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Evaluation of a species and provenance trial of Acacia and Prosopis at Bandia, Senegal

Trial no. 24 in the arid zone series

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Evaluation of a species and provenance trial of *Acacia* and *Prosopis* at Bandia, Senegal

Trial no. 24 in the arid zone series

by

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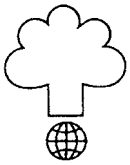

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Assessment of biomass production by destructive sampling. Plot of *Prosopis cineraria*. The tree has been divided into four size classes. Phot. Lars Graudal. 1993.

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

Preface

This report belongs to a series of analysis reports published by the Danida Forest Seed Centre. It is the intention that the series should serve as a place for publication of trial results for the Centre itself as well as for our collaborators. The reports will be made available from the DFSC publication service and online from the web-site www.dfsc.dk. The scope of the series is in particular the large number of trials from which no results have been made available to the public, and which are not appropriate for publication in scientific journals. We believe that the results from these trials will contribute considerably to the knowledge on genetic variation of tree species in the tropics. Also, the analysis report will allow a more detailed documentation than is possible in scientific journals.

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

This trial was established and maintained by the Institut Sénégalais de Recherches Agricoles (ISRA)/Centre National de Recherches Forestières (CNRF), Dakar, Senegal. The assessment team consisted of Abibou Gaye, Massamba Thiam (ISRA/CNRF), Holger Nielsen and Lars Graudal (DFSC), assisted by M. Seck (ISRA/CNRF) and 6 villagers (A. Thiaw I, M. Nboye, M.C. Fall, I. Ciss, A. Thiaw II, and M. Séne) at the trial site.

The authors wish to acknowledge the help of the personnel at ISRA/CNRF 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. Thanks to John Larmour (CSIRO, Australia) for comments on *Acacia aneura*. Drafts of the manuscript were commented on by Marcus Robbins, consultant to FAO.

Abstract

This report describes results from a trial with 40 provenances of species from the dry tropics, including *Acacia aneura*, *A. cowleana*, *A. holosericea*, *A. nilotica*, *A. senegal*, *A. tortilis*, *Prosopis chilensis*, *P. cineraria* and *P. juliflora* originating from Australia, Asia and Africa. The trial was established with a spacing of 4.5 x 2.5 metres at Bandia, Senegal, in 1984 and assessed after 10 growing seasons. Different growth parameters were measured and subjected to analyses of variance and multivariate analyses.

The fastest growing provenance (*P. juliflora*) had an increment rate of 1.1 m^2 ha^{-1} y^{-1}, corresponding to a dry weight production of 5.6 t ha^{-1} y^{-1}. Analyses of species differences demonstrated that the species were different in several aspects. *A. aneura* had a poor survival and problems with the stability. Within species, convincing evidence of differences were found in *Acacia aneura*, *A. nilotica*, *A. tortilis* and *P. cineraria*. In particular, a large variation was found in *A. tortilis*.

Resumé

Le présent rapport décrit les résultats obtenus d'un essai comparatif de quarante (40) provenances d'espèces du genre *Acacia* et *Prosopis* originaires des zones sèches d'Australie, d'Asie et d'Afrique. Ces espèces sont *Acacia aneura*, *A. cowleana*, *A. holosericea*, *A. nilotica*, *A. senegal*, *A. tortillis*, *Prosopis chilensis*, *P. cineraria* et *P. juliflora*. L'essai a été mis en place en 1984 à la station de recherche forestière de Bandia (Thiès, Sénégal) suivant un écartement de 4,5 x 2,5 mètres. Les mensurations ont eu lieu en 1993 soit dix (10) ans après l'implantation de l'essai. Les différents paramètres de croissance ont été mesurés et soumis à des analyses de variances et des analyses multivariées.

P. juliflora avait la croissance la plus rapide avec un taux d'accroissement de 1,1 $m^2ha^{-1}an^{-1}$ correspondant à une production de poids sec de 5,6 t $ha^{-1}an^{-1}$. L'analyse des différences entre espèces a montré que les espèces étaient différentes sur plusieurs aspects. *A. aneura* avait un faible taux de suirvie et des problèmes de stabilité. Il y avait des différences significatives à l'intérieur des espèces telles qu'*Acacia aneura*, *A. nilotica*, *A. tortillis* et *P. cineraria*. Il y avait particulièrement une grande variabilité avec les provenances d'*A. tortillis*.

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1. Introduction

This report describes the results from trial no. 24 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).

In this trial a large selection of both *Acacia* and *Prosopis* provenances is tested. The main species of the trial are *A. aneura*, *A. nilotica*, *A. tortilis* and *P. cineraria*. Furthermore, five species are represented with only one or two provenances: *A. cowleana*, *A. holosericea*, *A. senegal*, *P. chilensis* and *P. juliflora*.

A. aneura has a wide distribution in the central and southern of the Australian continent. The species is restricted to the arid and semi-arid zone with annual precipitation in the range of 100 to 500 mm, and the provenances in this trial covers the range both geographically and ecologically. Seed of the species are used for food by the aboriginal people in Australia (John Larmour, pers. com.) and could be an alternative food for people in the Sahel as well.

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

A. tortilis is widespread in the Sahel, East Africa and Arabia (Ross 1979, Brenan 1983, von Maydell 1986, Fagg & Barnes 1990). Although a matter of debate, it seems that four subspecies are recognised (Brenan 1983, Fagg & Barnes 1990). In this trial, the subspecies *raddiana* and *spirocarpa* are included. It is possible that the subspecies *tortilis* is included as well, since some of the seedlots has not been classified with regard to variety.

Many species of the genus *Prosopis* occur naturally in extremely hot and highly arid environments. *P. cineraria* is one of the four *Prosopis* species native to the Old World, and in this trial provenances from India have been included. The largest diversity of *Prosopis* is found in South and Central America (Ffolliott & Thames 1983), and the trial therefore also features provenances of *P. chilensis* and a landrace of *P. juliflora*.

2. Materials and methods

2.1 Site and establishment of the trial

The trial is placed at Bandia (14°30′N, 17°W) in Senegal at an altitude of 50-100 m. The mean annual temperature is approximately 25 °C, and the annual rainfall around 415 mm with a dry period of nine months. The trial was established in August 1984. Further information is given in the assessment report (DFSC 1994) and summarised in annex 1.

It should be noted that there was a small depression in the terrain in parts of the trial. It was attempted to account for this by measuring the level of each plot and include the level as a covariate in the analysis (see section 3.2).

2.2 Species and provenances

The trial includes 40 provenances of the *Acacia* and *Prosopis*, whose identity are given in Table 1. The provenances are given identification numbers relating to their geographical origin (name of province or country followed by a number), and the original seedlot numbers are provided in annex 2.

One provenance was originally believed to be *P. cineraria* from Yemen, but turned out to be *A. nilotica* when planted. Thus the identity of this seedlot is not known, and the provenance has been named 'unknown' in the report.

2.3 The experimental design

The experimental design is a randomised complete block design with four blocks. In each replicate block each 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 4.5 × 4.5 m, and only the 25 central trees were assessed. The layout of the design is shown in annex 3, and further details are given by DFSC (1994).

2.4 Assessment of the trial

In November 1993 ISRA/CNRF, FAO and DFSC undertook a joint assessment. The assessment included the following characters:

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

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

Table 1. Provenances tested in trial no. 24 at Bandia, Senegal.

Provenance identifiaction	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Annual Rainfall (mm)	No. of mother tree trees
N Territory1	*A. aneura*	Alice Springs, Nt	Australia	23°28' S	133°17' E	650	264	10
N Territory2	*A. aneura*	Vaughan Springs, Nt	Australia	22°12' S	130°55' E	600	264	10
N Territory3	*A. aneura*	Floodout, Nt	Australia	21°47' S	131°09' E	580	264	10
N Territory4	*A. aneura*	Glen Helen, Nt	Australia	23°47' S	132°27' E	650	264	10
NS Wales1	*A. aneura*	Cobar, Nsw	Australia	31°31' S	145°45' E	180	355	10
Queensland1	*A. aneura*	Morven, Qld	Australia	26°25' S	146°55' E	440	501	8
Queensland2	*A. aneura*	St. George, Qld	Australia	27°53' S	148°43' E	210	513	10
Queensland3	*A. aneura*	Charleville	Australia	26°25' S	146°17' E	300	501	10
Queensland4	*A. aneura*	Mt. Howitt, Qld	Australia	26°47' S	142°13' E	180	291	10
Queensland5	*A. aneura*	Eromanga, Qld	Australia	26°22' S	143°09' E	180	291	10
W Australia1	*A. aneura*	Kalgoorlie, Wa	Australia	30°45' S	121°30' E	400	247	
W Australia2	*A. aneura*	Jameson, Wa	Australia	25°54' S	126°31' E	440	213	10
N Territory5	*A. cowleana*	Vaughan Springs	Australia	22°12' S	130°55' E	600	264	
N Territory7	*A. holosericea*	Vaughan Springs	Australia	22°12' S	130°55' E	600	264	
Ahmedabad1	*A. nilotica* subsp. *jaquemontii*	Kutch (Bhuj)	India	23°50'N	69°48' E	80	349	25
Haryana1	*A. nilotica* subsp. *indica* var. *cupressiformis*	Nornaul Singhana (Mahandra Gahr) Bhiwani (Hissar)	India	28°03' N	76°07' E	250	714	4
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
Senegal21	*A. nilotica*	St-Louis	Senegal					
Unknown	*A. nilotica*							
Uttar Pradesh1	*A. nilotica* subsp. *indica* var. *jaquemontii*	Bawain Forest Block, Etawah (Mainpuri)	India	26°45' N	79° 00' E	157	762	26
Uttar Pradesh2	*A. nilotica* subsp. *indica* var. *jaquemontii*	Ajamgarh	India	26°03' N	83°30' E	78	1047	21
Yemen2	*A. senegal*	Ahwar	Yemen	13°25' N	46°40' E	500	225	20
Israel1	*A. tortilis*	Ein-Hazeva, Arava	Israel	30°47' N	35°12' W	100	40	
Israel2	*A. tortilis* subsp. *raddiana*	Ein-Hazeva, Arava	Israel	30°47' N	35°12' W	100	40	
Israel3	*A. tortilis*	Ein-Hazeva, Arava	Israel	30°47' N	35°12' W	100	40	60
Rajasthan6	*A. tortilis*	Ramgaon, Barmer	India	25°45' N	71°23' E	194	310	50
Rajasthan7	*A. tortilis*	Jodhpur	India	26°18' N	73°01' E	224	380	8
Senegal36	*A. tortilis* subsp. *raddiana*	Niomé, Louga	Senegal	15°42' N	16°10' W		350	
Sudan15	*A. tortilis* subsp. *spirocarpa*	Khartoum, West Nile	Sudan	15°36' N	32°33' E	330	165	25
Sudan16	*A. tortilis* subsp. *raddiana*	Khartoum, West Nile	Sudan	15°36' N	32°33' E	330	165	25
Yemen3	*A. tortilis*	Ahwar	Yemen	13°25' N	46°40' E	200	150	25
Chile2	*P. chilensis*	Rio Pama	Chile	31°09' S	71°04' W		250	26
Chile3	*P. chilensis*	C.A. Mt.Patria	Chile	30°39' S	71°58' W		175	25
Haryana2	*P. cineraria*	Khora-Ahamad, Bhiwani (Hissar)	India	28°45' N	76°10' E	250	446	5
Rajasthan8	*P. cineraria*	Sidhari-Guda, Barmer	India	25°45' N	71°23' E	194	310	20
Rajasthan9	*P. cineraria*	Jhunjhunu	India	28°10' N	75°15' E	338	648	27
Tamil Nadu3	*P. cineraria*	Krishnapuram, Trichy	India	10°46' N	78°43' E	88	876	27
Uttar Pradesh3	*P. cineraria*	Yamuna/ Chambal, Etawah	India	27°14' N	79°03' E	157	762	30
Senegal38	*P. juliflora*	Thies	Senegal	14°48' N	16°54' W		300	

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

It appeared that for some small trees, no assessment of diameter, number of stems and crown diameter was made. Omission of these data will produce biased results and lead to an over-estimation of the provenances in question, but since only 13 trees of the 2367 surviving trees had missing observations, this is believed to be of minor importance. Therefore no correction of the variables have been made.

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 regressions were available for the species *A. aneura*, *A. cowleana*, *A. holosericea* and *P. chilensis*, which were therefore omitted in the analyses of the dry weight variables.

Table 2. Coefficients for the dry weight regressions used for calculation of dry weight.

Species	a	b
Acacia nilotica	2.582	2.518
Acacia senegal	2.474	2.233
Acacia tortilis	2.294	1.685
Prosopis cineraria	2.657	3.162
Prosopis juliflora	2.466	2.036

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 $N(0, \sigma_e^2)$. The test of species differences was performed using the Satterthwaite method for calculation of the degrees of freedom (SAS 1988b).

The tests of significant differences between provenances were performed separately for each species with more than one provenance. 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 model but excluded successively if they were not significant at a 10% level (Keiding *et al.* 1985). 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. Level was also included. 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). 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 (ibid).

The P-values from the tests of provenance differences were corrected for the effect of multiple comparisons by the sequential tablewide Bonferroni method (Holm 1979). The tests were ranked according to their P values. 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. Kjær & Siegismund 1996). In this case the number of tests was set to 9, 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 only present BLUP estimates for *A. aneura*, *A. nilotica*, *A. tortilis* and *P. cineraria* 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, Affi & Clark 1996, Skovgård & Brockdorf 1998).

The statistical software package used was Statistical Analysis System (SAS 1988a, 1988b, 1991, Littell *et al.* 1996). 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 given in the result section.

4. Results

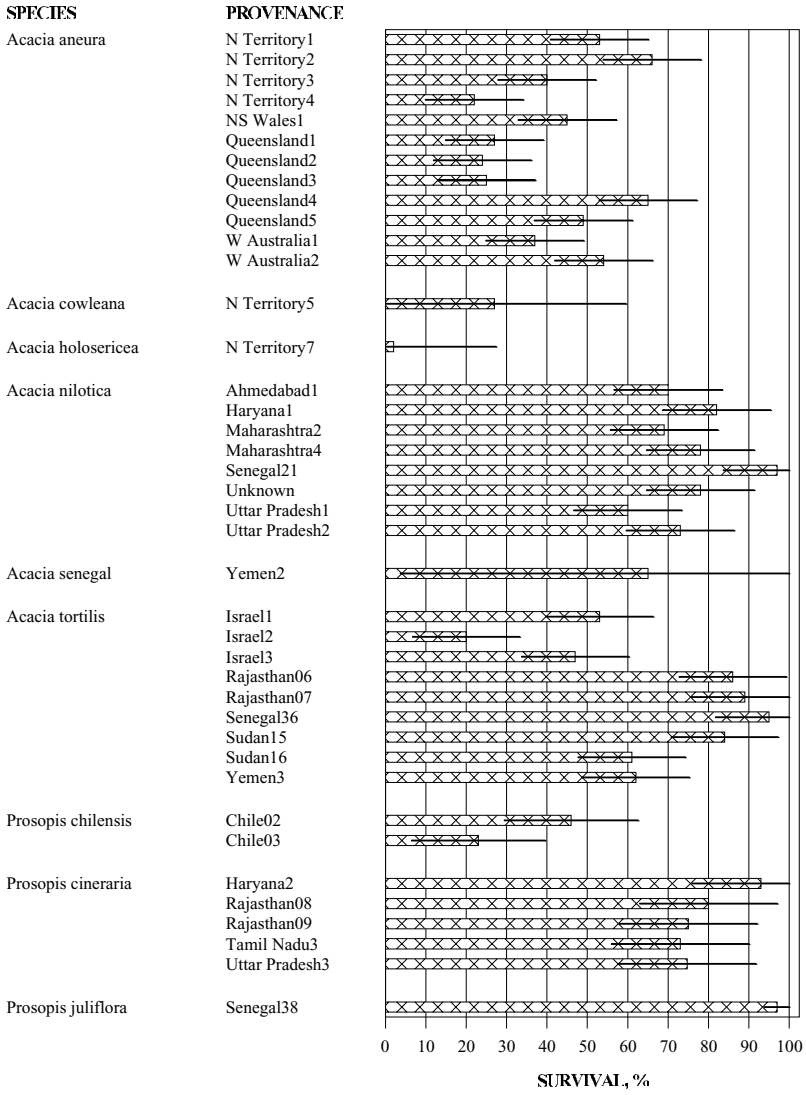


Figure 1. Survival in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.1 Survival

Survival is regarded as one of the key variables when analysing tree provenance trials, since it indicates the adaptability of the provenance to the environment at the trial site. It should be noted that 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

From the plots of residuals it appeared that Yemen2 in block 1 had a survival well above the average for the provenance and should be considered as an outlier. However, since there was no explanation for the outlier tendency and a repeated analysis without this observation did not change the conclusions, estimates and tests are presented with the outlier included. Apart from this, no transformations were necessary. None of the covariates were significant.

Results

The survival varied from close to zero in the provenance N Territory7 of *A. holosericea* to almost 100% in Senegal38 of *P. juliflora* (Fig. 1). The three local provenances or land races have the highest survival. There were several highly significant differences, both between species and within species (Table 3). Among the species represented with more than one provenance, *A. aneura* had the lowest survival, and *A. nilotica* and *P. cineraria* the highest, whereas *A. tortilis* was intermediate. In *A. aneura* and *A. tortilis* the differences between provenances were highly significant, but in *A. nilotica* and *P. cineraria* no significant differences could be detected. The two provenances of *P. chilensis* did not differ significantly. The predicted gains by selection of provenances within species ranged from 13 to 25 % in *A. aneura*, *A. nilotica* and *A. tortilis*, but was only 2-3 % in *P. cineraria* (Fig. 2-5).

Table 3. Results from analysis of variance of provenance differences of survival in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	8; 31	7498	6.6	<0.0001	***
Provenance(species)	31; 117	1140	5.6	<0.0001	
Block	3; 117	547	2.7	0.05	
Error	117	204			
A. aneura					
Provenance	11; 33	979	6.9	<0.0001	***
Block	3; 33	676	4.8	0.007	
Error	33	142			
A. nilotica					
Provenance	7; 21	477	2.9	0.03	n.s.
Block	3; 21	305	1.8	0.17	
Error	21	165			
A. tortilis					
Provenance	8; 24	2390	14.4	<0.0001	***
Block	3; 24	36	0.2	0.88	
Error	24	166			
P. chilensis					
Provenance	1; 3	1058	9.7	0.05	n.s.
Block	3; 3	327	3.0	0.19	
Error	3	108			
P. cineraria					
Provenance	4; 12	267	1.1	0.40	n.s.
Block	3; 12	107	0.4	0.73	
Error	12	245			

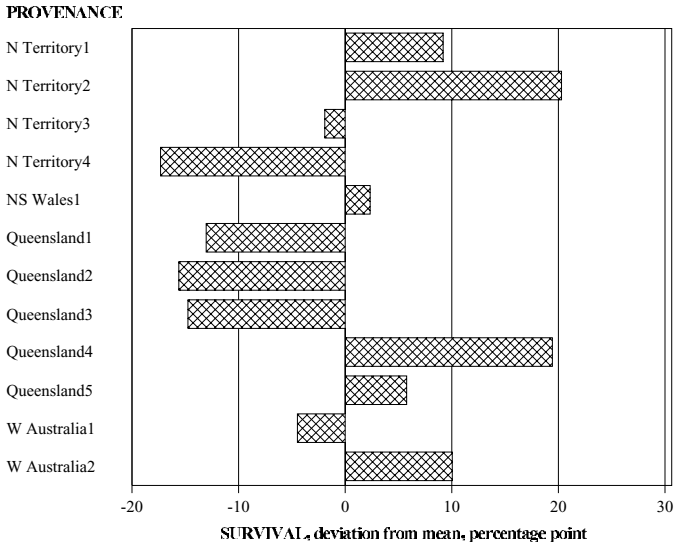


Figure 2. Best linear unbiased predictors (BLUPs) for survival in the *A. aneura* provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are deviations from the mean value in percentage points.

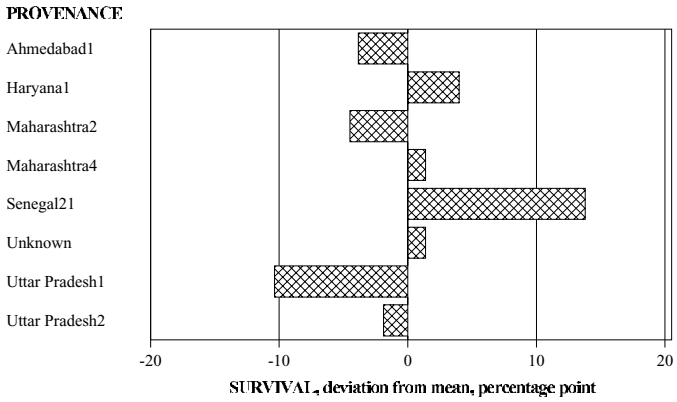


Figure 3. Best linear unbiased predictors (BLUPs) for survival in the *A. nilotica* provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are deviations from the mean value in percentage points.

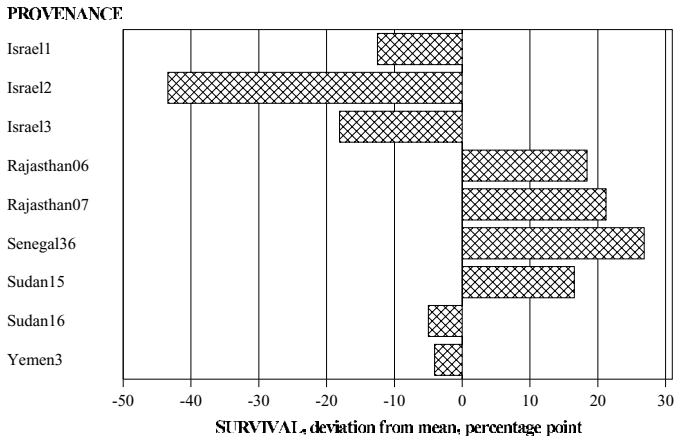


Figure 4. Best linear unbiased predictors (BLUPs) for survival in the *A. tortilis* provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are deviations from the mean value in percentage points.

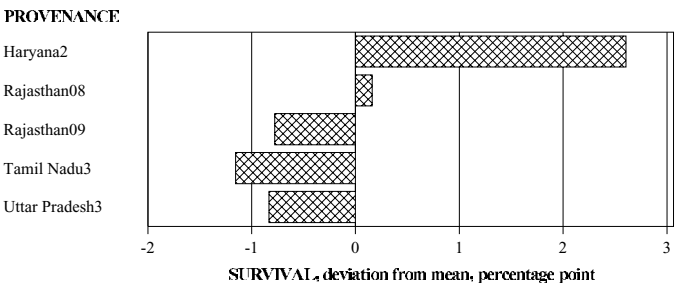


Figure 5. Best linear unbiased predictors (BLUPs) for survival in the *P. cineraria* provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are deviations from the mean value in percentage points.

4.2 Height

Height is usually considered an important variable in the evaluation of species and provenances. 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 adaptation of trees to the environment, tall provenances/trees usually being better adapted to the site than short provenances/trees. This interpretation need not always be true as there have been trials where the tallest provenances are suddenly affected by disease and subsequent die-off.

Statistical analysis

The plots of residuals revealed that two values (N Territory4 in block 1 and Rajahsthan09 in block 4) were outliers. Since both these plots were represented by single trees lying down it seemed reasonable to exclude them from the analyses. For N Territory7 of *A. holosericea* only two plots had surviving trees, and since the average heights for the plots by coincidence were the same, no confidence limits for this provenance were calculated. There were signs that the residuals from the analysis of differences within *A. nilotica* were not following the normal distribution, but since no transformations seemed to be able to solve the problem, the original model was used. Within *P. cineraria* there were signs of variance heterogeneity, and the data were weighted to ensure fulfilment of the assumptions of the model.

The co-variates plotx and level were significant in the analysis of species differences, and level was significant in all analysis of provenance differences within species except for in *P. chilensis*.

Results

The average heights varied between 2 m in Yemen2 of *A. senegal* and almost 8 m in the highest provenance, which was Senegal38 of *P. juliflora*. The provenance N Territory5 of *A. cowleana* was another high provenance with an average height of 6.5 m. Most of the other provenances had heights between 3 to 6 m (Fig. 6). The differences between species were highly significant, and it seemed that *A. aneura* and *A. nilotica* were at the high end, whereas *A. tortilis* and *P. cineraria* were at the low end. Even within the species there were significant differences, as seen from the highly significant provenance effects in Table 4. Only in *A. nilotica* and *P. chilensis* the differences were not significant. Correspondingly, the predicted gains by selection of provenances were high in *A. aneura*, *A. tortilis* and *P. cineraria*, but low for *A. nilotica* (Fig. 7-10).

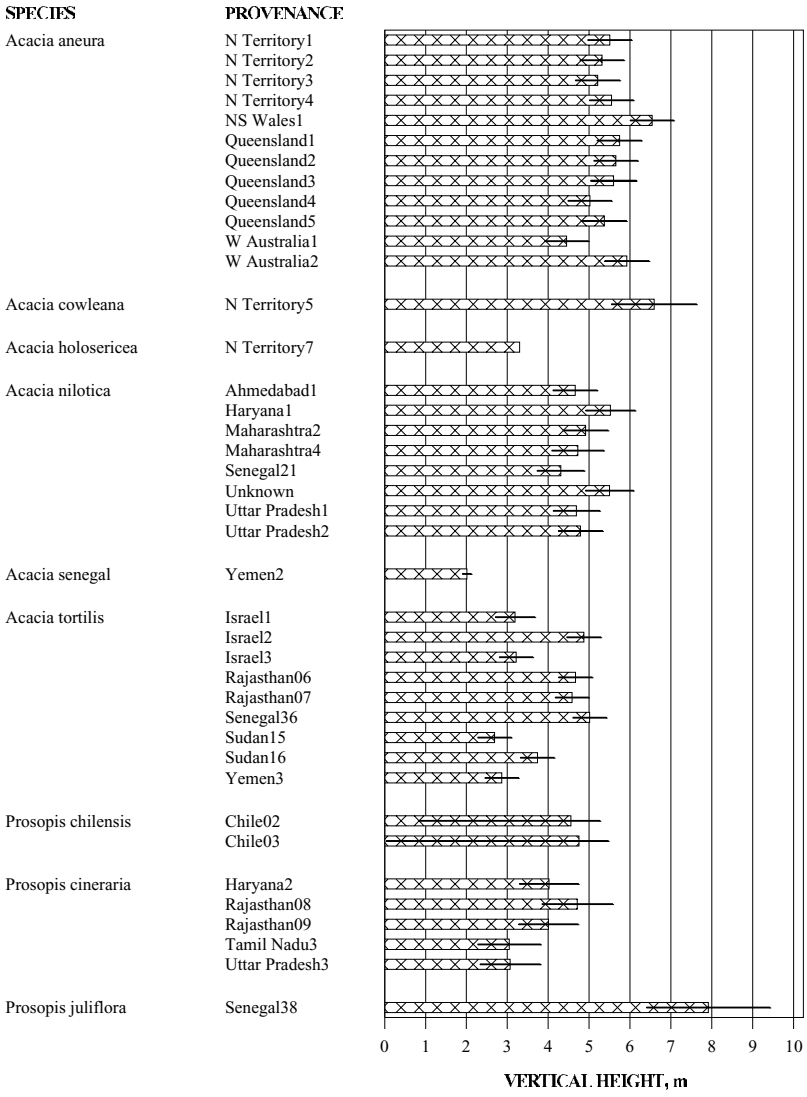


Figure 6. Vertical height in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 4. Results from analysis of variance of provenance differences of height in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	8; 32.0	18.8	13.1	<0.0001	***
Provenance(species)	31; 109	1.5	5.8	<0.0001	
Block	3; 109	3.3	12.4	<0.0001	
Plotx	1; 109	1.0	3.8	0.05	
Level	1; 109	13.2	49.8	<0.0001	
Error	109	0.3			
A. aneura					
Provenance	11; 32	1.0	3.7	0.002	**
Block	3; 32	1.4	5.1	0.005	
Level	1; 32	7.0	25.7	<0.0001	
Error	32	0.3			
A. nilotica					
Provenance	7; 19	0.46	1.8	0.16	n.s.
Block	3; 19	1.25	4.8	0.01	
Level	1; 19	1.51	5.7	0.03	
Error	19	0.26			
A. tortilis					
Provenance	8; 22	3.21	20.7	<0.0001	***
Block	3; 22	0.42	2.7	0.07	
Level	1; 22	1.78	11.4	0.003	
Error	22	0.16			
P. chilensis					
Provenance	1; 3	0.08	0.40	0.57	n.s.
Block	3; 3	0.19	0.93	0.52	
Error	3	0.20			
P. cineraria					
Provenance	4; 10	15.4	16.6	0.0002	**
Block	3; 10	13.2	14.3	0.0006	
Level	1; 10	34.4	37.1	<0.0001	
Error	10	0.9			

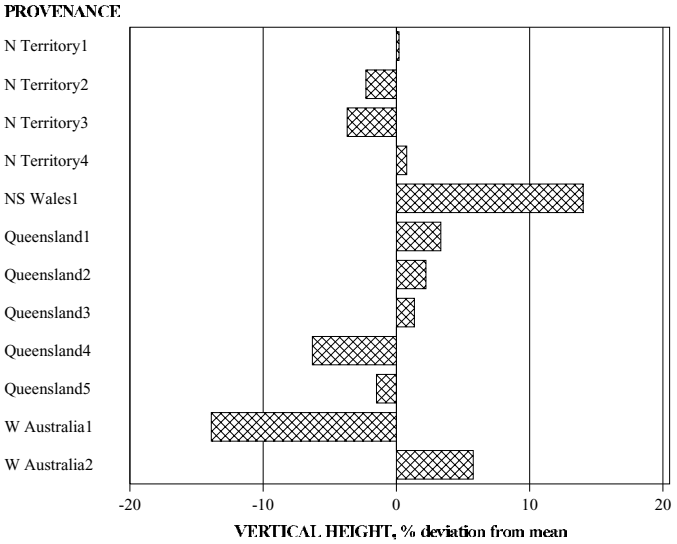


Figure 7. Best linear unbiased predictors (BLUPs) for vertical height in the *A. aneura* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

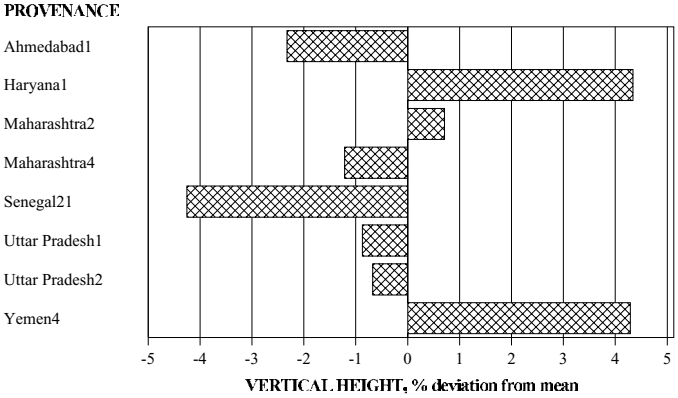


Figure 8. Best linear unbiased predictors (BLUPs) for vertical height in the *A. nilotica* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

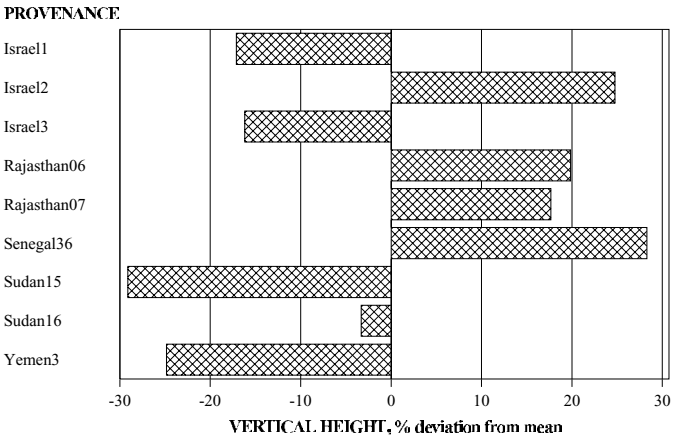


Figure 9. Best linear unbiased predictors (BLUPs) for vertical height in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

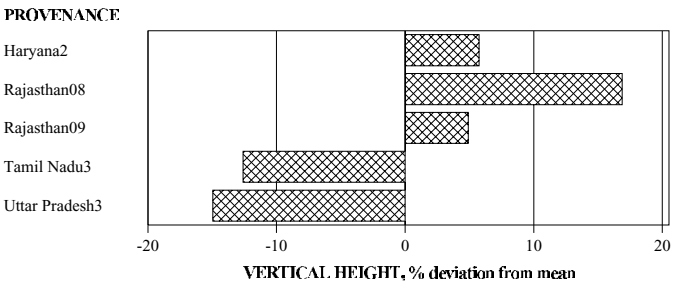


Figure 10. Best linear unbiased predictors (BLUPs) for vertical height in the *P. cineraria* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

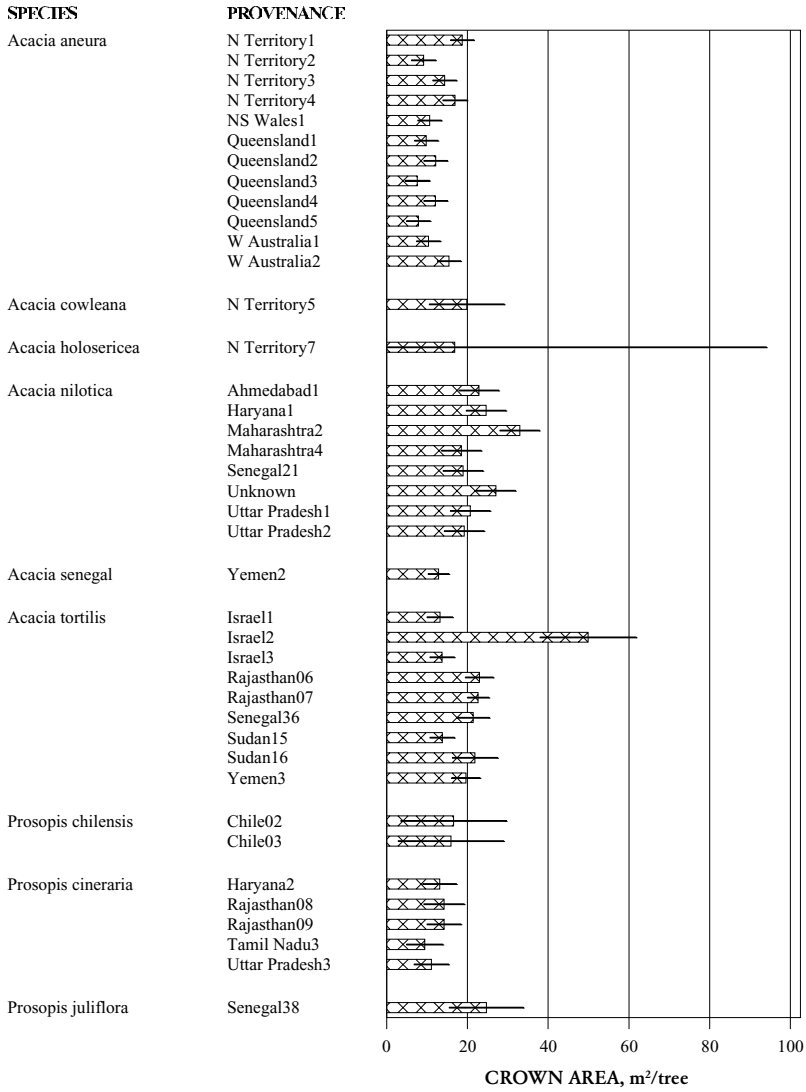


Figure 11. Crown area in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.3 Crown area

The crown area variable indicates 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

The plots of residuals indicated that there was variance heterogeneity, and in the test of species differences and of provenance differences within *A. tortilis* the data were weighted.

The co-variates plotx and level were significant in the analysis of species differences. Furthermore the level was significant in the analyses of provenance differences within *A. aneura*, *A. tortilis* and *P. cineraria*, and plotx was significant in the tests of *A. aneura* and *A. tortilis* provenance differences.

Results

Most provenances had average crown areas varying between 10 and 25 m^2 $tree^{-1}$ (Fig. 11). Considering that the trees were planted at 4.5 × 4.5 m (corresponding to 20.25 m^2 $tree^{-1}$), trees from the largest provenances were closing the canopy at the time of assessment. One provenance, Israel2 of *A. tortilis*, had a very large crown area (approximately 50 m^2 $tree^{-1}$). This provenance also had a low survival, meaning that the space would be sufficient for the trees to grow large. Probably trees from other provenances with high survival were restricted in their growth by competition with other trees, and it should be considered that this variable may represent a mixture of environmental and genetic effects. However, it is also possible that Israel2 has an extremely developed ability to grow wide, umbrella-like crowns.

The differences between species were highly significant with *A. aneura* and *P. cineraria* having low crown areas, while *A. nilotica* had generally high values and *A. tortilis* was intermediate (ignoring Israel2) (Table 5). Within the species, the differences between provenances were significant in all but *P. chilensis* and *P. cineraria*. The predicted gains by provenance selection were quite large, varying from 30 % in *A. nilotica* over 50 % in *A. aneura* to 120 % in *A. tortilis* (due to Israel2). The differences between the provenances of *P. cineraria* were too small to allow calculation of BLUP-values (the variance component for provenance equalled zero). Therefore no figure is presented for this species.

Table 5. Results from analysis of variance of provenance differences of crown area in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	8; 32.0	37.3	12.6	<0.0001	***
Provenance(species)	31; 109	7.2	7.2	<0.0001	
Block	3; 109	9.2	9.2	<0.0001	
Plotx	1; 109	18.4	18.3	<0.0001	
Level	1; 109	211.3	210.5	<0.0001	
Error	109				
A. aneura					
Provenance	11; 31	50.4	6.4	<0.0001	***
Block	3; 31	18.9	2.4	0.09	
Plotx	1; 31	32.9	4.2	0.05	
Level	1; 31	411.0	52.4	<0.0001	
Error	31				
A. nilotica					
Provenance	7; 21	99.2	4.4	0.004	*
Block	3; 21	14.7	0.7	0.59	
Error	21	22.4			
A. tortilis					
Provenance	8; 21	8.9	10.5	<0.0001	***
Block	3; 21	1.9	2.2	0.12	
Plotx	1; 21	0.5	0.6	0.46	
Level	1; 21	23.7	27.8	<0.0001	
Error	21	0.9			
P. chilensis					
Provenance	1; 3	0.9	0.01	0.92	n.s.
Block	3; 3	81.5	1.2	0.44	
Error	3	67.3			
P. cineraria					
Provenance	4; 10	15	1.1	0.41	n.s.
Block	3; 10	37	2.6	0.11	
Level	1; 10	273	19.3	0.001	
Error	10	14			

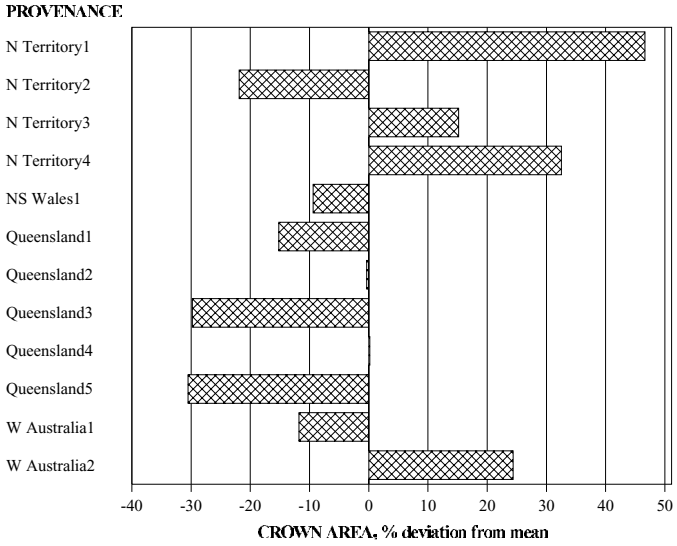


Figure 12. Best linear unbiased predictors (BLUPs) for crown area in the *A. aneura* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

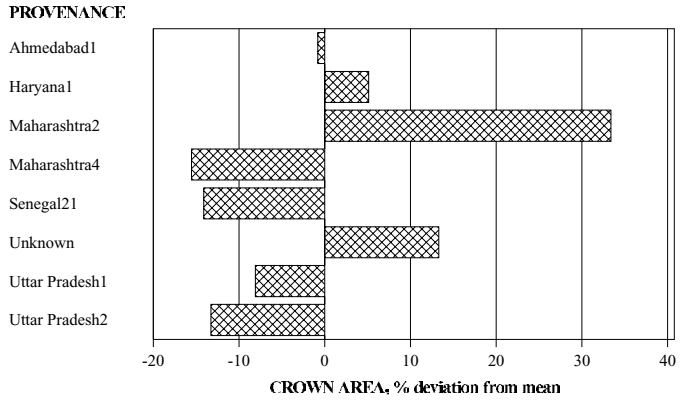


Figure 13. Best linear unbiased predictors (BLUPs) for crown area in the *A. nilotica* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

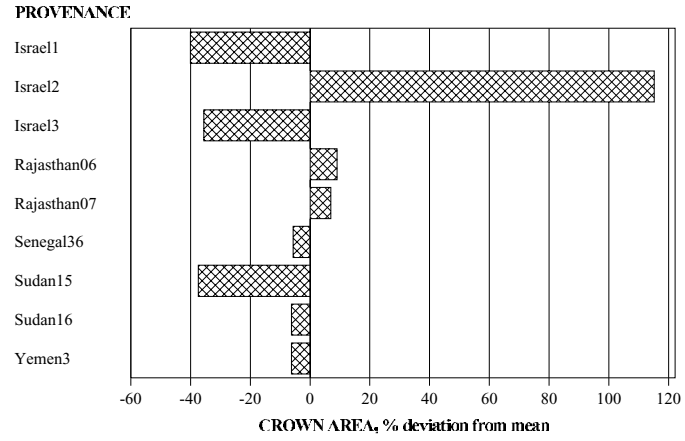


Figure 14. Best linear unbiased predictors (BLUPs) for crown area in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.4 Number of stems

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

Statistical analysis

The first analysis made it clear that there was substantial variance heterogeneity between the provenances, and the data were weighted in the analysis of species differences and in the tests of provenance differences within *A. aneura* and *A. tortilis*. No co-variates were significant.

Results

The number of stems varied from approximately one to almost 14 stems per tree. The differences between species were significant, and it appeared that especially some provenances of *A. tortilis* had large number of stems (Table 6, Fig. 15). Within *A. aneura*, *A. nilotica* and *A. tortilis*, the differences between provenances were highly significant, but in *P. cineraria* the differences were not significant after the correction for multiple tests. The variation within *A. tortilis* is conspicuous, but there is no clear relation between the number of stems and geographical origin or variety. Due to the large variation, the predicted gains by provenance selection are also very large for this species, varying from –70 to +120 % (Fig. 18). For the other species, the gains are more modest, varying from –2 to +5 % in *A. aneura* (Fig. 16) over –20 to +15 % in *P. cineraria* (Fig. 19) to –20 to +35 in *A. nilotica* (Fig. 17).

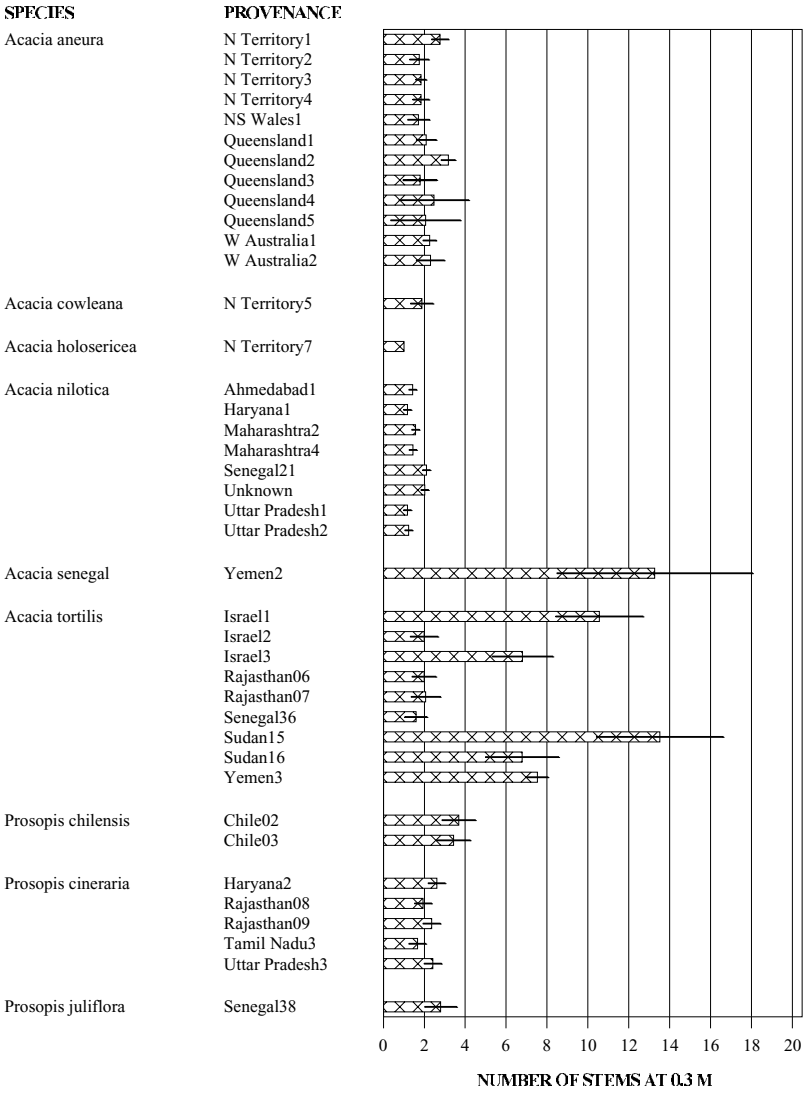


Figure 15. Number of stems in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 6. Results from analysis of variance of provenance differences of number of stems in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	8; 33.9	58.5	5.0	0.0004	**
Provenance(species)	31; 115	27.8	31.8	<0.0001	
Block	3; 115	8.2	9.4	<0.0001	
Error	115	0.9			
A. aneura					
Provenance	11; 33	5.8	5.7	<0.0001	***
Block	3; 33	5.8	5.7	0.003	
Error	33	1.0			
A. nilotica					
Provenance	7; 21	0.53	17.1	<0.0001	***
Block	3; 21	0.04	1.3	0.30	
Error	21	0.03			
A. tortilis					
Provenance	8; 24	60.4	70.0	<0.0001	***
Block	3; 24	0.3	0.4	0.78	
Error	24	0.9			
P. chilensis					
Provenance	1; 3	0.13	0.5	0.54	n.s.
Block	3; 3	0.42	0.3	0.35	
Error	3	0.26			
P. cineraria					
Provenance	4; 12	0.59	4.0	0.03	n.s.
Block	3; 12	0.08	0.6	0.65	
Error	12	0.15			

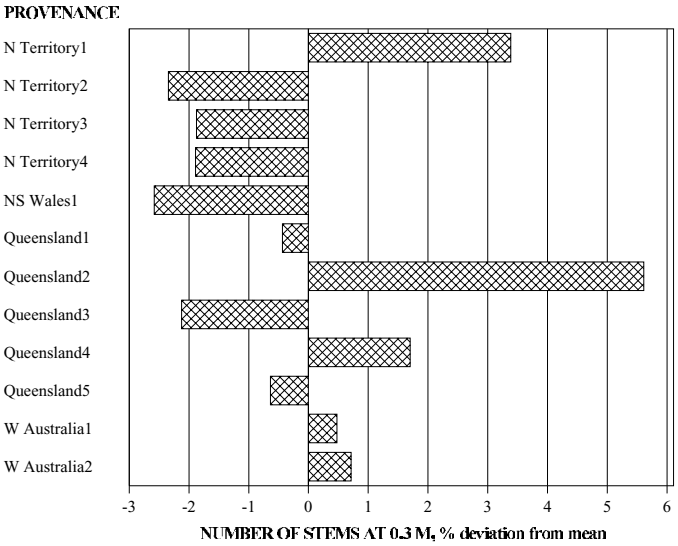


Figure 16. Best linear unbiased predictors (BLUP's) for number of stems in the *A. aneura* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

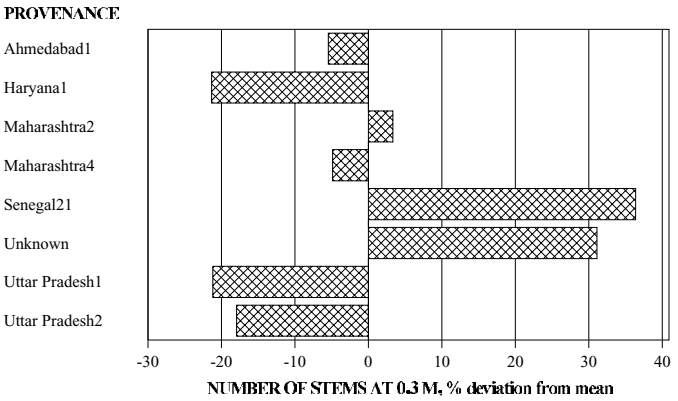


Figure 17. Best linear unbiased predictors (BLUP's) for number of stems in the *A. nilotica* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

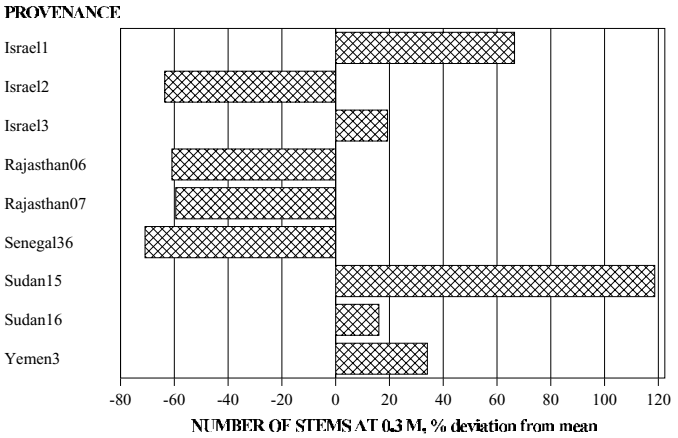


Figure 18. Best linear unbiased predictors (BLUP's) for number of stems in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

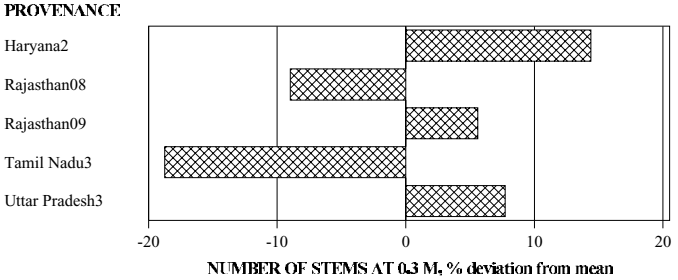


Figure 19. Best linear unbiased predictors (BLUP's) for number of stems in the *P. cineraria* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

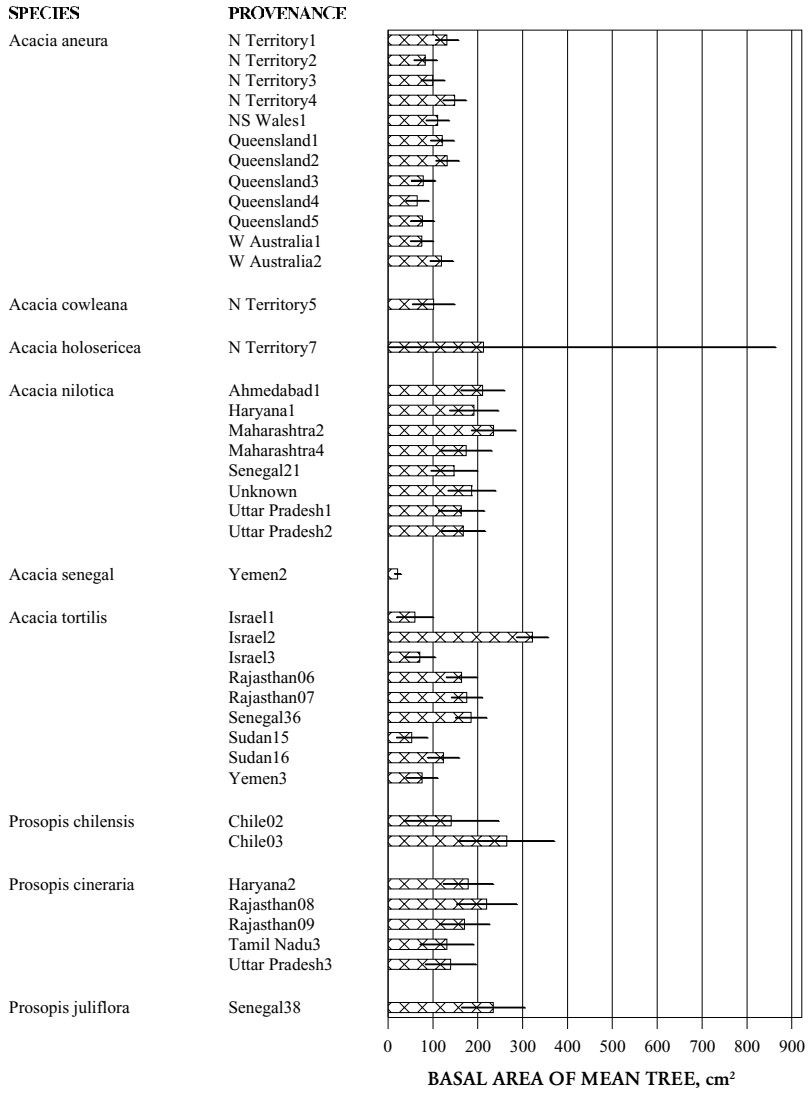


Figure 20. The basal area of the mean tree in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

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 gives an indication of the potential basal area production of the provenance provided that all trees survive.

Statistical analysis

The data were analysed without transformations or weights. The co-variates plotx and level were significant in the analysis of species differences, and level was significant in the analyses of provenance differences for all species**.**

Results

The basal area of the mean tree varied between 21 $cm^2\ tree^{-1}$ in Yemen2 (*A. senegal*) to 320 $cm^2\ tree^{-1}$ in Israel2 (*A. tortilis*). Israel2 thus again diverges from the other provenances of *A. tortilis*, but note that this could be due to lack of competition because of low survival (see the section on crown area). The species were significantly different (Table 7), with *A. aneura* having an average of approximately 100 $cm^2\ tree^{-1}$ and *A. nilotica* being close to 200 $cm^2\ tree^{-1}$ (Fig. 20). *A. tortilis* and *P. cineraria* were intermediate. Significant differences within species were found only in *A. aneura* and *A. tortilis*. Therefore the predicted gains by provenance selection were largest in these species, being 30 and 130% for the largest provenances of the two species respectively (Fig. 21 and 23). For *A. nilotica* and *P. cineraria*, the gains were much more modest, corresponding to 10 and 4 % (Fig. 22 and 24).

Table 7. Results from analysis of variance of provenance differences of basal area of the mean tree in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	8; 31.5	38191	4.1	0.002	**
Provenance(species)	31; 110	9655	6.9	<0.0001	
Block	3; 110	8414	6.0	0.0008	
Plotx	1; 110	6643	4.8	0.03	
Level	1; 110	89908	64.5	<0.0001	
Error	110	1394			
A. aneura					
Provenance	11; 32	2997	4.9	0.0002	***
Block	3; 32	1650	2.7	0.06	
Level	1; 32	26651	43.6	<0.0001	
Error	32	611			
A. nilotica					
Provenance	7; 19	2998	1.4	0.25	n.s.
Block	3; 19	6066	2.9	0.06	
Level	1; 19	9819	4.7	0.04	
Error	19	2109			
A. tortilis					
Provenance	8; 22	27965	25.7	<0.0001	***
Block	3; 22	1228	1.1	0.36	
Level	1; 22	21311	19.6	0.0002	
Error	22	1086			
P. chilensis					
Provenance	1; 2	7196	7.9	0.11	n.s.
Block	3; 2	1519	1.7	0.40	
Level	1; 2	9236	10.1	0.09	
Error	2	912			
P. cineraria					
Provenance	4; 10	3998	1.6	0.24	n.s.
Block	3; 10	8139	3.3	0.07	
Level	1; 10	45275	18.3	0.002	
Error	10	2471			

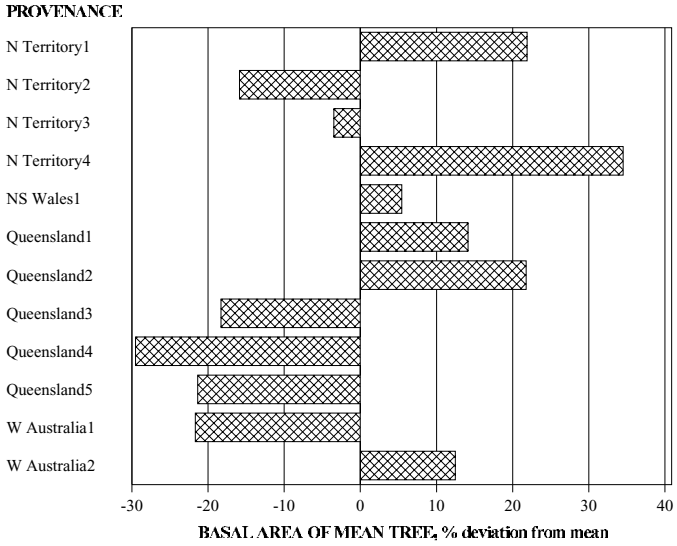


Figure 21. Best linear unbiased predictors (BLUPs) for basal area of the mean tree in the *A. aneura* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

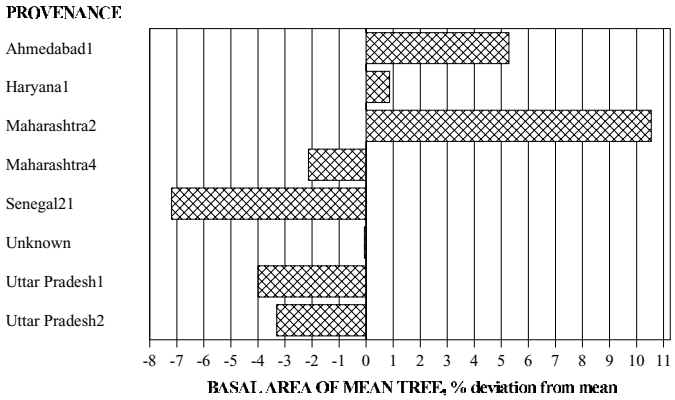


Figure 22. Best linear unbiased predictors (BLUPs) for basal area of the mean tree in the *A. nilotica* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

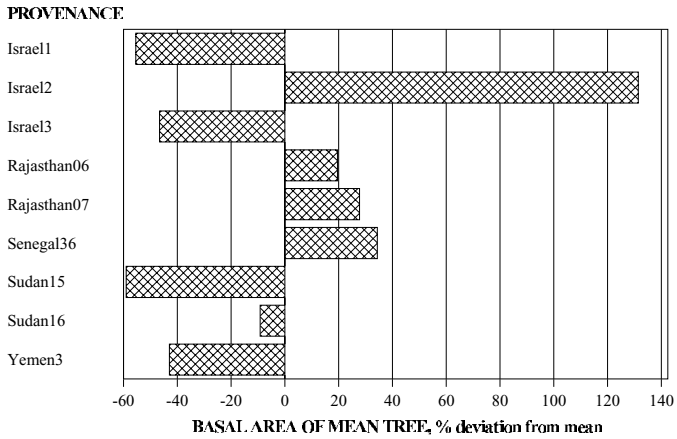


Figure 23. Best linear unbiased predictors (BLUPs) for basal area of the mean tree in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

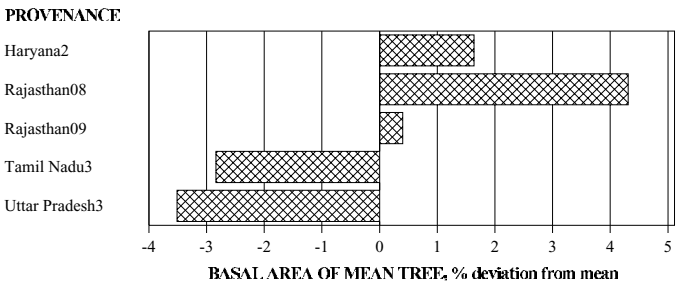


Figure 24. Best linear unbiased predictors (BLUPs) for basal area of the mean tree in the *P. cineraria* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

4.6 Total basal area

In comparison to the basal area of the mean tree, the total basal area accounts for missing trees and is thus a better measure of the actual production on the site.

Statistical analysis

Since it appeared from the first analysis that there was variance heterogeneity, the data were weighted to achieve fulfilment of the assumptions of the model. This was the case in the test of species differences, but was not necessary in the tests of provenance differences. The co-variate level was significant in all models except for the test of provenance differences in *P. chilensis*.

Results

The total basal area was quite variable, varying from below 1 in *A. holosericea* to 11 m^2 ha^{-1} in the provenance of *P. juliflora*. The species differences were highly significant, with *A. aneura* being at the low end, *A. nilotica* at the high and *A. tortilis* and *Prosopis cineraria* in between. Within the species, the provenance effects were significant in *A. aneura* and *A. tortilis*. Note that Israel2, despite its high basal area of the mean tree, does not have a large total basal area.

The predicted gains by selection of the best provenances varied from 10 % in *P. cineraria* over 45 % in *A. aneura* to 105 % in *A. tortilis*. Since *A. nilotica* was far from having significant provenance differences, it was not possible to calculate BLUP values, and no figure is presented. Thus the predicted gains for this species should be considered as zero.

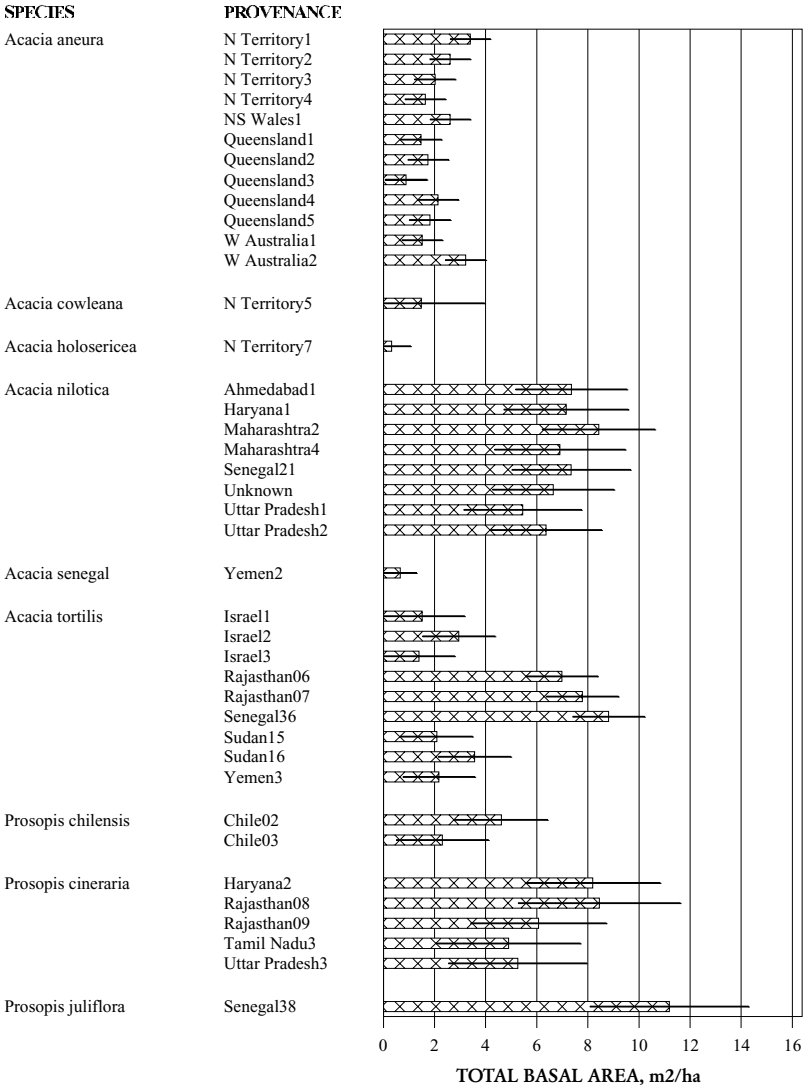


Figure 25. Total basal area in the *Acacia* and *Prosopis* species and provenances trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 8. Results from analysis of variance of provenance differences of total basal area in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	8; 34.5	88.3	13.7	<0.0001	***
Provenance(species)	31; 113	9.4	10.0	<0.0001	
Block	3; 113	13.6	14.4	<0.0001	
Level	1; 113	125.0	132.4	<0.0001	
Error	113	0.9			
A. aneura					
Provenance	11; 32	2.2	3.7	0.002	**
Block	3; 32	1.4	2.4	0.08	
Level	1; 32	11.5	19.3	<0.0001	
Error	32	0.6			
A. nilotica					
Provenance	7; 19	2.9	0.7	0.68	n.s.
Block	3; 19	14.6	3.4	0.04	
Level	1; 19	38.3	8.9	0.008	
Error	19	4.3			
A. tortilis					
Provenance	8; 22	32.3	17.7	<0.0001	***
Block	3; 22	3.9	2.2	0.12	
Level	1; 22	12.2	6.7	0.02	
Error	22	6.7			
P. chilensis					
Provenance	1; 3	10.6	8.3	0.06	n.s.
Block	3; 3	5.6	4.4	0.12	
Error	3	1.3			
P. cineraria					
Provenance	4; 10	9.6	1.7	0.22	n.s.
Block	3; 10	9.8	1.8	0.21	
Level	1; 10	87.9	15.7	0.003	
Error	10	5.6			

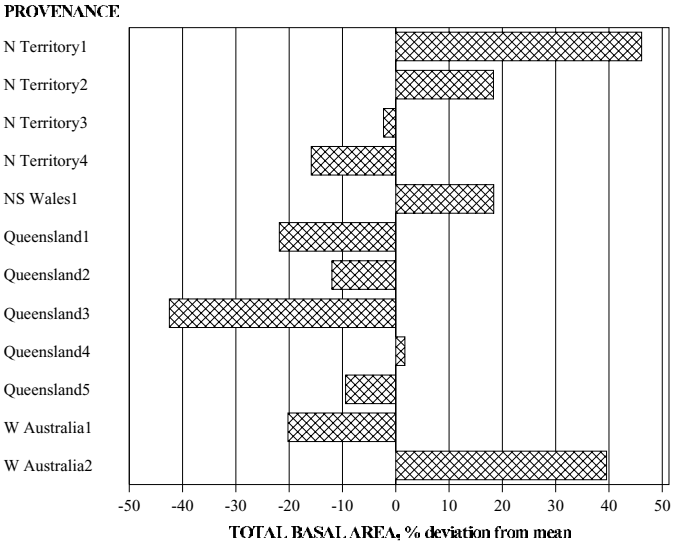


Figure 26. Best linear unbiased predictors (BLUPs) for total basal area in the *A. aneura* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

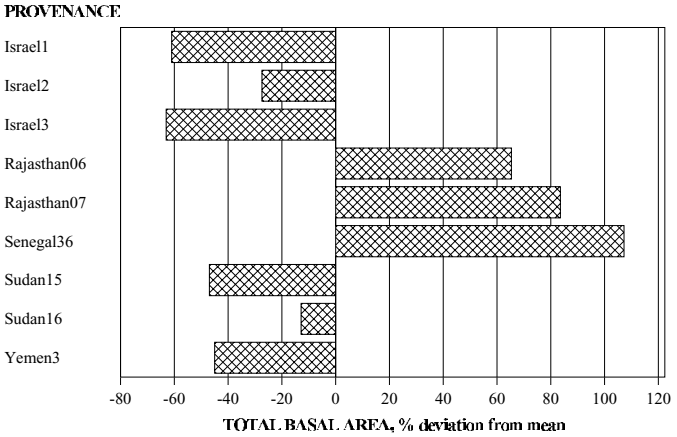


Figure 27. Best linear unbiased predictors (BLUPs) for total basal area in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

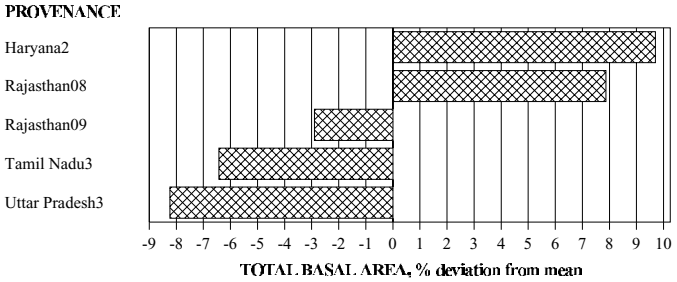


Figure 28. Best linear unbiased predictors (BLUPs) for total basal area in the *P. cineraria* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

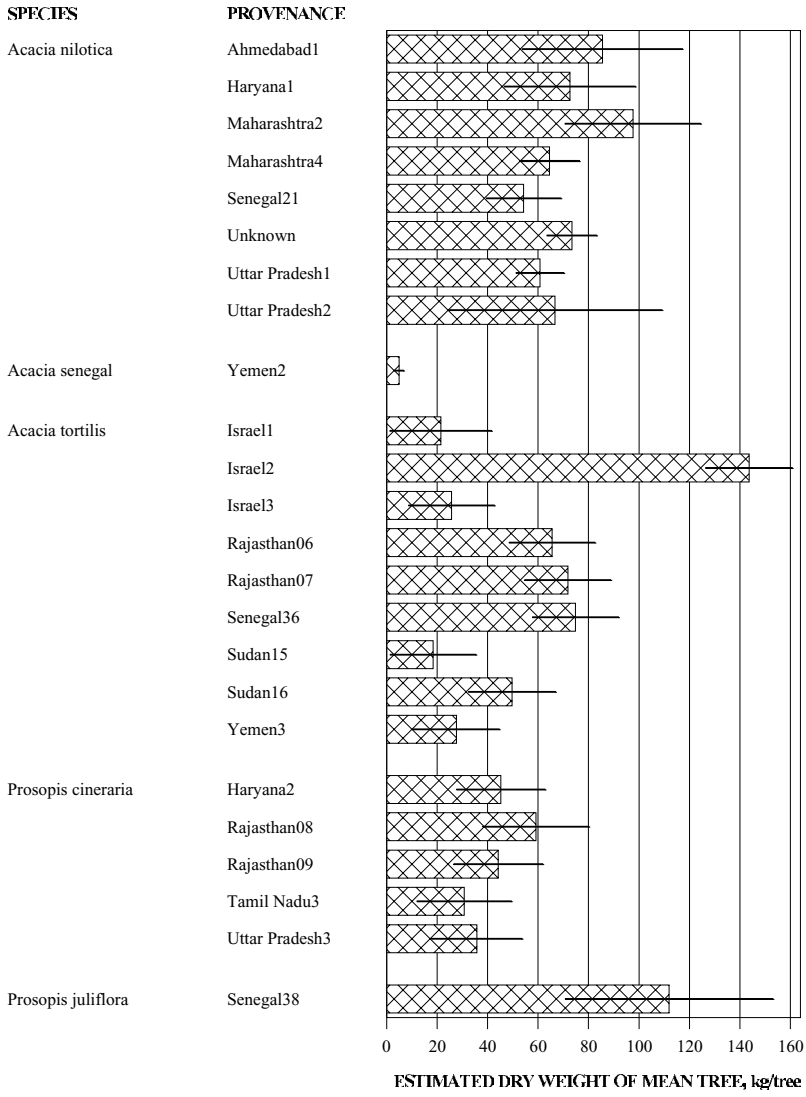


Figure 29. Dry weight of the mean tree in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.7 Dry weight of the mean tree

The dry weight of the mean tree is comparable to the basal area of the mean tree in that they both are calculated on the live trees only and thus serve as a measure of the potential production at the site, provided that all trees survive. Furthermore, the two variables are linked closely together as the basis for calculation 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

Since the regressions used for calculation of dry weight were only available for a limited number of species, only five species are included in the analysis of this variable and of the total dry weight.

Again the plots of residuals indicated that there was variance heterogeneity, and the data were weighted in the analyses of species differences and of provenance differences in *A. nilotica*. Level was significant in all analyses, but plotx was significant only in the test of species differences.

Results

The dry weight of the mean tree varied within a wide range from approximately 5 kg to 140 kg tree^{-1}. Yemen2 and Israel2 again represented the two extremes (Fig. 29). The differences between species were significant with *A. nilotica* (and *P. juliflora*) as the leader and *P. cineraria* with low values. *A. tortilis* was very variable, and even though the extreme provenances exceeded the values of the two other species, the mean value was intermediate. Within species, provenance effects were significant only for *A. tortilis*. The corresponding predicted values for provenance selection were no less than 150 % for Israel2 of *A. tortilis*, but only 10 % for the best provenance of *A. nilotica* (Maharashtra2). In *P. cineraria* the differences were too small to permit calculation of BLUP-estimates.

Table 9. Results from analysis of variance of provenance differences of dry weight of the mean tree in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	4; 33.0	33.0	5.0	0.005	**
Provenance(species)	19; 64	13.3	13.0	<0.0001	
Block	3; 64	22.4	21.8	<0.0001	
Plotx	1; 64	7.4	7.2	0.009	
Level	1; 64	142.2	138.6	<0.0001	
Error	64	1.0			
A. nilotica					
Provenance	7; 19	2.0	1.8	0.14	n.s.
Block	3; 19	5.4	5.0	0.01	
Level	1; 19	19.9	18.5	0.0004	
Error	19	1.1			
A. tortilis					
Provenance	8; 22	5950	22.1	<0.0001	***
Block	3; 22	250	0.9	0.44	
Level	1; 22	5501	18.6	0.0003	
Error	22	269			
P. cineraria					
Provenance	4; 10	369	1.5	0.28	n.s.
Block	3; 10	805	3.3	0.07	
Level	1; 10	4699	19.0	0.001	
Error	10	247			

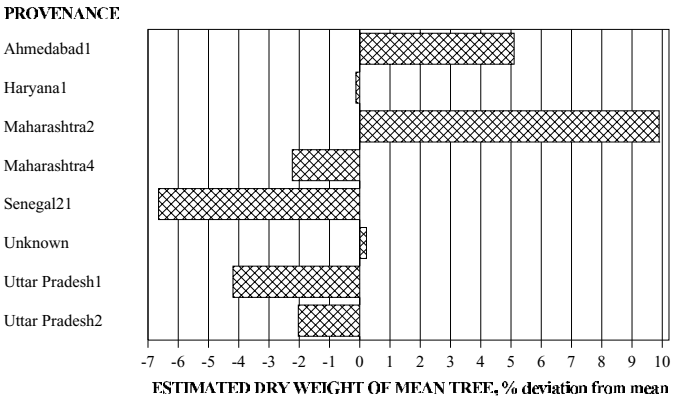


Figure 30. Best linear unbiased predictors (BLUPs) for dry weight of the mean tree in the *A. nilotica* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

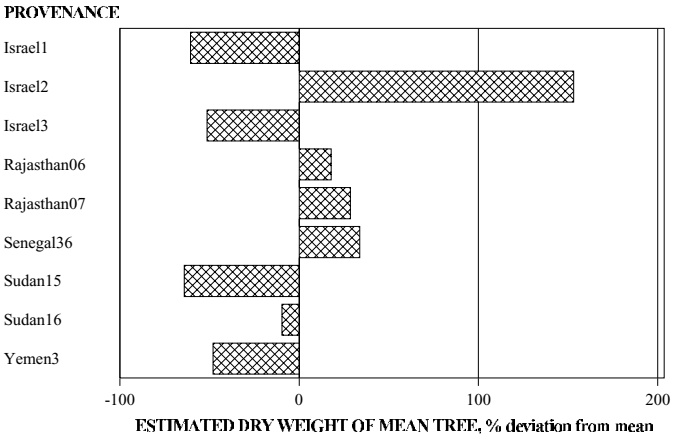


Figure 31. Best linear unbiased predictors (BLUPs) for dry weight of the mean tree in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

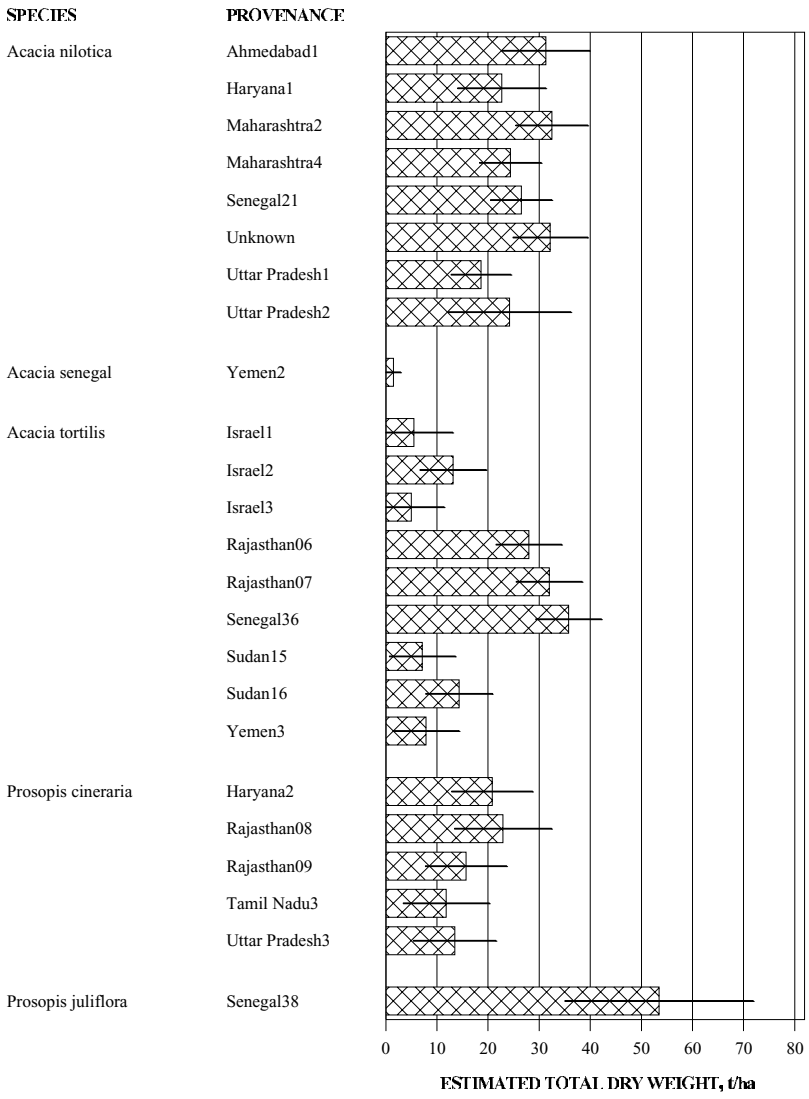


Figure 32. Total dry weight in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.8 Total dry weight

As with the total basal area, the total dry weight includes missing trees and gives the best measure of the actual production of biomass on the site.

Statistical analysis

Though there were no signs of variance heterogeneity in the analysis of species differences, residuals from the analysis of provenance differences in *A. nilotica* indicated that there were differences in variance between the provenances. Therefore the data were weighted in the analysis of this species. The co-variates plotx, ploty2 and level were included in the analysis of species differences and in the analysis of *A. nilotica* provenance differences. Only level was significant in the two other tests.

Results

The fastest growing provenance, Senegal38, had produced approximately 53 t dry weight per ha, corresponding to 5.6 t ha^{-1} y^{-1}. Yemen2, at the other end, had produced only 2 t ha^{-1} during the same period (Fig. 32). The differences between species were significant, with *A. nilotica* and *P. juliflora* being the largest, and *A. senegal*, *A. tortilis* and *P. cineraria* the smallest (Table 10). The differences between provenances were significant only in *A. tortilis*, resulting in predicted gains of more than 100 % by choice of the provenance Senegal36 (Fig. 34). For *A. nilotica* and *P. cineraria* the predicted gains by selection of the best provenances were only 3 and 5 %, respectively (Fig. 33 and 35).

Table 10. Results from analysis of variance of provenance differences of total dry weight in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	4; 19.2	1962	7.0	0.001	**
Provenance(species)	19; 63	281	4.8	<0.0001	
Block	3; 64	61	1.0	0.38	
Plotx	1; 64	203	3.4	0.07	
Ploty2	1; 63	200	3.4	0.07	
Level	1; 64	1584	26.8	<0.0001	
Error	64	59			
A. nilotica					
Provenance	7; 17	3.2	2.5	0.06	n.s.
Block	3; 17	3.9	3.1	0.05	
Level	1; 17	7.6	6.0	0.03	
Plotx	1; 17	21.9	17.2	0.0007	
Ploty2	1; 17	34.7	27.3	<0.0001	
Error	17	1.3			
A. tortilis					
Provenance	8; 22	560	14.6	<0.0001	***
Block	3; 22	79	2.1	0.14	
Level	1; 22	293	7.6	0.01	
Error	22	38			
P. cineraria					
Provenance	4; 10	77	1.5	0.27	n.s.
Block	3; 10	95	1.9	0.20	
Level	1; 10	830	16.5	0.002	
Error	10	50			

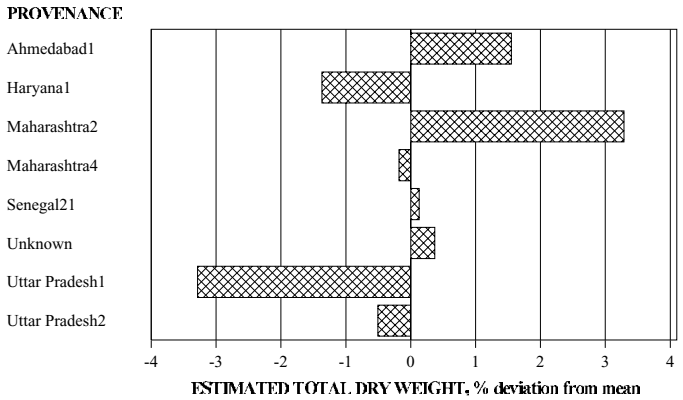


Figure 33. Best linear unbiased predictors (BLUPs) for total dry weight in the *A. nilotica* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

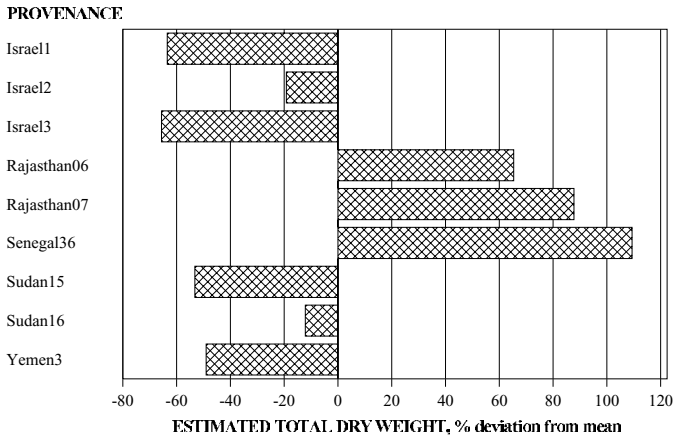


Figure 34. Best linear unbiased predictors (BLUPs) for total dry weight in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

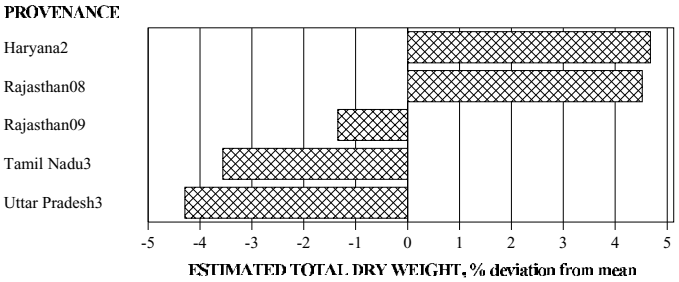


Figure 35. Best linear unbiased predictors (BLUPs) for total dry weight in the *P. cineraria* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations in percent of the mean value.

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 cause of the damage was not specified.

Statistical analysis

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 trees of different species and sizes, because the damage affects the trees differently. Second, the scores are not necessarily equidistant. For the growth of a tree it may mean less going from a damage score of 0 to 1 than going from a score of 1 to 2. There are ways of taking this into account, but this has not been attempted in the current analyses.

Since the provenances had different variances, the data were weighted in the analysis of species differences and in the analyses of provenance differences in *A. tortilis* and *P. cineraria*. No co-variates were significant.

Results

For damage scores, the differences between species were highly significant (Table 11). Within the species, provenance differences were only significant in *P. cineraria* and possibly *A. nilotica* (significance disappears when correcting for multiple tests). With damage scores, the species differences could be an artefact because it is difficult to compare the severity of damage on different species (see above), but in this case it seems that there are indeed differences between the species. *P. chilensis*, *A. cowleana* and *A. holosericea* had scores around 2.5, whereas *A. aneura* had damage scores between 1 and 2 and the rest of the species had scores below 1 and often below 0.5 (Fig. 36). The gains by provenance selection were moderate, between ±0.2 on the damage score scale (Fig. 37-40).

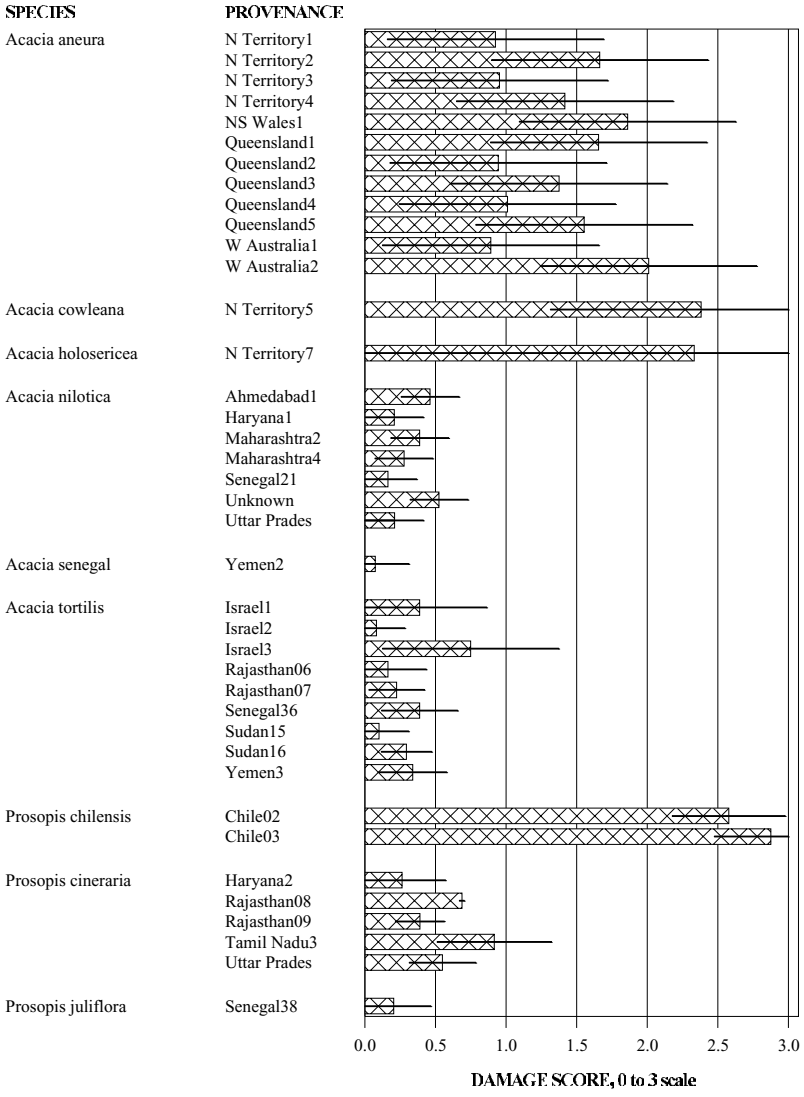


Figure 36. Damage score in the *Acacia* and *Prosopis* species and provenance trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values presented are least square means with 95 % confidence limits. The units are points on the damage score scale, where 0 is a healthy tree and 3 a severely damaged tree.

Table 11. Results from analysis of variance of provenance differences of damage score in trial 24.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	8; 38.1	130.9	74.1	<0.0001	***
Provenance(species)	31; 116	2.0	2.2	<0.001	
Block	3; 116	4.5	5.1	0.002	
Error	116	0.9			
A. aneura					
Provenance	11; 33	0.64	1.1	0.37	n.s.
Block	3; 33	3.31	5.8	0.003	
Error	33	0.57			
A. nilotica					
Provenance	7; 21	0.119	3.1	0.02	n.s.
Block	3; 21	0.064	1.7	0.21	
Error	21	0.039			
A. tortilis					
Provenance	8; 24	1.4	1.3	0.28	n.s.
Block	3; 24	2.4	2.4	0.10	
Error	24	1.0			
P. chilensis					
Provenance	1; 3	0.18	2.8	0.19	n.s.
Block	3; 3	0.02	0.3	0.84	
Error	3	0.06			
P. cineraria					
Provenance	4; 12	6.8	6.5	0.005	*
Block	3; 12	154.0	147.1	<0.0001	
Error	12	1.0			

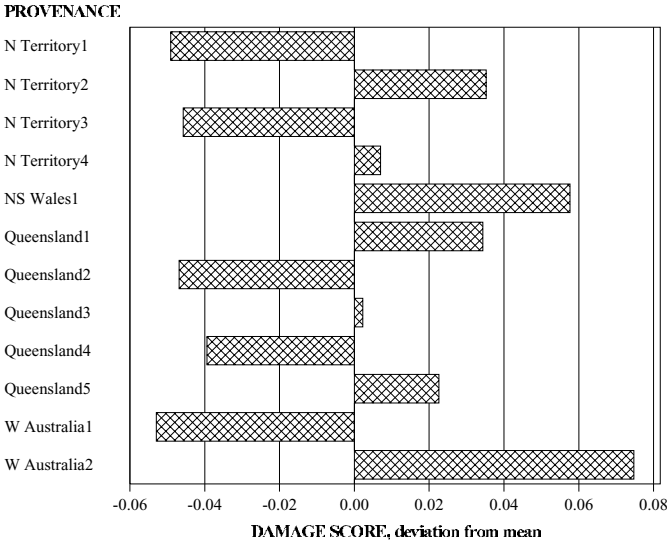


Figure 37. Best linear unbiased predictors (BLUPs) for damage score in the *A. aneura* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations from the mean value. Units are points on the damage score scale.

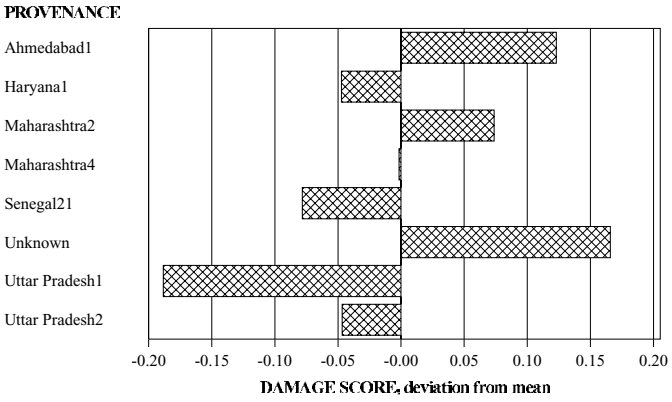


Figure 38. Best linear unbiased predictors (BLUPs) for damage score in the *A. nilotica* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations from the mean value. Units are points on the damage score scale.

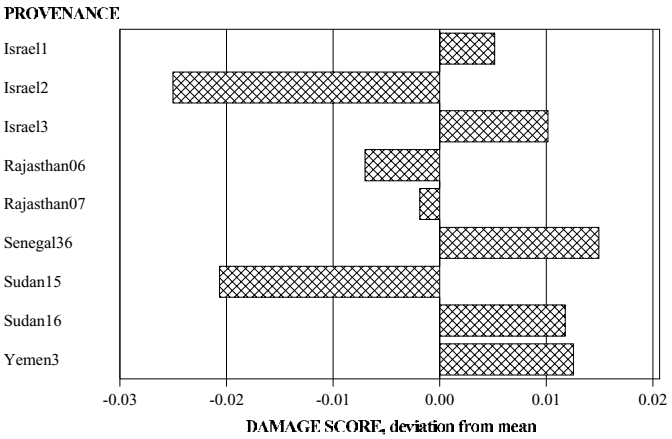


Figure 39. Best linear unbiased predictors (BLUPs) for damage score in the *A. tortilis* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations from the mean value. Units are points on the damage score scale.

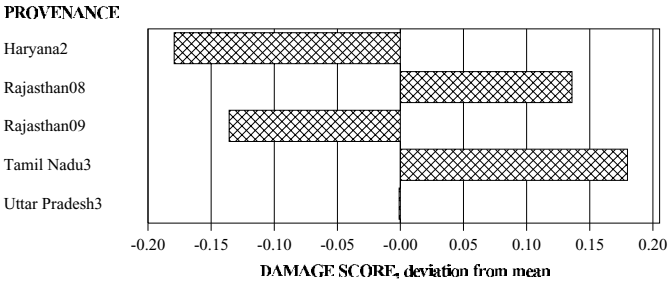


Figure 40. Best linear unbiased predictors (BLUPs) for damage score in the *P. cineraria* provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). Values are presented as deviations from the mean value. Units are points on the damage score scale.

4.10 Multivariate analysis

The multivariate analyses followed the same pattern as the univariate analyses: First an analysis of all provenances together followed by tests of provenances for the single species. It should be noted that the analyses do not account for variance heterogeneity, which was observed in several variables. This means that results from the analyses should be interpreted with caution**.**

Analysis of all provenances

This analysis was performed on the same variables that were analysed in the univariate analyses, excluding the two dry weight variables, which were only available for some of the species.

As much as six of the seven canonical variates were significant (Table 12). In total, the six variates accounted for 99 % of the variation. The differences between the provenances were as expected highly significant (P-values for Wilk's lambda and for Pillai's trace both below 0.0001). As it is difficult to comprehend variation in more than three dimensions, only result for the first three canonical variates are presented. This is justified by the fact that these three canonical variates account for 88 % of the variation.

The plot of scores for the two first canonical variates is given in Fig. 41. 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. It must be stressed that as the diagrams should be seen in combination, a separation between provenances or species in any of the dimensions means that the provenances are different.

With so many species and provenances involved no clear picture emerges, but certain patterns of variation are discernible. In the upper diagram of Fig. 41, two very dense groups are present. The group to the left comprises *A. cowleana*, *A. aneura*, *P. chilensis* and *P. juliflora*. In the lower diagram the group dissolves, leaving the provenances of *A. aneura* in a clump and the other species separated. The second dense group includes the provenances of *A. nilotica* and *P. chilensis*. Apparently, the two species are very similar in their growth at the site, as they do not separate in either of the diagrams. Finally, the upper diagram reveal a less dense band of provenances, stretching from Israel2 to Sudan15. The provenances in this band are *A. tortilis* (with one provenance of *A. senegal*), indicating a large variation between the provenances of this species.

The groupings observed confirm the findings from the univariate analyses, indicating that the species are different with respect to survival, growth, and damage scores. If the species had the same properties, the provenances would be mixed in between each other.

Table 12. Results from the canonical variate analyses for the canonical variates in trial 24. The canonical coefficients and canonical directions are given only for the first three canonical variates.

Canonical variate no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Proportion of variation	0.51	0.24	0.13	0.07	0.03	0.02	0.01
Significance, P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.05	0.58

	Raw canonical coefficients			**Standardised canonical coefficients**			**Canonical directions**		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	0.0033	0.0098	0.028	0.1	0.3	0.8	446	247	1039
Height	-2.2	-0.81	1.1	-3.0	-1.1	1.5	-32	14	27
Crown area	0.048	0.039	0.10	0.5	0.4	1.1	39	204	-27
Number of stems	0.28	-0.71	0.0069	0.9	-2.3	0.02	51	-111	-26
Basal area of mean tree	0.0011	0.017	-0.032	0.1	1.4	-2.7	-11	2396	-419
Total basal area	0.51	-0.070	0.37	1.7	-0.2	1.2	26	86	95
Damage score	-0.76	-0.37	-0.50	-0.7	-0.3	-0.5	-17	-7	-23

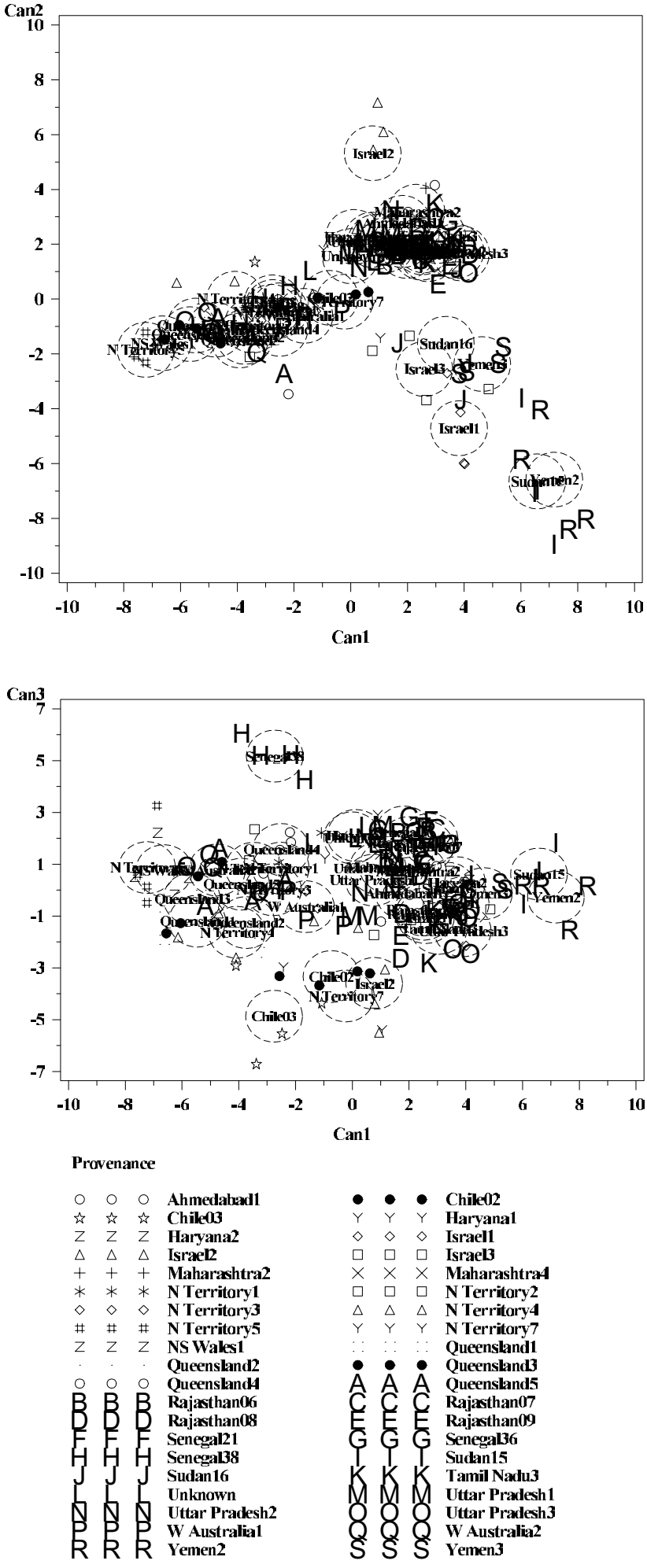


Figure 41. Score plot of the first and the second canonical variate (upper diagram) and of the first and the third canonical variate (lower diagram) from the canonical variate analysis for the provenances in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). The variables survival, height, crown area, number of stems, basal area of the mean tree, total basal area and damage score were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

Analysis of *A. aneura* provenances

Due to lack of regression for calculation of biomass, dry weight of the mean tree and total dry weight were omitted from the analysis**.**

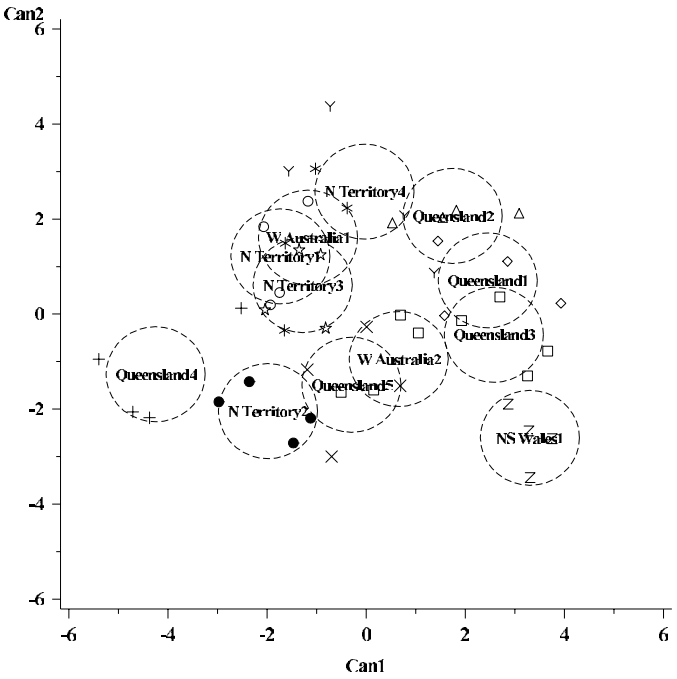
The first two canonical variates were significant, and the third was at the border of significance (Table 13). In total, these canonical variates accounted for 92 % of the variation. Only results for these canonical variates are shown. Again the differences between the provenances were highly significant (P-values for Wilk's lambda and for Pillai's trace both below 0.0001).

The plot of scores for the three first canonical variates is given in Fig. 42. The four easternmost provenances Queensland1, 2, 3 and NS Wales1 are located to the right in the diagrams, but the nearby provenances Queensland4 and 5 are located at the left and in the middle of the cluster. However, the precipitation data demonstrates that the four provenances to the right all have rainfall larger than 350 mm annually, while those in the centre and to the left have precipitation of less than 300 mm (cf. Table 1). Thus there could be a connection between rainfall at the site of origin and the growth at Bandia. This pattern is not observable in any of the univariate analyses, but can be seen only in the multivariate setting.

Table 13. Results from the canonical variate analyses for the first three canonical variates from the analysis of *A. aneura* in trial 24.

Canonical variate no.	**1**	**2**	**3**
Proportion of variation	0.52	0.30	0.10
Significance, P-value	<0.0001	<0.0001	0.06

	Raw canonical coefficients			**Standardised canonical coefficients**			**Canonical directions**		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	-0.17	-0.054	-0.088	-3.3	-1.0	-1.7	-150	-204	133
Height	1.4	-2.2	0.20	1.2	-1.8	0.2	6.6	-3.6	8.9
Crown area	-0.34	0.048	0.23	-1.9	0.3	1.4	-5.9	33.2	108
Number of stems	0.0009	0.38	0.42	0.0008	0.3	0.4	-1.2	3.8	3.9
Basal area of mean tree	-0.014	0.035	-0.050	-0.6	1.5	-2.2	235	280	556
Total basal area	2.4	0.069	1.9	2.8	0.1	2.2	-1.6	-4.8	22.2
Damage score	0.85	-0.40	0.75	0.7	-0.3	0.7	2.9	-4.6	1.9



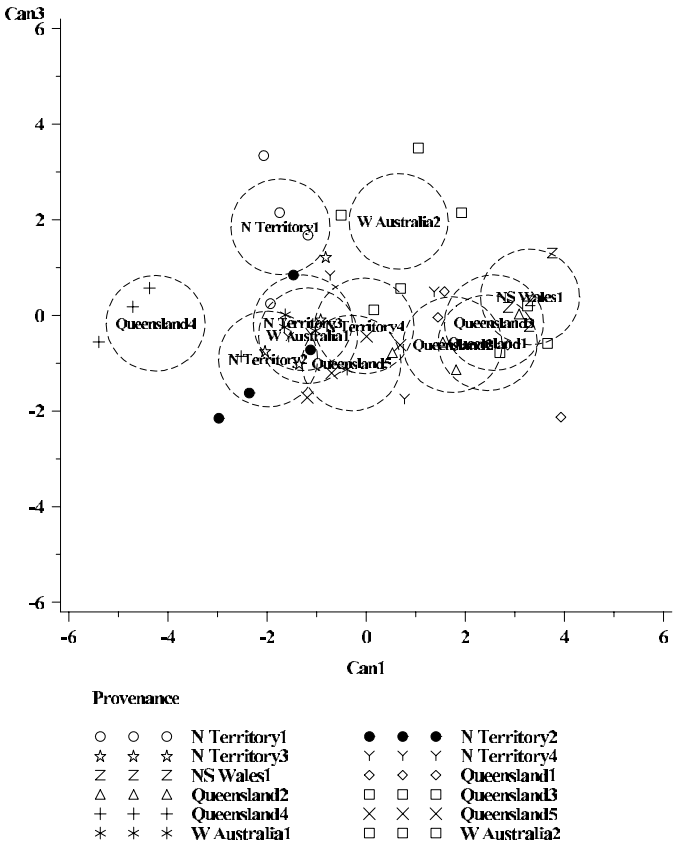


Figure 42. Score plot of the first and the second canonical variate (upper diagram) and of the first and the third canonical variate (lower diagram) from the canonical variate analysis for the provenances of *A. aneura* in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). The variables survival, height, crown area, number of stems, basal area of the mean tree and total basal area were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

Analysis of *A. nilotica* provenances

All variables from the univariate analyses were included in this analysis. The first four canonical variates were significant, but since the fourth did not add substantial new information, we present only results for the three first variates (Table 14). In total, these canonical variates accounted for 89 % of the variation. The differences between the provenances were highly significant (P-values for Wilk's lambda and for Pillai's trace both below 0.0001).

From the plot of scores (Fig. 43) it appears that the group of Indian provenances are located to the left, but the provenance from Senegal and the unknown provenance to the right (upper diagram). In the lower diagram, the unknown provenance and Senegal21 have separated, telling that they are different in some respects. However, even within the provenances from India, there is variation. This cannot be explained by geographical origin or precipitation patterns, and variety differences are not clear either. However, it seems that Maharashtra2 (subsp. *indica* var. *vediana*) is far from the other Indian provenances, including Maharasthra4 (subsp. *indica* var. *cupressiformis*) which was collected at the same site.

Table 14. Results from the canonical variate analyses for the first three canonical variates from the analysis of *A. nilotica* in trial 24.

Canonical variate no.	**1**	**2**	**3**	**4**
Proportion of variation	0.49	0.24	0.17	0.06
Significance, P-value	<0.0001	<0.0001	0.0007	0.05

	Raw canonical coefficients			**Standardised canonical coefficients**			**Canonical directions**		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	0.67	-0.62	-0.38	10.5	-9.8	-6.0	50.6	-10.2	-21.1
Height	1.7	-3.7	2.7	1.4	-3.0	2.2	-0.46	-1.1	6.9
Crown area	0.015	0.34	0.10	0.1	2.1	0.6	-4.5	36.2	37.8
Number of stems	6.4	1.8	1.3	2.4	0.7	0.5	2.3	1.3	0.23
Basal area of mean tree	1.1	-0.77	-0.54	64.9	-45.0	-31.4	-99.0	174.3	325.7
Total basal area	-36.0	25.3	14.9	-91.7	64.4	38.0	-0.42	4.9	11.3
Dry weight of mean tree	-2.4	1.4	1.0	-72.6	42.7	30.1	-46.2	87.3	160.6
Total dry weight	7.5	-4.6	-2.9	92.8	-56.9	-35.6	-5.7	25.8	57.7
Damage score	-1.2	2.0	2.1	-0.3	0.50	0.5	0.22	0.80	1.1

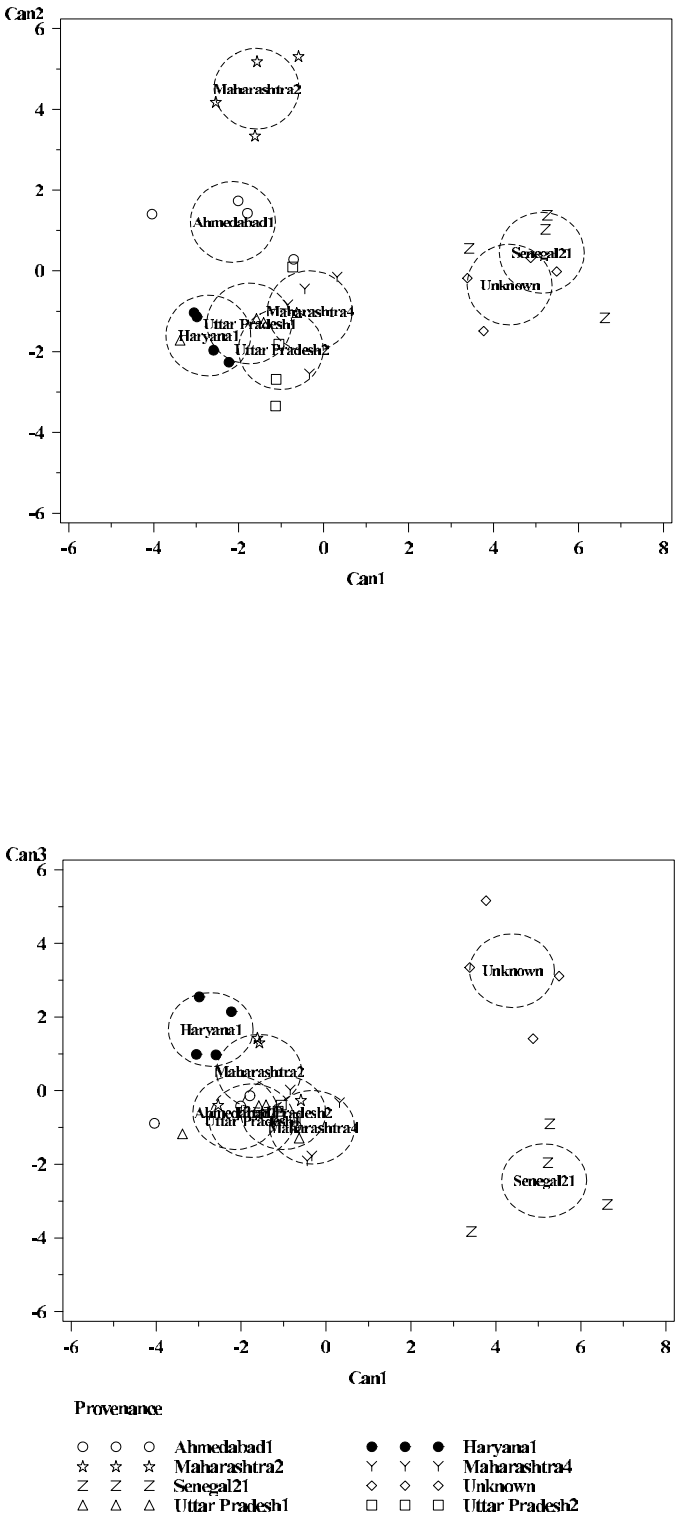


Figure 43. Score plot of the first and the second canonical variate (upper diagram) and of the first and the third canonical variate (lower diagram) from the canonical variate analysis for the provenances of *A. nilotica* in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). All variables were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

Analysis of *A. tortilis* provenances

All variables from the univariate analyses were included in this analysis. Only the first two canonical variates were significant (Table 15). These canonical variates accounted for 85 % of the variation. The differences between the provenances were highly significant (P-values for Wilk's lambda and for Pillai's trace both below 0.0001).

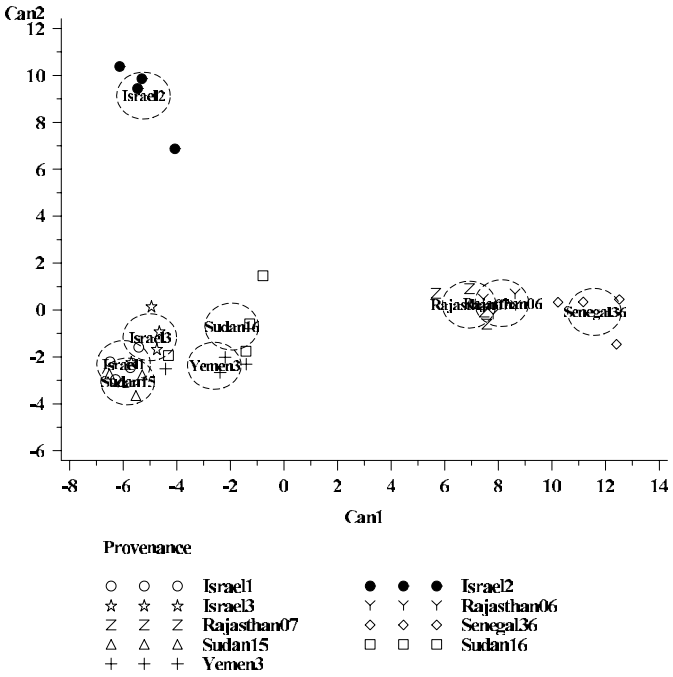
The plot of scores for the two first canonical variates is given in Fig. 44. It seems that there could be three groups: One with Rajasthan6, Rajasthan7 and Senegal36, one with Israel2 alone and one with the rest of the provenances. No clear picture emerges as regards differences between subspecies, since subsp. *raddiana* was present in all three groups. It is conspicous, however, that Israel2 differs considerably from the two other Israeli provenances, even though they were collected at the same location (Table 1). Whereas Israel2 is the subspecies *raddiana*, no information is available for Israel1 and Israel3. Comparing with the precipitation data, it seems that all provenances to the left of the diagram origin in areas with low precipitation (≤200 mm), and that the provenances to the right have higher precipitation (>300 mm). The precipitation data for Senegal34 are not known with certainty, but nowhere in Senegal the precipitation is lower than 300 mm (Pélissier 1983). Thus it could seem that separation along the first canonical variate is due to some reaction on the rainfall patterns.

Table 15. Results from the canonical variate analyses for the first two canonical variates from the analysis of *A. tortilis* in trial 24.

Canonical variate no.	**1**	**2**
Proportion of variation	0.74	0.21
Significance, P-value	<0.0001	<0.0001

	Raw canonical coefficients		**Standardised canonical coefficients**		**Canonical directions**	
Canonical variate no.	**1**	**2**	**1**	**2**	**1**	**2**
Survival	-0.15	0.093	-3.8	2.4	62.2	-91.1
Height	-0.52	0.77	-0.5	0.8	2.4	4.3
Crown area	0.10	-0.18	1.3	-2.3	1.7	77.1
Number of stems	-0.42	-0.14	-1.8	-0.6	-10.3	-17.0
Basal area of mean tree	-0.31	0.39	-30.1	37.5	106.3	570.4
Total basal area	28.3	-8.65	89.9	-27.5	10.1	3.3
Dry weight of mean tree	0.63	-0.68	28.4	-30.8	42.9	267.0
Total dry weight	-5.95	1.58	-81.1	21.6	41.8	18.5
Damage score	0.71	-0.79	0.3	-0.3	-0.1	-0.5

Figure 44. 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 canonical variate analysis for the provenances of *A. tortilis* in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). All variables were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.



Analysis of *P. cineraria* provenances

All variables from the univariate analyses were included in this analysis. Only the first canonical variate was significant in this analysis, accounting for 70 % of the variation (Table 16). However, since the plot of scores (Fig. 16) shows the scores in two dimensions, results from the two first canonical variates are shown. The differences between the provenances were significant (P-value for Wilk's lambda=0.03, P-value for Pillai's trace=0.02).

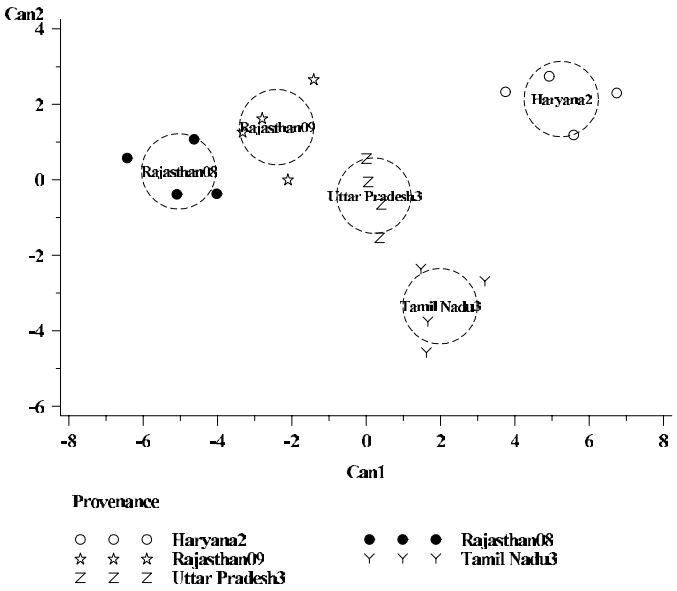
Since only the first canonical variate was significant, only differences along the can1 axis of Fig. 45 should be interpreted. No geographical or correspondence with rainfall patterns is be found. On the contrary it is noteworthy that the provenances Rajasthan09 and Haryana2, their origin being separated by only 150 km, lie quite far from each other in the diagram.

Table 16. Results from the canonical variate analyses for the first two canonical variates from the analysis of *P. cineraria* in trial 24.

Canonical variate no.	**1**	**2**
Proportion of variation	0.70	0.20
Significance, P-value	0.03	0.17

	Raw canonical coefficients		**Standardised canonical coefficients**		**Canonical directions**	
Canonical variate no.	**1**	**2**	**1**	**2**	**1**	**2**
Survival	-0.39	0.06	-5.9	0.9	12.5	31.1
Height	-12.2	4.9	-12.8	5.1	-0.018	1.2
Crown area	0.88	-0.16	4.6	-0.8	1.8	2.3
Number of stems	-1.2	2.8	-0.6	1.3	0.39	1.8
Basal area of mean tree	0.33	-0.08	23.4	-5.6	13.2	15.1
Total basal area	13.1	-3.3	42.6	-10.8	2.0	1.9
Dry weight of mean tree	-1.2	0.01	-27.1	0.3	2.5	3.9
Total dry weight	-2.7	1.2	-27.6	11.8	4.7	4.2
Damage score	-10.6	-1.3	-3.7	-0.5	-0.21	-1.4

Figure 45. 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 canonical variate analysis for the provenances of *P. cineraria* in the trial at Bandia, Senegal (Trial no. 24 in the arid zone series). All variables were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.



5. Discussion and conclusions

Productivity

The height of the fastest growing provenance in this trial (Senegal38, *P. juliflora*) was 8 m, and the corresponding production of dry weight was 5.6 t ha^{-1} y^{-1}. In the arid zone series in Africa, trials have been established under similar climatic conditions in Burkina Faso and Sudan. Nowhere does the production reach such high values even though the rainfall is larger in some trials in Burkina Faso (maximum dry weight production values in both countries were 1.5-2 ha^{-1} y^{-1}). When including trials from India and Pakistan, on the other hand, it appears that some trials have similar or even larger productions of dry weight. One may speculate on the reasons for this large production in comparison with the other African trials. If water is the limiting factor for growth, it could be natural to assume that the water availability is better in this trial, e.g. by the ground water being close to the surface, or that the soil has a high water holding capacity. However, as the indications are that there is hardpan in the soil (see annex 1), it appears that the space for root growth is limited. Another reason could be that the average temperatures are more moderate in Senegal due to the proximity to the Atlantic ocean. Lower temperatures during the growth season would probably mean a higher net photosynthesis due to smaller respiratory losses. However, soil physical and chemical properties may also play a role.

Species differences

There were clear differences between the species in the trial. However, recommending one species in favour of the others is difficult, because there is a large variation within the species (some provenances may have an outstanding performance while others are mediocre), but also because the products from the different species may be different. However, it seems that *A. aneura* has a rather low survival compared to other species, and also a large number of fallen trees in the plot indicate that the species has a problem with the stability at the site. The species also had a relatively high damage score.

Some provenances of *A. tortilis* and the provenance of *A. senegal* had large number of stems, which may be an advantage in the production of livestock fodder. When it comes to dry weight production, the best provenances were found in *P. juliflora*, *A. nilotica* and *A. tortilis*. Species with a low production were *A. aneura*, *A. holoserica*, *A. senegal* and perhaps *P. chilensis*, even though it should be remembered that many of these species were represented with only a few provenances that may not be representative for the full potential of the species.

Provenance differences within species

Acacia aneura

The univariate analyses indicated that there are differences between the provenances in several aspects, and this was later confirmed by the multivariate test. From the multivariate test it also appeared that the gradient in precipitation of the sites of origin was a determinant for the growth at the site, but that there is no simple connection is illustrated by the fact that this pattern was not recognisable in the univariate analyses. The provenances originating in areas with high rainfall were situated in the one side of the group of provenances in the multivariate analysis. It is interesting that this pattern prevailed over the variation caused by geographic distances. The provenances from Queensland, though being located within a small area, was showing a tremendous variation. Yet another thing of interest is that the differences between Queensland4 and Queensland5 can be explained neither by the precipitation data nor by the geographical distance between the provenances.

With regard to choice of provenances, it seems that the most productive provenances were N Territory1 and in particular W Australia2. These provenances were among the best both with respect to survival, height, basal area and crown area.

Acacia nilotica

Referring to the discussion on variety differences in the beginning, this trial brings no solution. It could be expected that if the subspecies *indica* var. *jaquemontii* was a separate species, it would also show up separately in the analyses, but this was not the case. On the other hand, the multivariate analysis indicated that the single provenance of the subspecies *indica* var. *vediana* was separated from the other provenances, and even from a provenance of the subspecies *indica* var. *cupressiformis* with the same origin.

The provenance from Senegal (Senegal21) and the unknown provenance was clearly separated from the rest of the provenances. The local provenance had the best survival, but a poor performance in most of the other variables, and it seemed that many of the Indian provenances were better or at least just as good. Of these, Maharashtra2 had the highest dry weight. It must be stressed, however, that differences in this species were small and often not significant, thus weakening the conclusions.

Acacia tortilis

This species was the most variable in the trial, and the differences were highly significant in all variables except damage score, where no significant differences were found.

Israel2 had a very different growth habit than the other provenances (including those from Israel), with large crowns, basal areas of the mean tree but also a low survival. As mentioned previously, the low survival could be a cause of the large crowns and basal areas. However, there is no doubt that Israel2 (subsp. *raddiana*) differs from the other two provenances from Israel, which have much higher numbers of stems.

Apart from the enormous crowns, mean basal areas and mean dry weights of Israel2, the overall best provenances were Rajasthan06, Rajasthan07 and Senegal36. These provenances had the largest survivals, heights, total basal areas and total dry weights and were thus the best producers of biomass. They originate in areas where the rainfall match the rainfall of Bandia, whereas the provenances with a poorer performance come from areas with low rainfall compared to the trial site.

Prosopis chilensis

No significant difference between the two provenances were found in this trial.

Prosopis cineraria

In the univariate analyses, only height was significant. In this character Rajasthan08 was the best. In the multivariate analysis, the provenances also turned out to be different. Judged from the overall performance of the provenances, the ones producing the largest biomass seem to be Haryana2 and Rajasthan08.

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Annex 1. Description of the trial site

Name of site:	Bandia Latitude: 14°30'N Longitude: 17°W Altitude: approx 50-100 m
Meteorological stations:	Bandia (Cazet and Sadio 1988) Mbour/bac Colorado (Cazet and Sadio 1988) Dakar-Yoff (14°44'N, 17°30'W, 24 m (FAO 1984))
Rainfall (Bandia):	Annual mean (period): 406 mm/year (1976-1986) 436 mm/year (1984-1993) Yearly registrations: 1984: 301.2 1985: 506.5 1986: 402.8 1987: 513.5 1988: 600.7 1989: 621.2 1990: 291.4 1991: 370.8 1992: 383.0 1993: 367.5 Month of establishment (August 1984): 72.8 mm ETP (evapotranspiration): ca. 2000 mm
Rainy season:	6-10 (June-October) Type: Normal with dry period (FAO 1984) Length (days): Approx 30 intermediate days and 50 wet days (FAO 1984)
Dry months/year:	No. of dry months (< 50 mm): 9 No. of dry periods: 1
Temperature:	Annual mean: approx 25 Coldest month: approx 15 Hottest month: approx 30
Wind:	Prevailing directions: N-NW humid trade wind (Alizé maritime) Speed: approx 2-3 m/s
Topography:	Flat/gentle. "Wadi" ("Talweg") B1 East - B2 North-East (Cazet and Sadio 1988).
Soil (Cazet and Sadio 1988):-	Type: Ferruginous tropical soil, high clay contents, deposits, low organic matter, neutral-alkaline Depth: 1.5 m (hard pan)
Climatic/agroecological zone:	Sahelo-Sudanian Zone, maritime influence, semi-arid.
Koeppen classification:	BSh
Dominant natural vegetation:	*Adansonia digitata*, *Acacia seyal*

Annex 2. Seedlots tested in trial no. 24 at Bandia, Senegal

The plot numbers refer to the location in the field, see annex 3. Species codes: aan=*A. aneura*, aco=*A. cowleana*, aho=*A. holosericea*, aniinja=*A. nilotica* var. *jaquemontii*, aniincu=*A. nilotica* var. *indica cupressiformis*, aniinve= *A. nilotica* var. *indica vediana*, ani= *A. nilotica*, ato=*A. tortilis*, atora=*A. tortilis* var. *raddiana*, atosp=*A. tortilis* var. *spirocarpa*, pch=*P. chilensis*, pci=*P. cineraria*, pju=*P. juliflora*.

Seedlot numbers					Provenance information						
Provenance i dentifiaction	Plot	DFSC	Ctr. of origin	Species code	Provenance site	Country of origin	Latitude	Longi-tude	Alti-tude (m)	Rain-fall (mm)	No. of mother trees
N Territory1	30		13716	aan	Alice Springs, Nt	Australia	23 28 S	133 17 E	650	264	10
N Territory2	31		13719	aan	Vaughan Springs, Nt	Australia	22 12 S	130 55 E	600	264	10
N Territory3	32		13720	aan	Floodout, Nt	Australia	21 47 S	131 09 E	580	264	10
N Territory4	33		13722	aan	Glen Helen, Nt	Australia	23 47 S	132 27 E	650	264	10
NS Wales1	29		12791	aan	Cobar, Nsw	Australia	31 31 S	145 45 E	180	355	10
Queensland1	26		13267	aan	Morven, Qld	Australia	26 25 S	146 55 E	440	501	8
Queensland2	28		13480	aan	St. George, Qld	Australia	27 53 S	148 43 E	210	513	10
Queensland3	27		13481	aan	Charleville	Australia	26 25 S	146 17 E	300	501	10
Queensland4	24		13489	aan	Mt. Howitt, Qld	Australia	26 47 S	142 13 E	180	291	10
Queensland5	25		13490	aan	Eromanga, Qld	Australia	26 22 S	143 09 E	180	291	10
W Australia1	34		12838	aan	Kalgoorlie, Wa	Australia	30 45 S	121 30 E	400	247	
W Australia2	35		14079	aan	Jameson, Wa	Australia	25 54 S	126 31 E	440	213	10
N Territory5	37		13774	aco	Vaughan Springs	Australia	22 12 S	130 55 E	600	264	
N Territory7	36		13771	aho	Vaughan Springs	Australia	22 12 S	130 55 E	600	264	
Ahmedabad1	5	1076/82		aniinja	Kutch (Bhuj)	India	23 50 N	69 48 E	80	349	25
Haryana1	1	1081/82		aniincu	Nornaul Singhana (Mahandra Gahr) Bhiwani (Hissar)	India	28 03 N	76 07 E	250	714	4
Maharashtra2	6	1071/82		aniinve	Pune	India	18 32 N	73 51 E	559	715	25
Maharashtra4	2	1082/82		aniincu	Pune	India	18 32 N	73 51 E	559	714	25
Senegal21	39		81/443	ani	St-Louis	Senegal					
Unknown	14	1062/82	(1)	ani							
Uttar Pradesh1	3	1069/82		aniinja	Bawain Forest Block, Etawah (Mainpuri),	India	26 45 N	79 00 E	157	762	26

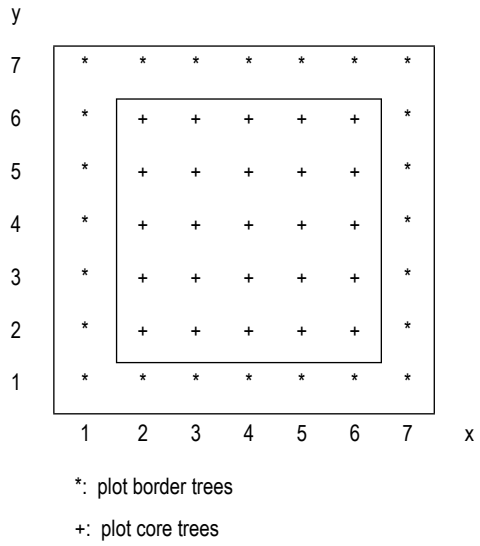
Seedlot numbers					Provenance information						
Provenance i dentifiaction	Plot	DFSC	Ctr. of origin	Species code	Provenance site	Country of origin	Latitude	Longi-tude	Alti-tude (m)	Rain-fall (mm)	No. of mother trees
Uttar Pradesh2	4	1073/82		aniinja	Ajamgarh	India	26 03 N	83 30 E	78	1047	21
Yemen2	8	1063/82	(2)	ase	Ahwar	Yemen	13 25 N	46 40 E	500	225	20
Israel1	11	1012/81		ato	Ein-Hazeva, Arava	Israel	30 47 N	35 12 W	100	40	
Israel2	7	1013/81		atora	Ein-Hazeva, Arava	Israel	30 47 N	35 12 W	100	40	
Israel3	12	1066/82		ato	Ein-Hazeva, Arava	Israel	30 47 N	35 12 W	100	40	60
Rajasthan6	9	1085/82		ato	Ramgaon, Barmer	India	25 45 N	71 23 E	194	310	50
Rajasthan7	10	1086/82		ato	Jodhpur	India	26 18 N	73 01 E	224	380	8
Senegal36	38		82/599	atora	Niomé ?, Louga	Senegal	15 42 N	16 10 W		350	
Sudan15	16	1045/82	3/82	atosp	Khartoum, West Nile	Sudan	15 36 N	32 33 E	330	165	25
Sudan16	15	1047/82	1/1982	atora	Khartoum, West Nile	Sudan	15 36 N	32 33 E	330	165	25
Yemen3	3	1065/82	(4)	ato	Ahwar	Yemen	13 25 N	46 40 E	200	150	25
Chile2	17	1027/82		pch	Rio Pama	Chile	31 09 S	71 04 W		250	26
Chile3	18	1028/82		pch	C.A. Mt.Patria	Chile	30 39 S	71 58 W		175	25
Haryana2	19	1087/82		pci	Khora-Ahamad, Bhiwani (Hissar)	India	28 45 N	76 10 E	250	446	5
Rajasthan8	22	1090/82		pci	Sidhari-Guda, Barmer	India	25 45 N	71 23 E	194	310	20
Rajasthan9	23	1091/82		pci	Jhunjhunu	India	28 10 N	75 15 E	338	648	27
Tamil Nadu3	21	1089/82		pci	Krishnapuram, Trichy	India	10 46 N	78 43 E	88	876	27
Uttar Pradesh3	20	1088/82		pci	Yamuna/ Chambal, Etawah	India	27 14 N	79 03 E	157	762	30
Senegal38	40		746/82	pju	THIES	SENEGAL	14 48 N	16 54 W		300	

Annex 3. Layout of blocks and plots in the field

The provenances are indicated by the plot numbers given in annex 2. The plots denoted 'mix' are not included in the analyses.

y							
29	39	21	9	6	1	30	
28	32	3	4	8	26	5	
27	29	31	34	33	18	15	
26	13	7	10	40	35	25	BLOCK 1
25	28	38	19	16	27	17	
24	20	24	12	36	23	14	
23	2	22	11	37	MIX	MIX	
22	24	18	8	36	31	34	
21	40	39	13	37	30	22	
20	10	5	32	23	7	19	
19	35	11	15	2	21	26	BLOCK 2
18	16	20	14	29	1	38	
17	4	9	3	27	33	12	
16	6	25	17	28	MIX	MIX	
15							
14	20	26	38	28	6	36	
13	30	29	40	5	31	7	
12	24	33	14	15	23	3	
11	1	9	21	2	25	18	BLOCK 3
10	32	12	17	19	39	33	
9	10	22	27	37	16	11	
8	8	4	34	13	MIX	MIX	
7	13	11	26	7	14	15	
6	27	17	36	10	21	38	
5	9	5	29	40	35	32	
4	19	34	12	39	24	1	BLOCK 4
3	23	25	37	30	33	16	
2	2	18	8	28	30	31	
1	4	22	6	3	MIX	MIX	
	1	2	3	4	5	6	x

Individual tree positions in each plot:



Annex 4. Plot data set

Species codes: aan=*A. aneura*, aco=*A. cowleana*, aho=*A. holosericea*, aniinja=*A. nilotica* subsp. *indica* var. *jaquemontii*, aniincu=*A. nilotica* subsp. *indica* var.*cupressiformis*, aniinve= *A. nilotica* subsp. *indica* var. *vediana*, ani= *A. nilotica*, ato=*A. tortilis*, atora=*A. tortilis* subsp. *raddiana*, atosp=*A. tortilis* subsp. *spirocarpa*, pch=*P. chilensis*, pci=*P. cineraria*, pju=*P. juliflora*.

Block	Plot	Plotx	Ploty	Level	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area of the mean tree	Total basal area	Dry weight of the mean tree	Total dry weight	Damage score
							%	m	m^2 $tree^{-1}$	no $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	
1	1	5	29	-1.23	aniincu	Haryana1	80	6.15	27.5	1.2	268	10.58	114	44.9	0.00
1	2	1	23		aniincu	Maharashtra4	72	4.46	20.5	1.6	142	5.04	51	18.0	0.33
1	3	2	28	-0.48	aniinja	Uttar Pradesh1	36	4.22	20.6	1.1	154	2.73	55	9.8	0.00
1	4	3	28	-0.93	aniinja	Uttar Pradesh2	76	4.44	20.2	1.5	145	5.43	51	19.1	0.32
1	5	6	28	-1.27	aniinja	Ahmedabad1	76	5.67	33.3	1.5	321	12.04	145	54.4	0.16
1	6	4	29	-1.27	aniinve	Maharashtra2	84	5.63	29.7	1.6	262	10.86	109	45.2	0.38
1	7	2	26	-0.89	atora	Israel2	36	5.10	31.7	2.6	246	4.36	105	18.7	0.33
1	8	4	28	-1.58	ase	Yemen2	8	2.00	15.1	15.5	26	0.10	6	0.2	0.00
1	9	3	29	-0.73	ato	Rajasthan06	92	4.13	19.5	1.9	130	5.89	50	22.6	0.00
1	10	3	26	-1.15	ato	Rajasthan07	84	4.77	23.3	2.3	171	7.11	69	28.6	0.00
1	11	3	23		ato	Israel1	60	3.09	10.9	7.1	54	1.59	19	5.5	0.33
1	12	3	24	-0.78	ato	Israel3	52	2.95	10.5	4.8	60	1.43	22	5.1	1.50
1	13	1	26	-0.65	ato	Yemen3	52	2.92	17.3	7.5	62	1.60	22	5.6	0.46
1	14	6	24	-1.28	ani	Yemen4	68	5.75	29.1	2.2	214	7.18	87	29.2	0.24
1	15	6	27	-0.73	atora	Sudan16	60	3.97	27.5	4.5	190	5.64	80	23.7	0.33
1	16	4	25	-1.32	atosp	Sudan15	76	3.28	21.1	17.0	75	2.81	27	10.1	0.00
1	17	6	25	-1.14	pch	Chile02	36	4.51	15.9	3.7	200	3.56			2.67
1	18	5	27	-1.07	pch	Chile03	12	5.33	28.2	4.0	314	1.86			3.00
1	19	3	25	-0.90	pci	Haryana2	84	3.15	9.1	2.9	107	4.43	23	9.5	0.14
1	20	1	24	-0.54	pci	Uttar Pradesh3	80	3.41	12.2	2.5	152	6.02	40	15.9	0.55
1	21	2	29	-0.41	pci	Tamil Nadu3	40	2.22	5.4	1.7	63	1.12	11	2.0	1.09
1	22	2	23		pci	Rajasthan08	88	2.14	5.1	2.0	61	2.67	13	5.6	0.68
1	23	5	24	-1.69	pci	Rajasthan09	72	5.78	25.9	2.0	295	10.48	86	30.6	0.22
1	24	2	24	-0.59	aan	Queensland4	76	5.16	9.9	5.4	60	2.24			1.47
1	25	6	26	-1.00	aan	Queensland5	52	5.72	9.2	1.1	75	1.93			1.15
1	26	5	28	-1.46	aan	Queensland1	12	6.30	14.3	3.0	155	0.92			2.33
1	27	5	25	-1.87	aan	Queensland3	20	6.12	13.0	2.0	143	1.41			2.00
1	28	1	25	-0.65	aan	Queensland2	32	4.83	7.1	4.1	125	1.98			2.88

Block	Plot	Plotx	Ploty	Level	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area of the mean tree	Total basal area	Dry weight of the mean tree	Total dry weight	Damage score
							%	m	m^2 $tree^{-1}$	no $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	
1	29	1	27	-0.51	aan	NS Wales1	28	5.73	6.4	1.4	70	0.97			2.43
1	30	6	29	-1.25	aan	N Territory1	36	5.91	23.7	3.0	174	3.09			1.11
1	31	2	27	-0.55	aan	N Territory2	60	4.75	5.0	2.8	56	1.66			2.73
1	32	1	28	-0.17	aan	N Territory3	32	4.03	7.2	2.0	56	0.89			1.00
1	33	4	27	-1.76	aan	N Territory4	24	5.73	26.0	2.5	221	2.61			2.50
1	34	3	27	-1.02	aan	W Australia1	52	4.61	9.3	2.5	76	1.94			1.92
1	35	5	26	-1.11	aan	W Australia2	48	5.78	17.2	2.1	105	2.48			2.58
1	36	4	24	-1.16	aho	N Territory7	4	2.50	22.9	1.0	87	0.17			3.00
1	37	4	23	-1.29	aco	N Territory5	8	6.20	22.4	1.5	113	0.45			3.00
1	38	2	25	-0.73	atora	Senegal36	96	4.88	20.2	1.7	166	7.88	66	31.3	0.04
1	39	1	29	0.00	ani	Senegal21	100	4.06	17.9	2.3	115	5.70	38	18.9	0.00
1	40	4	26	-1.57	pju	Senegal38	96	8.43	22.2	3.0	227	10.74	107	50.9	0.04
2	1	5	18	-1.47	aniincu	Haryana1	80	5.70	24.8	1.2	209	8.28	81	32.2	0.25
2	2	4	19	-1.67	aniincu	Maharashtra4	76	4.88	24.0	1.4	186	6.99	70	26.4	0.00
2	3	3	17	-1.58	aniinja	Uttar Pradesh1	88	4.78	23.9	1.2	157	6.83	56	24.5	0.00
2	4	1	17	-1.02	aniinja	Uttar Pradesh2	56	3.67	10.5	1.1	76	2.10	22	6.1	0.00
2	5	2	20	-0.64	aniinja	Ahmedabad1	52	3.80	20.1	1.5	151	3.89	55	14.1	0.69
2	6	1	16	-1.07	aniinve	Maharashtra2	64	3.79	29.9	1.3	151	4.79	56	17.7	0.50
2	7	5	20	-1.72	atora	Israel2	4	4.40	70.9	2.0	318	0.63	138	2.7	0.00
2	8	3	22	-0.89	ase	Yemen2	76	2.11	12.9	11.9	23	0.86	5	2.0	0.30
2	9	2	17	-1.32	ato	Rajasthan06	72	4.40	24.7	2.5	150	5.33	58	20.8	0.39
2	10	1	20	-0.74	ato	Rajasthan07	88	3.75	16.4	2.2	124	5.40	48	20.8	0.09
2	11	2	19	-1.01	ato	Israel1	56	2.64	8.1	8.6	30	0.83	9	2.6	0.00
2	12	6	17	-1.06	ato	Israel3	40	3.42	14.1	8.3	76	1.50	28	5.5	0.00
2	13	3	21	-0.86	ato	Yemen3	80	2.12	14.9	6.9	50	1.88	17	6.4	0.15
2	14	3	18	-1.36	ani	Yemen4	80	4.69	24.3	2.1	155	6.12	58	22.8	0.45
2	15	3	19	-0.90	atora	Sudan16	72	3.67	14.7	5.2	73	2.46	27	9.0	0.28
2	16	1	18	-1.16	atosp	Sudan15	92	2.33	10.2	13.7	39	1.78	13	5.8	0.26

Block	Plot	Plotx	Ploty	Level	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area of the mean tree	Total basal area	Dry weight of the mean tree	Total dry weight	Damage score
							%	m	m^2 $tree^{-1}$	no $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	
2	17	3	16	-1.55	pch	Chile02	28	4.93	25.9	4.0	210	2.90			2.71
2	18	2	22	-0.58	pch	Chile03	24	4.53	11.7	3.7	217	2.57			2.50
2	19	6	20	-1.55	pci	Haryana2	92	4.55	20.0	2.8	255	11.58	70	31.7	0.35
2	20	2	18	-1.29	pci	Uttar Pradesh3	56	2.23	6.1	1.6	83	2.30	20	5.4	0.00
2	21	5	19	-1.56	pci	Tamil Nadu3	80	3.45	13.0	1.8	156	6.17	38	14.8	0.55
2	22	6	21	-1.66	pci	Rajasthan08	92	5.08	16.5	1.6	256	11.62	71	32.0	0.43
2	23	4	20	-1.21	pci	Rajasthan09	84	2.50	8.6	2.3	70	2.92	13	5.4	0.19
2	24	6	22	-1.30	aan	Queensland4	72	4.74	14.7	1.2	74	2.65			1.33
2	25	2	16	-1.18	aan	Queensland5	44	4.82	5.2	4.4	61	1.32			0.36
2	26	6	19	-1.26	aan	Queensland1	28	4.60	11.3	1.4	113	1.56			1.71
2	27	4	17	-2.01	aan	Queensland3	8	5.70	9.4	1.0	59	0.23			0.00
2	28	4	16	-1.83	aan	Queensland2	24	5.25	10.9	2.8	136	1.61			0.33
2	29	4	18	-1.72	aan	NS Wales1	40	6.18	11.3	1.9	118	2.33			1.10
2	30	5	21	-1.73	aan	N Territory1	44	5.77	27.0	2.9	163	3.55			0.36
2	31	5	22	-1.87	aan	N Territory2	72	5.68	14.9	1.3	106	3.78			0.61
2	32	3	20	-0.62	aan	N Territory3	44	4.15	8.5	1.7	56	1.23			0.55
2	33	5	17	-1.36	aan	N Territory4	12	6.33	20.0	1.3	190	1.13			0.67
2	34	1	22	-0.45	aan	W Australia1	28	3.53	4.6	2.3	49	0.68			0.14
2	35	1	19	-0.87	aan	W Australia2	60	4.79	6.5	3.0	76	2.25			2.00
2	36	4	22	-1.28	aho	N Territory7	4	3.30	10.8	1.0	38	0.08			3.00
2	37	4	21	-1.29	aco	N Territory5	24	6.25	16.8	1.7	83	0.98			2.50
2	38	6	18	-0.99	atora	Senegal36	92	4.83	19.3	1.5	164	7.43	65	29.6	0.35
2	39	2	21	-0.44	ani	Senegal21	88	3.61	17.9	2.2	120	5.22	40	17.6	0.45
2	40	1	21	-0.38	pju	Senegal38	100	6.51	19.8	3.3	175	8.64	77	38.2	0.36
3	1	1	11	-2.00	aniincu	Haryana1	68	5.80	27.7	1.1	201	6.73	77	25.9	0.59
3	2	4	11	-1.35	aniincu	Maharashtra4	84	4.69	16.0	1.4	188	7.80	74	30.7	0.48
3	3	6	12	-0.37	aniinja	Uttar Pradesh1	40	4.38	18.9	1.1	131	2.59	45	8.8	0.00
3	4	2	8	-1.66	aniinja	Uttar Pradesh2	76	5.86	27.9	1.1	300	11.28	139	52.3	0.53
3	5	4	13	-1.39	aniinja	Ahmedabad1	76	4.63	17.5	1.5	174	6.52	65	24.5	0.47

Block	Plot	Plotx	Ploty	Level	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area of the mean tree	Total basal area	Dry weight of the mean tree	Total dry weight	Damage score
							%	m	m^2 $tree^{-1}$	no $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	
3	6	5	14	-0.82	aniinve	Maharashtra2	52	4.40	33.3	2.0	227	5.82	92	23.6	0.31
3	7	6	13	-0.39	atora	Israel2	16	4.73	49.3	1.3	320	2.53	140	11.1	0.00
3	8	1	8	-1.17	ase	Yemen2	92	1.96	12.3	9.7	22	1.01	5	2.3	0.00
3	9	2	11	-2.02	ato	Rajasthan06	88	5.41	26.6	2.0	237	10.30	100	43.3	0.14
3	10	1	9	-1.35	ato	Rajasthan07	84	4.56	26.0	2.4	186	7.70	76	31.5	0.57
3	11	6	9	-0.85	ato	Israel1	72	3.44	11.9	11.0	54	1.90	18	6.5	0.22
3	12	2	10	-1.88	ato	Israel3	28	4.01	22.6	5.6	114	1.57	44	6.0	1.14
3	13	4	8	-1.90	ato	Yemen3	48	3.33	24.7	7.8	104	2.47	39	9.2	0.75
3	14	3	12	-1.64	ani	Yemen4	76	6.62	27.5	1.9	240	9.02	100	37.7	0.74
3	15	4	12	-1.26	atora	Sudan16	56	3.26	15.9	8.6	88	2.44	34	9.3	0.57
3	16	5	9	-0.86	atosp	Sudan15	84	2.21	9.5	8.9	42	1.76	14	5.7	0.14
3	17	3	10	-2.07	pch	Chile02	64	4.89	14.7	3.6	242	7.65			2.50
3	18	6	11	-0.73	pch	Chile03	40	4.60	19.3	3.8	217	4.28			3.00
3	19	4	10	-1.44	pci	Haryana2	96	3.93	10.8	2.3	164	7.44	41	18.5	0.17
3	20	1	14	-1.38	pci	Uttar Pradesh3	71	2.55	9.4	3.0	112	3.75	27	9.1	0.82
3	21	3	11	-2.07	pci	Tamil Nadu3	96	3.75	13.7	1.5	193	9.14	50	23.6	1.50
3	22	2	9	-1.76	pci	Rajasthan08	80	4.50	13.8	1.7	196	7.74	51	20.2	0.90
3	23	5	12	-0.60	pci	Rajasthan09	76	2.93	7.8	2.8	88	3.14	18	6.5	0.50
3	24	1	12	-1.70	aan	Queensland4	76	5.08	14.1	1.6	73	2.74			0.79
3	25	5	11	-0.98	aan	Queensland5	64	4.75	4.5	1.6	59	1.86			2.25
3	26	2	14	-1.59	aan	Queensland1	24	6.73	9.4	1.7	136	1.61			0.67
3	27	3	9	-2.09	aan	Queensland3	48	6.40	15.0	2.7	124	2.94			0.67
3	28	4	14	-1.44	aan	Queensland2	28	6.46	15.9	2.7	154	2.13			0.57
3	29	2	13	-1.88	aan	NS Wales1	60	7.55	15.5	1.7	152	4.49			1.07
3	30	1	13	-1.70	aan	N Territory1	84	5.57	18.2	2.1	136	5.64			0.48
3	31	5	13	-0.73	aan	N Territory2	72	4.66	5.3	1.7	58	2.06			2.44
3	32	1	10	-1.43	aan	N Territory3	40	5.20	13.0	1.8	91	1.80			1.00
3	33	6	10	-0.50	aan	N Territory4	36	5.61	12.8	2.0	109	1.93			2.00

Block	Plot	Plotx	Ploty	Level	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area of the mean tree	Total basal area	Dry weight of the mean tree	Total dry weight	Damage score
							%	m	m^2 $tree^{-1}$	no $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	
3	34	3	8	-1.99	aan	W Australia1	52	5.03	13.8	1.8	104	2.66			1.00
3	35	2	12	-1.88	aan	W Australia2	56	6.87	20.5	1.6	168	4.63			1.07
3	36	6	14	-0.48	aho	N Territory7	0					0.00			
3	37	4	9	-1.47	aco	N Territory5	56	7.56	26.6	2.1	137	3.78			1.43
3	38	3	14	-1.93	atora	Senegal36	96	5.10	29.8	1.5	247	11.71	104	49.2	0.63
3	39	5	10	-0.92	ani	Senegal21	100	4.11	19.1	1.8	139	6.88	50	24.6	0.04
3	40	3	13	-2.01	pju	Senegal38	96	8.19	33.0	2.2	274	13.00	135	64.1	0.33
4	1	6	4	-1.65	aniincu	Haryana1	100	5.69	18.5	1.2	188	9.29	71	34.9	0.00
4	2	1	2	0.16	aniincu	Maharashtra4	80	4.27	13.6	1.3	114	4.52	37	14.8	0.30
4	3	4	1	0.06	aniinja	Uttar Pradesh1	76	4.51	19.5	1.3	141	5.29	50	18.8	0.00
4	4	1	1	0.04	aniinja	Uttar Pradesh2	84	4.96	18.2	1.1	132	5.47	45	18.5	0.00
4	5	2	5	-1.12	aniinja	Ahmedabad1	76	4.76	20.6	1.3	215	8.09	86	32.4	0.53
4	6	3	1	0.02	aniinve	Maharashtra2	76	5.38	38.9	1.4	264	9.91	114	42.9	0.37
4	7	4	7	-2.41	atora	Israel2	24	5.65	54.7	2.0	447	5.30	212	25.1	0.00
4	8	3	2	0.01	ase	Yemen2	84	1.98	11.3	16.0	16	0.64	3	1.4	0.00
4	9	1	5	-0.73	ato	Rajasthan06	92	4.79	20.2	2.0	144	6.54	57	25.9	0.13
4	10	4	6	-1.79	ato	Rajasthan07	100	5.42	26.4	1.9	240	11.38	104	49.2	0.24
4	11	2	7	-1.42	ato	Israel1	24	3.12	14.8	12.0	69	0.82	24	2.8	1.00
4	12	3	4	-1.06	ato	Israel3	68	2.51	8.3	8.6	36	1.14	11	3.6	0.35
4	13	1	7	-1.08	ato	Yemen3	68	2.95	18.3	8.2	71	2.38	26	8.6	0.00
4	14	5	7	-1.76	ani	Yemen4	88	6.02	27.2	1.9	224	9.73	94	40.8	0.68
4	15	6	7	-1.07	atora	Sudan16	56	3.60	24.2	8.1	93	2.57	35	9.7	0.00
4	16	6	3	-1.18	atosp	Sudan15	84	2.81	13.1	14.2	43	1.69	14	5.5	0.00
4	17	2	6	-0.94	pch	Chile02	56	3.88	9.9	3.5	157	4.35			2.43
4	18	2	2	0.29	pch	Chile03	16	4.55	4.5	2.3	66	0.52			3.00
4	19	1	4	-0.72	pci	Haryana2	100	4.43	12.5	2.5	187	9.24	47	23.3	0.40
4	20	5	2	-0.53	pci	Uttar Pradesh3	92	2.89	9.5	2.5	118	4.88	27	11.0	0.83
4	21	5	6	-2.12	pci	Tamil Nadu3	76	4.84	17.9	1.7	271	10.16	76	28.4	0.53
4	22	2	1	0.16	pci	Rajasthan08	60	3.80	7.3	2.5	158	4.38	39	10.7	0.73
4	23	1	3	-0.71	pci	Rajasthan09	68	4.24	11.4	2.3	184	5.82	46	14.4	0.65

Block	Plot	Plotx	Ploty	Level	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area of the mean tree	Total basal area	Dry weight of the mean tree	Total dry weight	Damage score
							%	m	m^2 $tree^{-1}$	no $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	t ha^{-1}	
4	24	5	4	-1.33	aan	Queensland4	36	5.20	10.6	1.7	60	1.07			0.44
4	25	2	3	-0.50	aan	Queensland5	36	5.21	5.2	1.2	49	0.88			2.44
4	26	3	7	-1.62	aan	Queensland1	44	6.35	13.7	2.3	142	3.09			1.91
4	27	1	6	-0.65	aan	Queensland3	24	5.78	5.5	1.5	88	1.05			2.83
4	28	4	2	-0.13	aan	Queensland2	12	5.43	8.7	3.0	73	0.43			0.00
4	29	3	5	-0.85	aan	NS Wales1	52	6.85	8.5	1.8	111	2.84			2.85
4	30	4	3	-0.56	aan	N Territory1	48	5.18	10.5	3.1	78	1.84			1.75
4	31	6	2	-0.75	aan	N Territory2	60	5.39	7.3	1.3	65	1.93			0.87
4	32	6	5	-1.50	aan	N Territory3	44	6.52	19.2	1.8	136	2.95			1.27
4	33	5	3	-0.76	aan	N Territory4	16	4.15	9.4	1.5	52	0.41			0.50
4	34	2	4	-1.06	aan	W Australia1	16	4.40	8.9	2.5	59	0.46			0.50
4	35	5	5	-1.70	aan	W Australia2	52	6.94	22.7	2.5	170	4.36			2.38
4	36	3	6	-1.28	aho	N Territory7	4	6.80	89.9	16.0	514	1.02			1.00
4	37	3	3	-0.65	aco	N Territory5	20	6.34	13.5	2.2	73	0.72			2.60
4	38	6	6	-1.42	atora	Senegal36	96	5.44	20.4	1.5	185	8.75	75	35.5	0.54
4	39	4	4	-0.90	ani	Senegal21	100	4.52	20.8	2.2	140	6.93	50	24.5	0.16
4	40	4	5	-1.21	pju	Senegal38	96	8.55	23.7	2.7	261	12.37	128	60.6	0.08