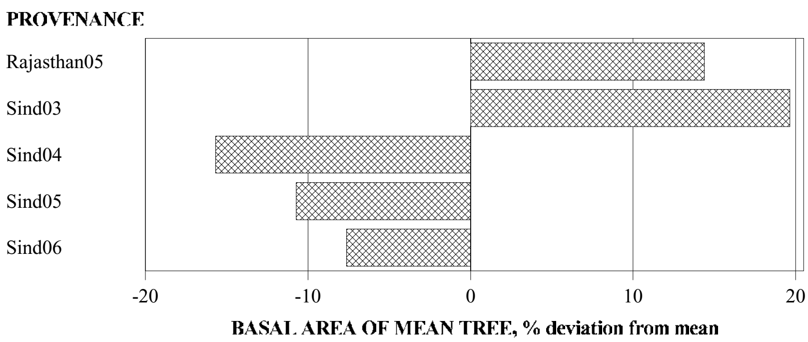
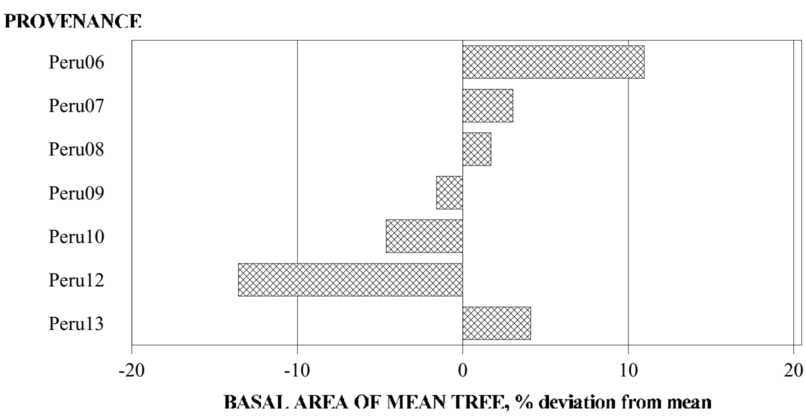


Figure 19. Best linear unbiased predictors (BLUP's) for basal area of the mean tree in the *P. pallida* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.



4.6 Total basal area

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

Statistical analysis

There were clear signs of variance heterogeneity in the data, and a weighted analysis was performed in the test species differences and in the test of provenance differences within *A. niloticaa*. No covariates were significant.

Results

There was a large variation in total basal area between the provenances, the range going from below 0.1 kg ha^{-1} to almost 3 m^2 ha^{-1} for Peru06 and Peru10. For the best provenances, this corresponds to an annual increment of 0.5 m^2 ha^{-1}. Again the species differences were highly significant, *P. pallida* being superior to the rest of the species. Only the provenance Rajasthan11 of *A. niloticaa* was comparable to the provenances of *P. pallida* (Table 8, Fig. 20).

The fact that Rajasthan11 was so different from the other provenances of *A. niloticaa* was not sufficient for the provenance effect to become significant (Table 8). It should be mentioned, however, that when the provenances in which there were no surviving trees (basal area equalling zero) were included, the differences within *A. niloticaa* were significant (P=0.004, not presented). The estimated BLUP value for Rajasthan11 was enormous, being 150 % better than the average provenance (Fig. 21).

Also for *A. senegal* and *P. pallida* the differences were not significant, but the best provenances had BLUP values of 60 % and 20 % better than the average (Fig. 22 and 23).

Table 8. Results from analysis of variance of species and provenance differences of total basal area in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	5; 25.3	37.5	7.6	0.0002	***
Provenance(species)	24; 58	5.8	7.5	<0.0001	
Block	2; 58	2.0	2.6	0.08	
Error	58	0.7			
A. niloticaa					
Provenance	6; 12	3.10	2.7	0.07	n.s.
Block	2; 12	1.08	0.9	0.42	
Error	12	1.14			
A. senegal					
Provenance	4; 8	0.094	2.0	0.18	n.s.
Block	2, 8	0.107	2.3	0.16	
Error	8	0.047			
P. pallida					
Provenance	6; 12	1.76	2.7	0.07	n.s.
Block	2; 12	0.66	1.0	0.39	
Error	12	0.65			

Figure 20. Total basal area in the *Acacia* and *Prosopis* species and provenances trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits.

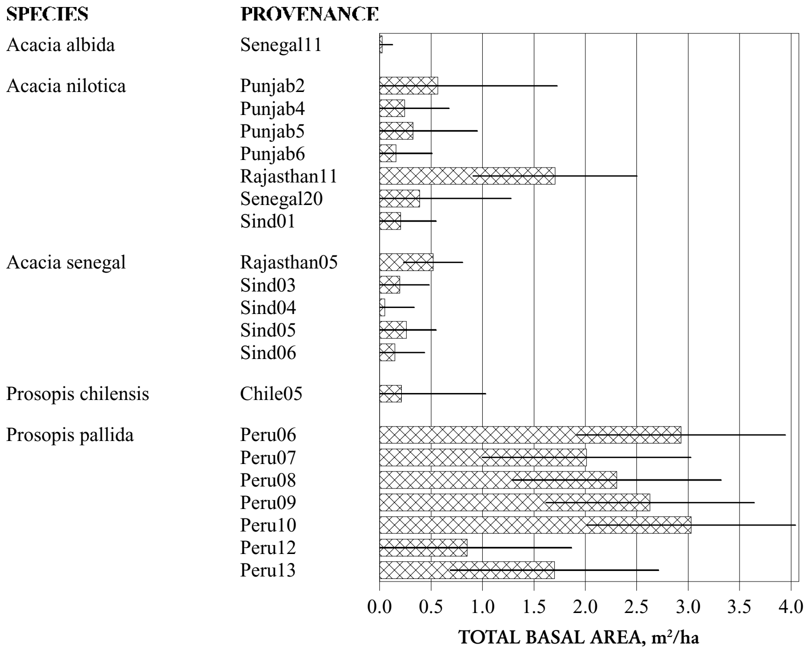


Figure 21. Best linear unbiased predictors (BLUP's) for total basal area in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

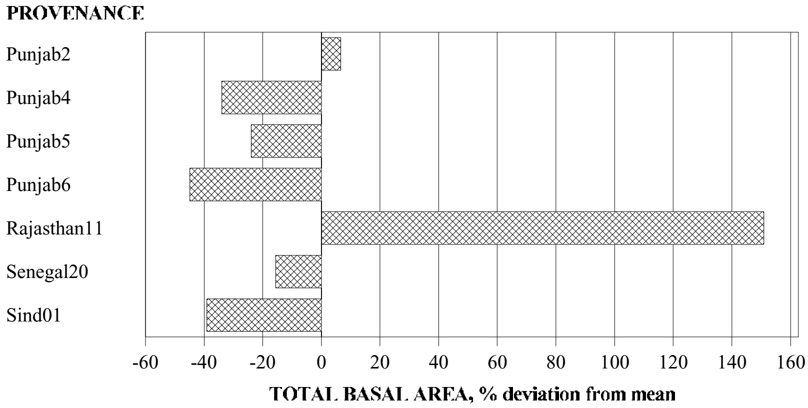


Figure 22. Best linear unbiased predictors (BLUP's) for total basal area in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

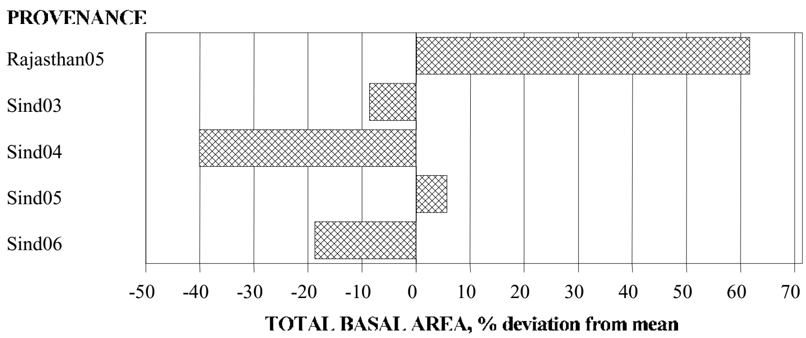
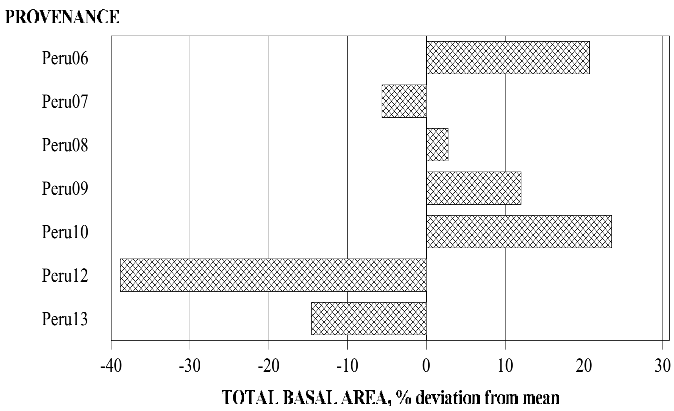


Figure 23. Best linear unbiased predictors (BLUP's) for total basal area in the *P. pallida* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.



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 a measure of the potential production at the site, provided 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 large trees with a large dry mass are weighted heavily in this variable. The dry weight is thus the best estimate for the production of biomass at the site.

Statistical analysis

As the variance seemed to be different for the different provenances, the data were weighted to ensure fulfilment of the assumptions of the model of species differences. In this model, the co-variates ploty2 and level were significant. In the test of differences between the provenances of *P. pallida*, ploty2 and level were also significant, but in tests of *A. senegal* only ploty2 was significant, and in *A. niloticaa* no co-variates were significant. Note that there are no estimates for *P. chilensis* as the dry weight regression was not available for this species (see 3.1).

Results

This variable followed the pattern observed in the basal area of the mean tree. There were highly significant differences between the species, and within the species, the provenance differences were almost significant for all species. However, the close-to-significance disappeared after the correction for multiple comparisons (Table 9).

For *A. senegal* and the single tree of *A. albida*, which had the slowest growth, the dry weight of the mean tree was always below 3 kg tree^{-1} (Fig. 24). In *P. pallida*, most of the provenances had dry weights of approximately 10 kg tree^{-1} except for the provenance Peru12 with only 5 kg tree^{-1}. *A. niloticaa* was again very variable, ranging from 3 to 23 kg tree^{-1}, the best provenance being Sind01. This was also reflected in the BLUP values, where Sind01 had a performance of 150 % better than the average (Fig. 25). For *A. senegal* and *P. pallida* the gains were more modest, reaching 23 and 13 % of the average values, respectively (Fig. 26 and 27).

Table 9. Results from analysis of species and provenance differences in dry weight of the mean tree in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	2; 27.3	49.4	27.1	<0.0001	***
Provenance(species)	12; 21	5.1	5.4	0.0004	
Block	2; 21	7.6	7.9	0.003	
Ploty2	1; 21	18.2	18.9	0.0003	
Level	1; 21	10.8	11.3	0.003	
Error	23	1.0			
A. niloticaa					
Provenance	6; 2	61.4	10.7	0.09	n.s.
Block	2; 2	10.5	1.8	0.35	
Error	2	5.74			
A. senegal					
Provenance	4; 5	0.649	4.8	0.06	n.s.
Block	2; 5	0.754	5.6	0.05	
Ploty	1; 5	0.716	5.3	0.07	
Error	5	0.135			
P. pallida					
Provenance	6; 9	17.9	3.5	0.05	n.s.
Block	2; 9	8.1	1.6	0.26	
Ploty2	1; 9	60.2	11.7	0.008	
Level	1; 9	55.1	10.7	0.01	
Error	9	9.89			

Figure 24. Dry weight of the mean tree in the *Acacia* and *Prosopis* species and provenance trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits.

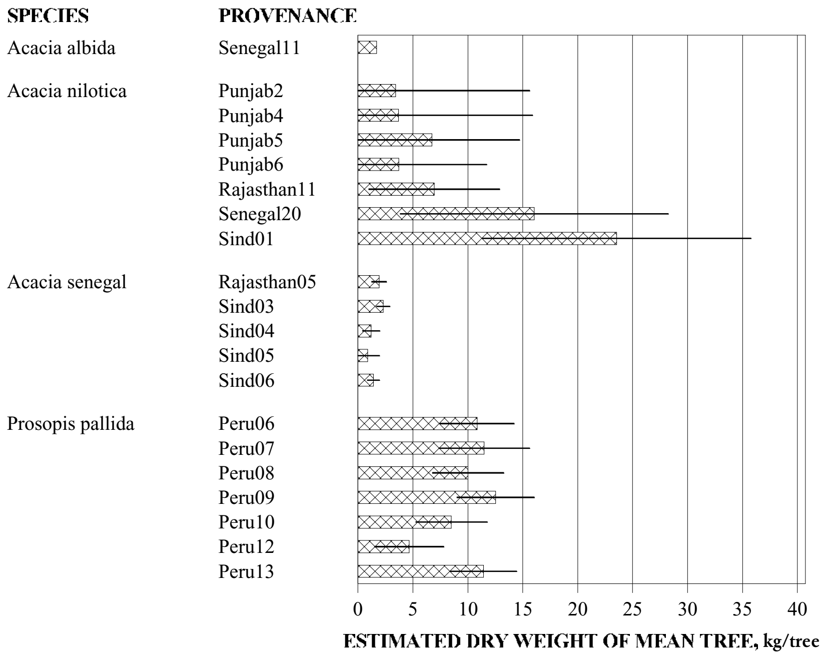


Figure 25. Best linear unbiased predictors (BLUP's) for dry weight of the mean tree in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

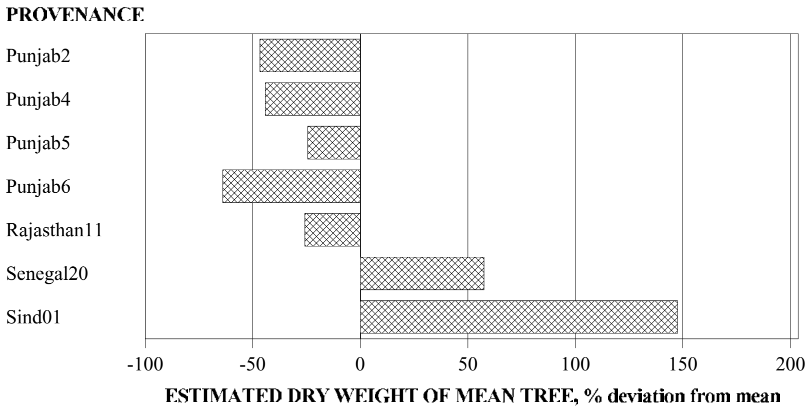


Figure 26. Best linear unbiased predictors (BLUP's) for dry weight of the mean tree in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

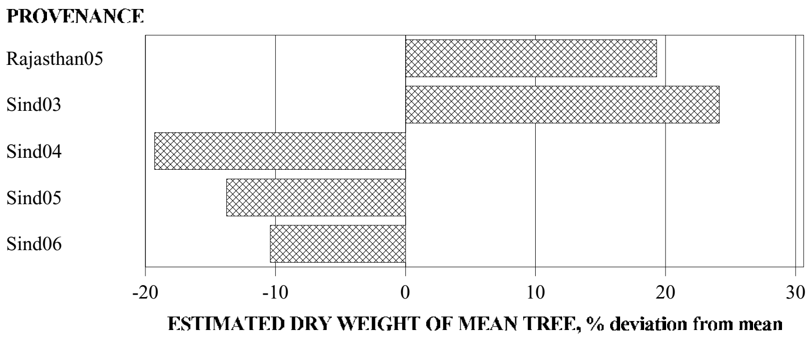
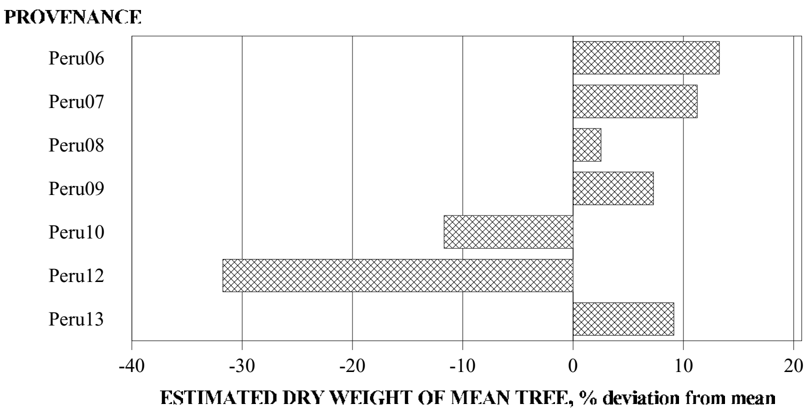


Figure 27. Best linear unbiased predictors (BLUP's) for dry weight of the mean tree in the *P. pallida* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.



4.8 Total dry weight

As with the total basal area, the total dry weight is expressed per area and gives the best measure of the actual production on the site.

Statistical analysis

There was variance heterogeneity between provenances, and a weight statement was applied in the test of differences between species and in the test of provenance differences within *A. niloticaa*. Plotx2 was significant in the test of species differences and in the test of the *P. pallida* provenances.

Results

The variation in total dry weight was large, ranging from a few hundred kg ha^{-1} to 10 t ha^{-1} (Fig. 28). The largest provenances were again found in *P. pallida*, and the difference between species was as usual highly significant (Table 10). In *A. senegal* the production was very low, but in *A. niloticaa* it was a bit more variable.

Peru06 of *P. pallida* took the lead, whereas Rajasthan11 of *A. niloticaa* had a faster growth than the rest of the provenances of this species. The annual production of Peru06 corresponded to approximately 1.7 t ha^{-1}. Both within *P. pallida* and *A. niloticaa* the effect of provenances was significant but disappeared after the correction for multiple comparisons (Table 10). In *A. senegal*, there were no signs of significant provenance differences.

According to the BLUP values, Rajasthan11 was again outstanding with a total dry weight 150 % better than the rest of the provenances of *A. niloticaa* (Fig. 29). For *A. senegal*, the BLUP values ranged between –40 and +70 %, also indicating a substantial gain (Fig. 30). The best provenance was Rajasthan05. However, it should be remembered that the average for this species is very low, and that the differences within the species were not significant. For *P. pallida*, the gains varied between –40 to 50 % (Fig. 31).

Table 10. Results from analysis of variance of species and provenance differences of total dry weight in trial 17.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential table-wide correction
Test of species differences					
Species	3; 22.0	58.8	9.3	0.0004	***
Provenance(species)	18; 41	14.5	14.3	<0.0001	
Block	2; 41	45.7	45.0	<0.0001	
Plotx2	1; 41	24.0	23.6	<0.0001	
Error	41	1.02			
A. niloticaa					
Provenance	6; 12	3.76	3.3	0.04	n.s.
Block	2; 12	1.07	0.94	0.42	
Error	12	1.14			
A. senegal					
Provenance	4; 8	0.374	2.1	0.17	n.s.
Block	2; 8	0.413	2.4	0.16	
Error	8	0.175			
P. pallida					
Provenance	6; 11	18.0	3.6	0.03	n.s.
Block	2, 11	4.02	0.8	0.47	
Plotx2	1; 11	17.8	3.6	0.08	
Error	11	4.94			

Fig.ure 28. Total dry weight in the *Acacia* and *Prosopis* species and provenance trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values presented are least square means with 95 % confidence limits.

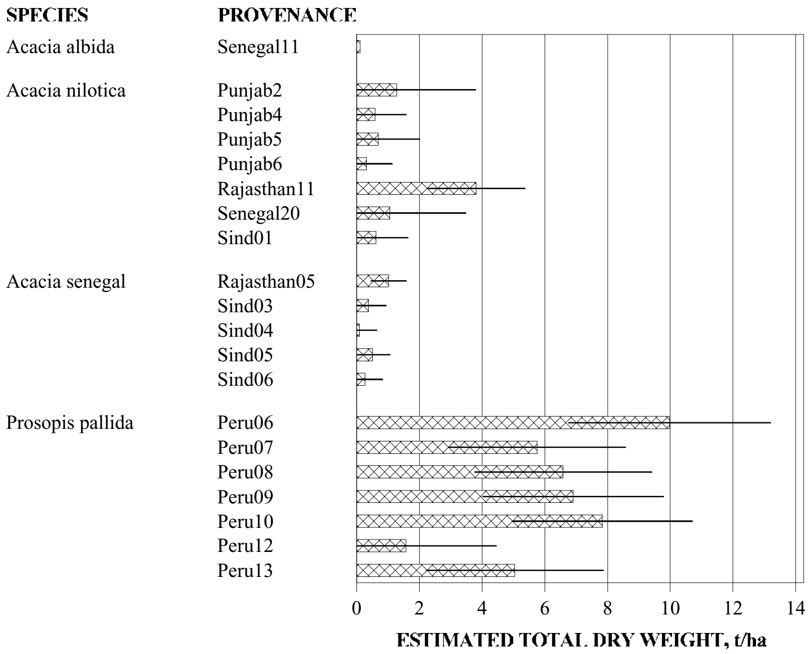


Figure 29. Best linear unbiased predictors (BLUP's) for total dry weight in the *A. niloticaa* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

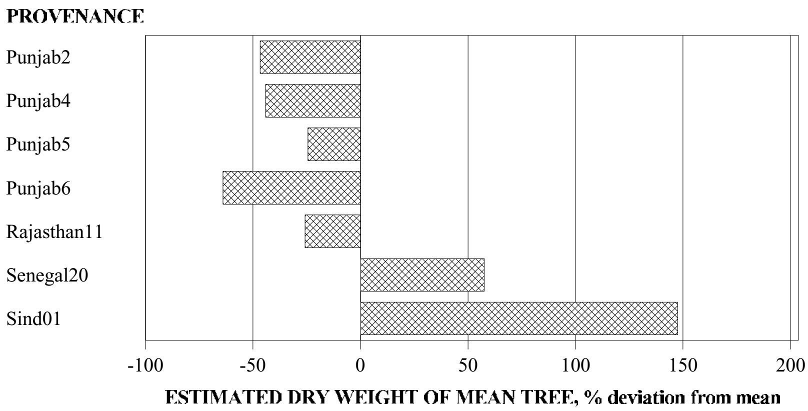


Figure 30. Best linear unbiased predictors (BLUP's) for total dry weight in the *A. senegal* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.

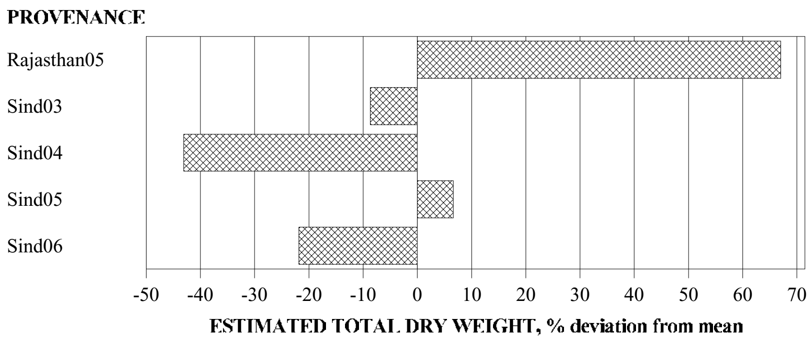
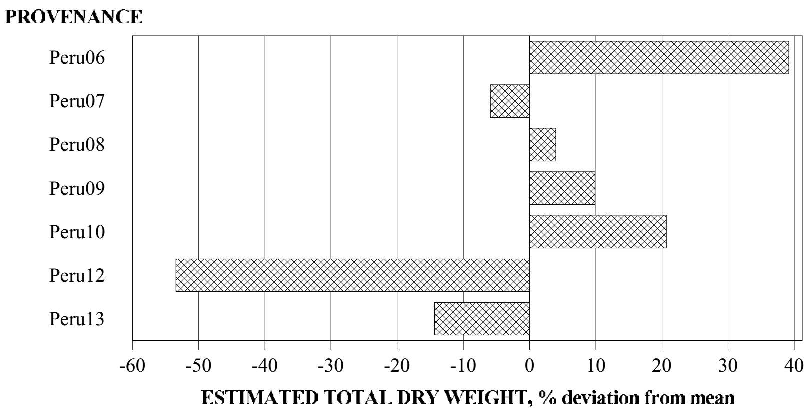


Figure 31. Best linear unbiased predictors (BLUP's) for total dry weight in the *P. pallida* provenances in the trial at Jodhpur, India (Trial no. 17 in the arid zone series). Values are presented as deviations in percent of the mean value.



4.9 Multivariate analysis

Multivariate analyses were attempted for the species *A. niloticaa*, *A. senegal* and *P. pallida*. However, in *A. niloticaa* and *A. senegal* too many observations were missing, and the error degrees of freedom were not sufficient to allow for analyses. Only one observation was missing in *P. pallida*, which meant that the analysis was possible. The multivariate analysis included the eight variables analysed in the univariate analyses, using the same transformations. Therefore survival was transformed with the arc sine function, and crown area was transformed with the square root.

In the analysis only the first canonical variate was significant, accounting for 78 % of the variation (Table 11). The differences between provenances were significant or at the border of significance (P-value for Wilk's lambda=0.02, P-value for Pillai's trace=0.07). In order to illustrate differences between the provenances, the plot of scores for the two first canonical variates is given in Fig. 32. Apart from the scores, the mean values for the provenances are given together with their approximate 95 % confidence regions. 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 two provenances have different properties. However, as the variation on the second canonical variate was not significant, differences along the second axis should not be considered.

It appears from the diagram that there is one large group of provenances containing all provenances but Peru10; this provenance is located at a distance from the other provenances and seems to constitute a genetic unit of its own.

Table 11. Results from the canonical variate analyses of *P. pallida* for the first two canonical variates in trial 17.

Canonical variate no.	**1**	**2**
Proportion of variation accounted for	0.78	0.12
Significance, P-value	0.02	0.21

	Raw canonical coefficients		**Standardised canonical coefficients**		**Canonical directions**	
Canonical variate no.	**1**	**2**	**1**	**2**	**1**	**2**
Survival	99.1	-62.2	23.8	-14.9	0.3	0.4
Height	-9.0	10.4	-5.0	5.8	-0.1	0.6
Crown area	-8.5	5.8	-2.8	1.9	0.1	0.5
Number of stems	-7.5	-0.3	-4.3	-0.2	-0.9	-0.8
Average basal area	-3.0	2.6	-27.0	23.6	2.9	2.0
Total basal area	98.9	-64.3	86.6	-56.3	-0.7	-1.1
Average dry weight	9.2	-7.2	34.0	-26.8	1.2	0.7
Total dry weight	-25.1	15.3	-65.4	39.8	-1.8	-2.9

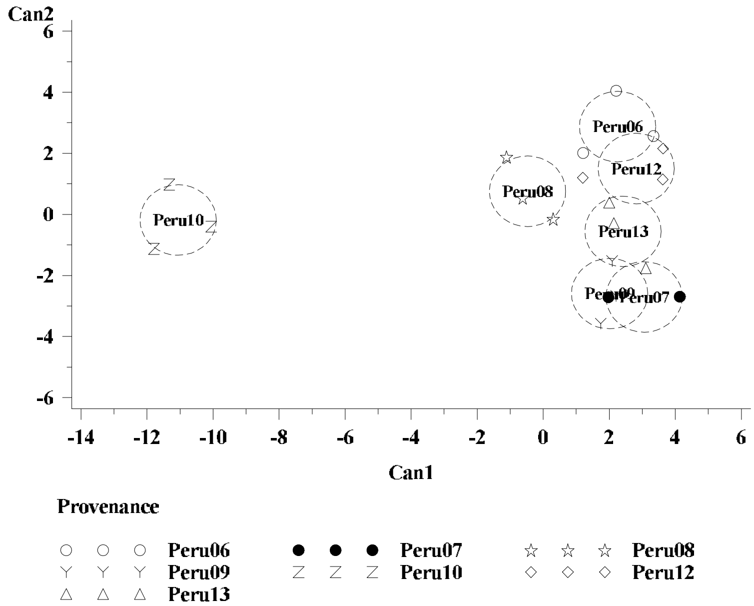


Figure 32. Score plot of the first and the second canonical variate from the canonical variate analysis for the 7 provenances of *P. pallida* in the trial at Jodhpur (Trial no. 17 in the arid zone series). All variables analysed in the univariate analyses were included. The second canonical variate was not significant. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

5. Discussion and conclusions

Productivity

Prosopis pallida had the overall fastest growth in this trial with an average production for the best provenance of 10 t dry weight ha^{-1}, corresponding to 1.7 t ha^{-1} y^{-1}. The production for the other species was much more modest, being approximately 1 and 4 t ha^{-1} (or 0.2 and 0.6 t ha^{-1} y^{-1}) for the best provenances of *A. senegal* and *A. niloticaa* respectively.

One year before a similar trial was established at the same location (Trial no. 16 in the arid zone series). Here the fastest growing provenances were of *A. tortilis* with an average production of 1 t dry weight ha^{-1} y^{-1}. *A. senegal* and *A. niloticaa* were also included, and for these species the fastest growing provenances had average productions of 0.25 and 0.2 t dry weight ha^{-1} y^{-1}, respectively. The lower production in *A. niloticaa* could be due to a different representation of provenances in the two trials (see below).

Species differences

There were significant species differences for all the analysed variables. *P. pallida* had the best survival, even though survival for some provenances of *A. niloticaa* and *A. senegal* was also acceptable. The high survival of *P. pallida* was reflected in the basal area and dry weight, where the species had the largest values expressed per ha. Results from this trial thus indicate that *P. pallida* is a promising species for similar areas in Rajasthan. It is recommended that a new assessment is made of the trial to confirm the potential of the species, and if this new assessment does not reveal any unforeseen problems, to initiate testing of the species on a larger scale.

Even though *A. niloticaa* had a poor survival for most provenances, the height growth was comparable to that of *P. pallida*, and some provenances had even larger basal areas and dry weights when expressed as the mean of surviving trees. This means that if the problems with low survival were solved, production of this species would increase considerable. It would be worthwhile to see if a different establishment technique could increase survival, or if plus tree selection of the best trees and with subsequent production of improved material could give better results.

The survival for *A. albida* was extremely poor, as only one tree from the three provenances survived. The trial thus could lead to the conclusion that this species has a limited potential at the site. The same applies to the trees of *P. chilensis*, which had a poor survival and a slow growth for the surviving trees. However, since no plants of the local species *P. cineraria* had survived, interpretation should be cautious: The reasons for the low survival could be extreme weather conditions during establishment, or the establishment technique could be inappropriate. *A. senegal* had a slow growth but survival was acceptable for some of the provenances (see below).

Provenance differences

Within the species, the differences were not as clear as between species. This is probably partly due to the low survival, causing high variation both within and between plots of the same provenance. Obviously no provenance recommendations can be given for *A. albida* and *P. cineraria*, where survival was (almost) zero.

Drawing conclusions for *A. niloticaa* is difficult, because only survival and total dry weight were significant in the univariate tests, and because the correction for multiple comparisons made significance disappear. Nevertheless it is important to notice that the provenance with the best survival and the highest production of dry weight was the local provenance, Rajasthan11. In the other trial at Jodhpur (trial no. 16), a range of Indian provenances of *A. niloticaa* outside of Rajasthan were included, but none with a growth as fast as Rajasthan11. Even though it did not have a fast height growth it seems to be the safe choice for this species.

The same applies to the provenances of *A. senegal.* There were significant differences in survival and height, even after correction for multiple comparisons, and again the local provenance was the best. This was also reflected in the dry weight per ha, which was much higher in Rajasthan5 than in the other provenances (though not significantly so). However, comparing with trial no. 16 it appears that provenances from Senegal may have a similar or perhaps slightly better growth. This would need verification in a trial designed to compare local provenances with provenances from Senegal.

The provenances of *P. pallida* are from two relatively small areas in Peru. The northern group is composed of Peru06, Peru08, Peru10, Peru12, and the southern includes Peru07, Peru09 and Peru13. In both the univariate and the multivariate analyses the two groups are more or less mixed in-between each other. However, whereas the southern provenances seem to behave rather homogeneously, the northern provenances have different behaviours and seem to have a larger diversity. When corrected for multiple comparisons, only height and number of stems were significantly different, but there were signs of differences in the basal area and dry weight variables as well. Overall, the fastest growing provenances seem to be Peru06 and Peru10. Interestingly, these provenances appear to differ in the number of stems, Peru10 having more stems than Peru06.

6. References

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

Boffa, J.M. 1999. Agroforestry parklands in sub-Saharan Africa. FAO Conservation Guide 34, 230 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. 17. *Acacia* and *Prosopis* species and provenance trial, Jodhpur, India. Joint assessment, May 1992 by CAZRI, AFRI, FAO and DFSC. Danida Forest Seed Centre, Humlebaek, Denmark.

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

Dwivedi, A.P. 1993. Babul (*Acacia nilotica*) – a multipurpose tree of dry areas. Milton Book Company, Dehradun, India, 226 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.

Ffolliott, P.F. and J.L. Thames. 1983. Handbook on taxonomy of *Prosopis* in Mexico, Peru and Chile. Food and Agriculture Organization of the United Nations, Rome, 31 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, Humlebaek, 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.

Pasiecznik, N.M., P. Felker, P.J.C. Harris, L.N. Harsh, G. Cruz, J.C. Tewari, K. Cadoret and L.J. Maldonado. 2001. The *Prosopis juliflora – Prosopis pallida* complex: A monograph. HDRA, Coventry, UK, 162 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, Humlebaek, Denmark

Ræbild *et al.* (in prep).: Evaluation of an *Acacia* and *Prosopis* provenances trial at Jodhpur, India. Trial no. 16 in the Arid Zone Series. Danida Forest Seed Centre.

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. 17 at Jodhpur, India. The plot number refers to the seedlot in the map of the trial, see annex 3. One seedlot (plot no. 19) was a mixture of two species and was not included in the analyses.

Seedlot numbers				Provenance information							
Provenance	DFSC	Country of origin	Plot	Species	Provenance name	Country of origin	Latitude	Longi-tude	Alti-tude (m)	Rain-fall (mm)	No. of moth-er trees
Senegal06		3253	26	*Acacia albida*	Kirdiom	Senegal	15 38 N	16 12 W	40	450	
Senegal07		3862	27	*Acacia albida*	Region De Long Nayobe	Senegal	15 38 N	16 13 W	50	450	
Senegal11	1193/83	83/765	12	*Acacia albida*	Bignona	Senegal	12 45 N	16 25 W	10	1170	34
Punjab2	1168/83		1	*Acacia nilotica*	Patoki, Lahore Punjab	Pakistan	31 05 N	73 30 E	200	350	25
Punjab3	1169/83		2	*Acacia nilotica*	Fazal Abad Rice Mill, D.I.Khan	Pakistan	31 15 N	70 45 E	330	300	25
Punjab4	1170/83		3	*Acacia nilotica*	Dargai-Jehangira, Peshawar	Pakistan	33 50 N	72 20 E	500	750	25
Punjab5	1171/83		4	*Acacia nilotica*	Muzaffar Garh, Punjab	Pakistan	30 05 N	71 10 E	170	200	25
Punjab6	1178/83		7	*Acacia nilotica*	Nullah, Gujrat	Pakistan	32 49 N	73 53 E	220	500	25
Rajasthan11		Jodhpur2	31	*Acacia nilotica subsp. indica var. cupressiformis*	Pali	India	24 N	73 35 E	382	400	
Senegal17		2821	28	*Acacia nilotica*	Podor	Senegal	16 38 N	14 57 W	50	200	
Senegal20		3247	29	*Acacia nilotica*	Dinaga, Podor	Senegal	16 30 N	14 55 W	50	200	
Sind01	1176/83		5	*Acacia nilotica*	Ziala Forest, Thatta, Sind	Pakistan	24 41 N	67 57 E	14	204	25
Sind02	1177/83		6	*Acacia nilotica*	Sukhur, Sind	Pakistan	27 42 N	67 54 E	50	100	25
Rajasthan5		Jodhpur3	32	*Acacia senegal*	Jodhpur	India	26°18'N	73°40'E	224	317	
Sind03	1172/83		8	*Acacia senegal*	Bourberband, Dadu	Pakistan	25 N	67 E	100	200	25
Sind04	1173/83		9	*Acacia senegal*	Dhabiji (Thatta)	Pakistan	24 49 N	67 32 E	14	204	25
Sind05	1174/83		10	*Acacia senegal*	Loonio, Tharparkar, Sind	Pakistan	24 38 N	70 31 E	150	350	25
Sind06	1175/83		11	*Acacia senegal*	Nagar-Parkar, Tharparkar, Sind	Pakistan	24 21 N	70 47 E	200	350	
Chile5	1161/83		13	*Prosopis chilensis*	Lampa	Chile	33 17 S	70 53 W	500	306	5

Seedlot numbers				Provenance information							
Provenance	DFSC	Country of origin	Plot	Species	Provenance name	Country of origin	Latitude	Longi-tude	Alti-tude (m)	Rain-fall (mm)	No. of moth-er trees
NW Frontier1	1183/83		16	*Prosopis chilensis*	Darya Khan, Bhakkar	Pakistan	31 47 N	71 10 N	200	200	30
NW Frontier2	1184/83		17	*Prosopis chilensis*	Goharwala, Bhakkar	Pakistan	31 42 N	71 34 E	200	200	28
Rajasthan10		Jodhpur1	30	*Prosopis chilensis*	Jodhpur	India	26°18'N	73°40'E	224	317	
Sind09	1179/83		14	*Prosopis chilensis*	Islam-Kot, Tharparkar, Registan (Loonio)	Pakistan	24 40 N	70 12 E	50	150	25
Sind10	1182/83		15	*Prosopis chilensis*	Saeed-Abad, Hyderabad	Pakistan	25 25 N	68 24 E	30	157	25
	1235/84		19	*Prosopis glandulosa*	Fazal Abad Rice Mill, D.I.Khan	Pakistan	31 15 N	70 45 E	330	300	25
	1235/84		19	*Prosopis juliflora*	Fazal Abad Rice Mill, D.I.Khan	Pakistan	31 15 N	70 45 E	330	300	25
Peru06	1119/83		18	*Prosopis pallida*	Puerte Del Vice, Piura	Peru	05 25 S	80 47 W	13	70	18
Peru07	1122/83		20	*Prosopis pallida*	Huacachina, Ica	Peru	14 07 S	76 45 W	100	1	60
Peru08	1123/83	10 03 83	21	*Prosopis pallida*	Rinconada (Piura)	Peru	05 30 S	80 35 W	30	60	18
Peru09	1124/83		22	*Prosopis pallida*	Cachiche, Ica	Peru	13 45 S	75 50 W	0	2	22
Peru10	1126/83		23	*Prosopis pallida*	Pueblo De Santa Clara, Piura	Peru	05 29 S	80 45 W	7	8.3	10
Peru12	1127/83	15 03 83	24	*Prosopis pallida*	Sechura (Piura)	Peru	05 33 S	80 48 W	4	25	5
Peru13	1156/83	15.7.83	25	*Prosopis pallida*	Ocucaje (Ica), Zona: Tres Esquinas	Peru	14 20 S	75 40 W	420	35	

Annex 3. Layout of the trial

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

y			BLOCK 1				BLOCK 3			
16	13	23	24	32	30	19	23	3	18	
15	7	8	11	12	11	15	28	10	25	
14	27	25	2	4	6	5	32	14	12	
13	15	9	16	22	16	17	22	9	8	
12	30	6	28	17	13	7	2	20	21	
11	19	29	3	31	1	31	26	29	27	
10	10	26	5	14				4	24	
9	18	21	20	1						
8	22	11	14	6						
7	7	8	1	9						
6	16	23	3	19						
5	4	17	21	31		BLOCK 2				
4	29	26	25	24						
3	18	15	27	32						
2	30	2	10	28						
1	20	5	13	12						
	1	2	3	4	5	6	7	8	9	x

Individual tree positions in each plot:

y							
6	*	*	*	*	*	*	*: plot border
5	*	+	+	+	+	*	
4	*	+	+	+	+	*	+: plot core trees
3	*	+	+	+	+	*	
2	*	+	+	+	+	*	
1	*	*	*	*	*	*	
	1	2	3	4	5	6	x

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
							proportion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}
Punjab2	*A. niloticaa*	1	1	4	9	9.06	0					0.00		0.00
Punjab3	*A. niloticaa*	1	2	3	14	9.5	0					0.00		0.00
Punjab4	*A. niloticaa*	1	3	3	11	9.24	0					0.00		0.00
Punjab5	*A. niloticaa*	1	4	4	14	9.49	0					0.00		0.00
Sind01	*A. niloticaa*	1	5	3	10	9.09	0					0.00		0.00
Sind02	*A. niloticaa*	1	6	2	12	9.31	0					0.00		0.00
Punjab6	*A. niloticaa*	1	7	1	15	9.44	19	3.13	2.00	3.9	18.4	0.38	3.8	0.79
Sind03	*A. senegal*	1	8	2	15	9.59	38	1.30	1.67	4.2	10.4	0.43	2.0	0.84
Sind04	*A. senegal*	1	9	2	13	9.38	19	0.87		1.4		0.00		0.00
Sind05	*A. senegal*	1	10	1	10	9.11	31	1.02		1.5		0.00		0.00
Sind06	*A. senegal*	1	11	3	15	9.57	19	1.77	1.00	4.3	5.8	0.12	1.0	0.20
Senegal11	*A. albida*	1	12	4	15	9.51	6	1.70	2.00	1.9	10.2	0.07	1.5	0.10
Chile05	*P. chilensis*	1	13	1	16	9.66	6	1.60	3.00	4.5	6.3	0.04		
Sind09	*P. cineraria*	1	14	4	10	9.13	0					0.00		0.00
Sind10	*P. cineraria*	1	15	1	13	9.35	0					0.00		0.00
NW Frontier1	*P. cineraria*	1	16	3	13	9.46	0					0.00		0.00
NW Frontier2	*P. cineraria*	1	17	4	12	9.39	0					0.00		0.00
Peru06	*P. pallida*	1	18	1	9	9.07	81	4.84	2.15	9.5	39.0	3.52	11.3	10.16
Punjab9	*P. glandulosa*	1	19	1	11	9.23	50	2.17	3.00	8.4	13.9	0.58	24.9	3.46
Punjab9	*P. juliflora*	1	19	1	11	9.23	50	3.25	4.00	35.1	70.5	0.98	24.9	3.46
Peru07	*P. pallida*	1	20	3	9	9.04	63	3.71	2.70	11.9	36.4	2.53	10.2	7.11
Peru08	*P. pallida*	1	21	2	9	9.03	56	3.93	2.89	11.5	33.7	2.11	9.1	5.71
Peru09	*P. pallida*	1	22	4	13	9.42	75	3.67	2.17	12.1	35.3	2.94	10.3	8.62
Peru10	*P. pallida*	1	23	2	16	9.71	88	3.61	3.50	11.7	33.5	3.25	9.6	9.36
Peru12	*P. pallida*	1	24	3	16	9.66	44	3.04	2.14	13.4	25.1	1.22	6.2	3.01
Peru13	*P. pallida*	1	25	2	14	9.56	31	3.14	2.60	10.1	26.8	0.93	6.9	2.39
Senegal06	*A. albida*	1	26	2	10	9.1	0					0.00		0.00
Senegal07	*A. albida*	1	27	1	14	9.41	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
							propor-tion	m	m² tree⁻¹	no. tree⁻¹	cm² tree⁻¹	m² ha⁻¹	kg tree⁻¹	t ha⁻¹
Senegal17	*A. niloticaa*	1	28	3	12	9.44	0					0.00		0.00
Senegal20	*A. niloticaa*	1	29	2	11	9.24	19	3.37	1.33	16.3	56.0	1.17	15.1	3.15
Rajasthan10	*P. cineraria*	1	30	1	12	9.29	0					0.00		0.00
Peru11	*A. niloticaa* var. *indica cupressiformis*	1	31	4	11	9.26	88	2.76	1.50	4.9	23.8	2.31	5.1	4.92
Rajasthan05	*A. senegal*	1	32	4	16	9.67	56	1.51	1.44	4.6	10.3	0.64	2.0	1.24
Punjab2	*A. niloticaa*	2	1	3	7	8.88	0					0.00		0.00
Punjab3	*A. niloticaa*	2	2	2	2	8.64	0					0.00		0.00
Punjab4	*A. niloticaa*	2	3	3	6	8.82	0					0.00		0.00
Punjab5	*A. niloticaa*	2	4	1	5	8.83	31	3.06	1.20	5.3	19.2	0.67	3.8	1.33
Sind01	*A. niloticaa*	2	5	2	1	8.54	0					0.00		0.00
Sind02	*A. niloticaa*	2	6	4	8	8.96	0					0.00		0.00
Punjab6	*A. niloticaa*	2	7	1	7	8.92	13	1.75	1.50	1.8	6.6	0.09	1.0	0.14
Sind03	*A. senegal*	2	8	2	7	8.89	6	1.40	1.00	2.1	8.6	0.06	1.5	0.11
Sind04	*A. senegal*	2	9	4	7	8.9	6	0.90	1.00	1.3	3.1	0.02	0.4	0.03
Sind05	*A. senegal*	2	10	3	2	8.7	6	1.40	4.00	2.3	9.1	0.06	1.7	0.12
Sind06	*A. senegal*	2	11	2	8	8.98	13	1.50	1.50	2.7	6.7	0.09	1.1	0.16
Senegal11	*A. albida*	2	12	4	1	8.55	0					0.00		0.00
Chile05	*P. chilensis*	2	13	3	1	8.55	0					0.00		0.00
Sind09	*P. cineraria*	2	14	3	8	8.93	0					0.00		0.00
Sind10	*P. cineraria*	2	15	2	3	8.76	0					0.00		0.00
NW Fronier1	*P. cineraria*	2	16	1	6	8.88	0					0.00		0.00
NW Fronier2	*P. cineraria*	2	17	2	5	8.81	0					0.00		0.00
Peru06	*P. pallida*	2	18	1	3	8.73	38	4.53	2.00	17.3	57.7	2.41	19.3	8.04
Punjab9	*P. glandulosa*	2	19	4	6	8.77	13	2.10	7.50	8.3	11.7	0.16		
Punjab9	*P. juliflora*	2	19	4	6	8.77	13					0.00		0.00
Peru07	*P. pallida*	2	20	1	1	8.59	0					0.00		0.00
Peru08	*P. pallida*	2	21	3	5	8.79	63	4.49	2.40	11.0	39.6	2.75	11.5	7.98
Peru09	*P. pallida*	2	22	1	8	9	56	3.64	2.33	10.6	33.5	2.10	9.3	5.84

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
							proportion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}
Peru10	*P. pallida*	2	23	2	6	8.85	94	3.88	2.67	10.2	29.4	3.06	7.6	7.96
Peru12	*P. pallida*	2	24	4	4	8.8	19	2.97	1.67	15.2	31.7	0.66	8.1	1.70
Peru13	*P. pallida*	2	25	3	4	8.79	31	4.18	2.80	14.6	57.9	2.01	19.9	6.91
Senegal06	*A. albida*	2	26	2	4	8.78	0					0.00		0.00
Senegal07	*A. albida*	2	27	3	3	8.76	0					0.00		0.00
Senegal17	*A. niloticaa*	2	28	4	2	8.7	0					0.00		0.00
Senegal20	*A. niloticaa*	2	29	1	4	8.78	0					0.00		0.00
Rajasthan10	*P. cineraria*	2	30	1	2	8.67	0					0.00		0.00
Peru11	*A. niloticaa* var. *indica cupressiformis*	2	31	4	5	8.78	44	2.89	1.14	7.4	32.4	1.57	7.3	3.57
Rajasthan05	*A. senegal*	2	32	4	3	8.73	13	1.95	1.50	5.8	13.7	0.19	2.8	0.38
Punjab2	*A. niloticaa*	3	1	5	11	9.24	56	3.48	1.33	8.5	27.1	1.69	6.1	3.80
Punjab3	*A. niloticaa*	3	2	7	12	9.44	0					0.00		0.00
Punjab4	*A. niloticaa*	3	3	8	16	9.71	25	3.33	1.75	7.5	26.3	0.73	6.4	1.76
Punjab5	*A. niloticaa*	3	4	8	10	9.17	6	4.50	1.00	11.9	43.6	0.30	10.5	0.73
Sind01	*A. niloticaa*	3	5	6	14	9.56	6	4.60	1.00	12.9	88.2	0.61	26.2	1.82
Sind02	*A. niloticaa*	3	6	5	14	9.535	0					0.00		0.00
Punjab6	*A. niloticaa*	3	7	6	12	9.59	0					0.00		0.00
Sind03	*A. senegal*	3	8	9	13	9.56	6	1.60	3.00	5.1	13.2	0.09	2.6	0.18
Sind04	*A. senegal*	3	9	8	13	9.52	13	1.10	1.50	3.6	8.9	0.12	1.6	0.22
Sind05	*A. senegal*	3	10	8	15	9.66	69	1.45	1.27	4.4	9.4	0.72	1.8	1.40
Sind06	*A. senegal*	3	11	5	15	9.62	19	1.80	1.33	5.6	10.9	0.23	2.1	0.43
Senegal11	*A. albida*	3	12	9	14	9.62	0					0.00		0.00
Chile05	*P. chilensis*	3	13	5	12	9.41	31	2.18	4.60	6.1	17.0	0.59		
Sind09	*P. cineraria*	3	14	8	14	9.6	0					0.00		0.00
Sind10	*P. cineraria*	3	15	6	15	9.64	0					0.00		0.00
NW Frontier1	*P. cineraria*	3	16	5	13	9.47	0					0.00		0.00
NW Frontier2	*P. cineraria*	3	17	6	13	9.49	0					0.00		0.00
Peru06	*P. pallida*	3	18	9	16	9.82	75	4.34	2.58	11.9	34.4	2.87	9.3	7.75
Punjab9	*P. juliflora*	3	19	6	16	9.77	56	2.51	4.63	11.5	22.0	1.22	6.7	3.72
Peru07	*P. pallida*	3	20	8	12	9.41	88	3.70	2.29	13.1	36.1	3.51	10.3	10.03

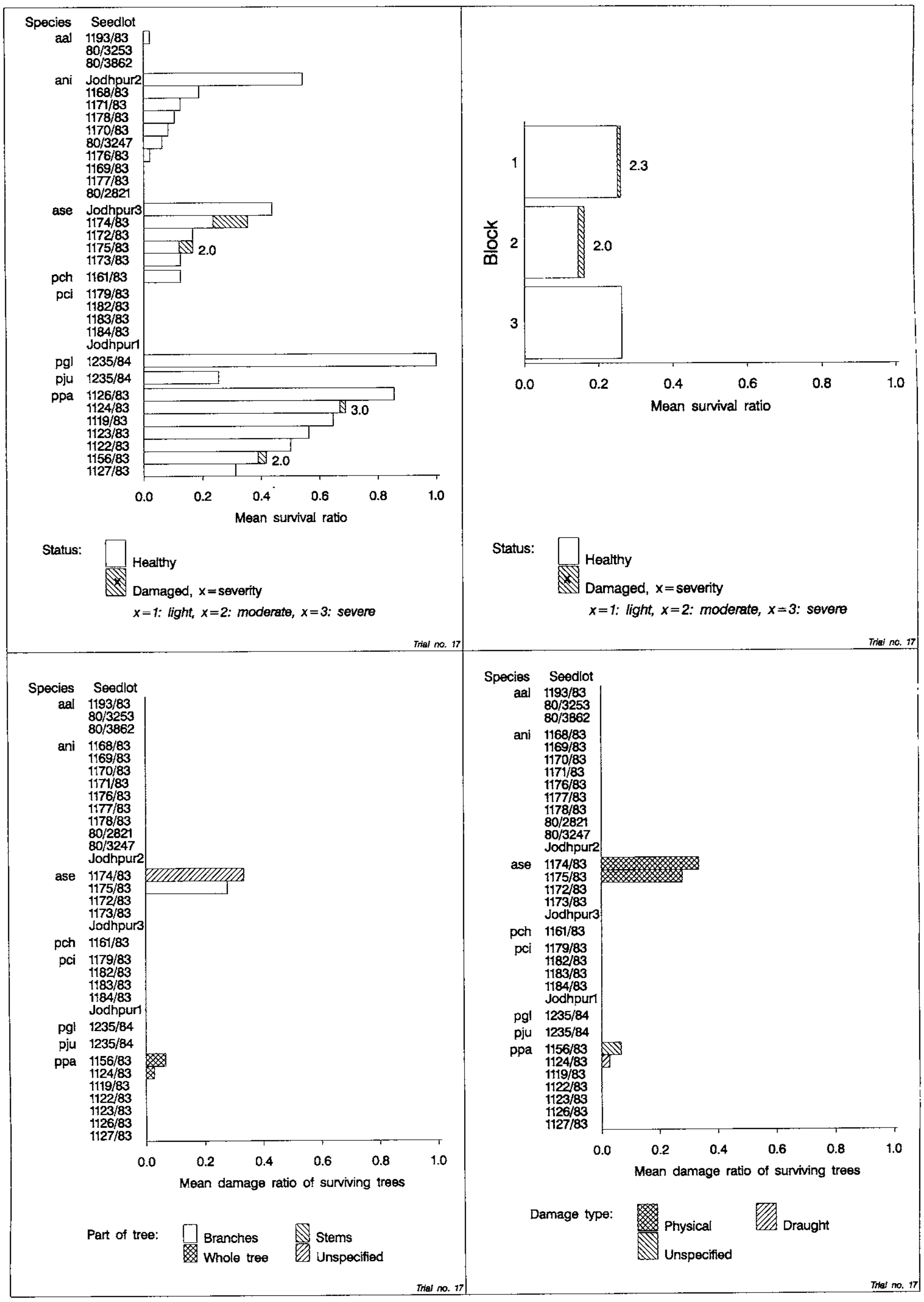
Provenance	Species	Block	Plot	Plotx	Ploty	Level	Survival	Height	Crown area	Number of stems	Basal area of mean tree	Total basal area	Dry weight of mean tree	Total dry weight
							proportion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}
Peru08	*P. pallida*	3	21	9	12	9.39	50	3.20	2.63	18.4	37.1	2.06	10.7	5.95
Peru09	*P. pallida*	3	22	7	13	9.47	75	3.99	3.00	10.0	34.2	2.85	9.3	7.76
Peru10	*P. pallida*	3	23	7	16	9.76	75	4.04	4.08	13.3	33.3	2.77	9.0	7.48
Peru12	*P. pallida*	3	24	9	10	9.2	31	2.82	1.60	13.9	19.4	0.67	4.3	1.51
Peru13	*P. pallida*	3	25	9	15	9.67	63	3.55	2.40	13.6	31.0	2.16	8.2	5.70
Senegal06	*A. albida*	3	26	7	11	9.28	0					0.00		0.00
Senegal07	*A. albida*	3	27	9	11	9.31	0					0.00		0.00
Senegal17	*A. niloticaa*	3	28	7	15	9.67	0					0.00		0.00
Senegal20	*A. niloticaa*	3	29	8	11	9.27	0					0.00		0.00
Rajasthan10	*P. cineraria*	3	30	5	16	9.73	0					0.00		0.00
Peru11	*A. niloticaa* var. *indica cupressiformis*	3	31	6	11	9.2	31	2.74	1.40	6.1	35.4	1.23	8.4	2.93
Rajasthan05	*A. senegal*	3	32	7	14	9.58	63	1.39	2.20	4.2	10.5	0.73	2.1	1.43

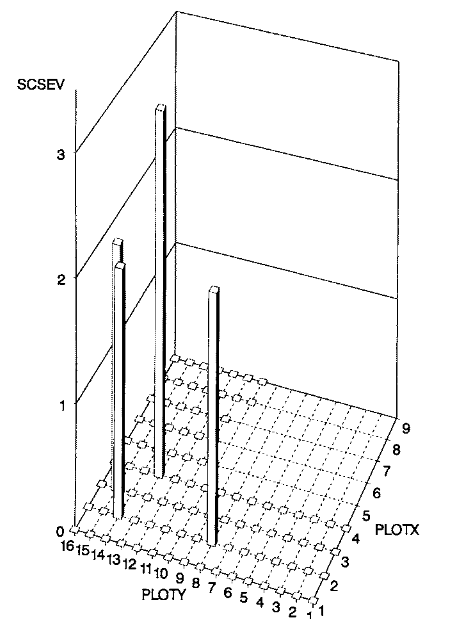
Annex 5.
Graphical presentation of the health data

The health status of the trees were evaluated on a scale from 0 to 3, where 0 indicates no damage, and 1, 2 and 3 indicates light, moderate and severe damage, respectively. The health status code is named SCSEV in the diagrams on the following pages.

The diagrams present the mean survival ratios, the damage ratios of the surviving trees and the average damage scores for the damaged trees. They also indicate the distribution of the damage on the trees and the cause of the damage. The damage scores are presented according to plots, blocks and seedlots.

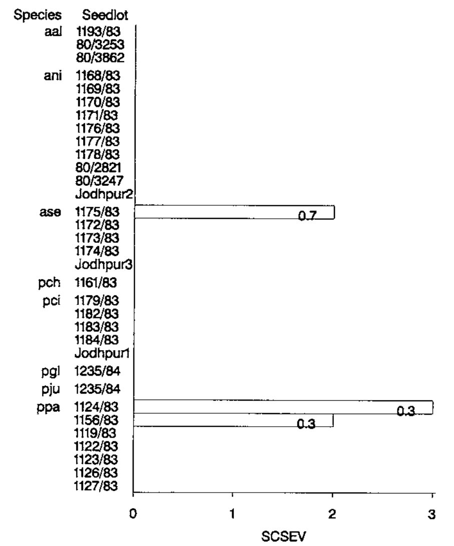
Please note that the seedlot codes correspond to the numbers given in annex 2.





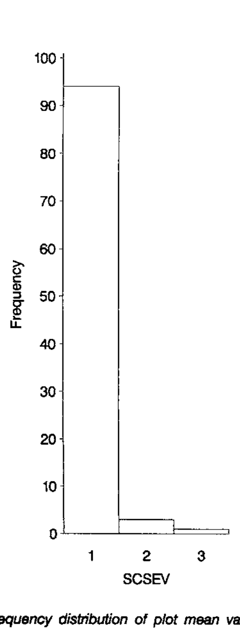
SCSEV = Health status code, severity of attack
Scatter of plot mean values

Trial no. 17



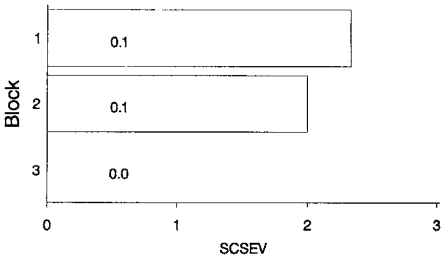
Mean SCSEV of seedlot with error bar line (+/− standard deviation of the mean) and the average number of assessed (living) trees per plot for each seedlot.

Trial no. 17



Frequency distribution of plot mean values

Trial no. 17



Mean SCSEV of block with error bar line (+/− standard deviation of the mean) and the average number of assessed (living) trees per plot in each block.

Trial no. 17