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Trial no. 20 in the arid zone series

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by

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The *Prosopis* trial at Phaltan, India. Superior tree of *Prosopis pallida*, provenance Huayuri (Palpa, Peru).
Phot: Anders Pedersen. 1992.

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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 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 to1994. DFSC is responsible for the reporting of this assessment.

This trial was established and maintained by the Nimbkar Agricultural Research Institute (NARI) Maharashtra in collaboration with Forest Research Institute & Colleges (FRI), Dehra Dun, U.P. India. The assessment team consisted of N. Nimbkar (NARI), Vinod Kumar (FRI), Anders Pedersen (DFSC), and 5 locally employed labourers (Garpat Bhonsale, Sawita Pawar, Vandara Pawar, Gharwat S. J. and Vani S.L.).

The authors wish to acknowledge the help of the personnel at NARI with the establishment, maintenance and assessment of the trials, and thank the personnel of DFSC for their help with the data management and preliminary analyses. Drafts of the manuscript were commented on by Marcus Robbins, consultant to FAO, and Nandini Nimbkar (NARI).

Abstract

This report describes results from a trial with 17 provenances of *Prosopis*, one provenance of *Acacia nilotica* and one provenance of *Leucaena leucocephala*. The *Prosopis* provenances included *P. cineraria* (Pakistan and Yemen, four provenances), *P. flexuosa* (Chile, two provenances), *P. glandulosa var. torreyana* (Mexico, three provenances), a landrace of *P. juliflora* with presumed local origin (India), *P. pallida* (Peru, three provenances), *P. tamarugo* (Chile, three provenances) and four provenances from Mexico and Chile with unknown species identification. The trial was established at Phaltan, India in 1989 with a spacing of 3x3 metres. It was fertilised twice, and irrigated several times during the first years after planting. The intensive tending means that recommendations from the trial should only be used under similar circumstances. The trial was assessed at an age of five years in 1992. Different growth parameters were measured and subjected to analyses of variance and multivariate analyses.

The differences between species were significant for all the analysed variables. *P. tamarugo* and *P. flexuosa* had a very low survival, whereas the rest of the provenances had survivals ranging from 35 % to 95 %. Of the new introductions, *P. pallida* seemed the most promising. However, the overall best performance was found in the local provenances and landraces (*A. nilotica*, *L. leucocephala* and *P. juliflora*). The fastest growing provenances had increment rates in basal area of 1 m^2 ha^{-1} y^{-1}, corresponding to a dry weight production of approximately 3 t ha^{-1} y^{-1}. Differences within species were not significant.

Contents

1. Introduction

This report describes the results from trial no. 20 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).

Many species of the genus *Prosopis* occur naturally in extremely hot and highly arid environments. Only four *Prosopis* species are native to the Old World, and the largest diversity of species is found in South and Central America (Pasiecnik *et al.* 2001). The current trial includes provenance of a range of species, both native species, landraces and new introductions.

The taxonomy of *Prosopis* is difficult and still debated (Ffolliott & Thames 1983, Pasiecnik *et al.* 2001). Especially within the '*Prosopis juliflora-Prosopis pallida*'-complex (a term applied by Pasiecnik *et al.* 2001) mis-identification is frequent. The early literature is more often than not mixing the names of species, and even today the identification should be considered with considerable care. Pasiecnik *et al.* suggest putting emphasise on the geographical origin of seedlots, because this will often indicate to which species the seedlot belongs. Although care has been taken in assuring the correct species names in this trial, a critical attitude to the species names may be appropriate.

Apart from the two provenances of *Acacia nilotica* and *Leucaena leucocephala* that are included as controls, the provenances in this trial all belong to the *Prosopis* genus, and can be divided into groups according to their taxonomic classification. Burkart (1976) places *P. cineraria* in the section *Prosopis*. *P. cineraria* is native to the arid zones of the Arabian Gulf, Pakistan and parts of India (Pedersen 1980, Brown no date). Despite its many potentials as producer of wood and fodder and use in soil amelioration and cultivation of saline soils, little is known on the genetic variation within the species (Leakey & Last 1978).

The provenances from the New World in this trial fall within three sections, section *strombocarpae* (*P. tamarugo*) and section *algarobia*, which is further subdivided into series *Pallidae* (*P. pallida*) and series *Chilensis* (*P. flexuosa*, *P. glandulosa* and *P. juliflora*) (Burkart 1976). Four of the provenances could not be identified to the species level and could thus not be classified. *P. juliflora* was introduced to India before 1900, whereas other *Prosopis* species were introduced during the 20^{th} century. It is believed that early introductions of material from the Americas to India and Pakistan are of narrow genetic origin, and there is a need to examine the potential of this genus in more detail (Pasiecnik *et al.* 2001).

2. Materials and methods

2.1 Site and establishment of the trial

The trial is located at Lundy Farm in Village Rajale, Phaltan (17°55′N, 74°25′E) in India at an altitude of 560 m. The mean annual temperature is approximately 25 °C, and the annual rainfall around 500 mm with a dry period of eight to eleven months.

The trial was established in December 1987. The date of sowing is not known, but for calculations of annual increments it is assumed that the seed were sown in May 1987. Beating up took place in January 1988, and 50 g NPK (19:19:19) was applied to each plant in February 1988. A further 100 g single super phosphate was added in October 1988. The trial was irrigated by flooding 16 times from 1987 to 1991, most intensive during the first years. It was weeded five times during the first three years. Further information is given in the assessment report (DFSC 1994) and summarised in annex 1.

2.2 Species and provenances

The trial includes 22 provenances, of which 20 are of the genus *Prosopis*. The two additional provenances are local seedlots of *Acacia nilotica* and *Leucaena leucocephala*. As mentioned in the introduction, the *Prosopis* provenances include *P. cineraria*, *P. flexuosa*, *P. glandulosa*, *P. juliflora*, *P. pallida*, *P. tamarugo* and four provenances with unknown species identity. 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. The provenances India5, India8 and India9 are local provenances, but their exact origin is not known.

For the provenances Mexico10, Mexico12 and Mexico13 the rainfall data supplied from the seed collectors in Mexico were smaller by a factor 100. However, a comparison with climatic data (FAO 1985) indicated that the data was much too small, and we believe that the difference to the original data is due to a scaling problem. Therefore the data for the these provenances given in table 1 is the original data multiplied by 100, which brings them within the range observed elsewhere in Mexico. Still these data should be considered with care. The provenances of *P. flexuosa*, *P. pallida* and *P. tamarugo* appear to be from areas of extremely low rainfall. This is not necessarily wrong (comparison with the FAO rainfall data confirm the low precipitation for their origin), but could be because these species are able to absorb water from the air under conditions of high air humidity. This is recognised at least for *P. tamarugo* (Burkart 1976, Habit *et al.* 1981).

2.3 The experimental design

The experimental design is a randomised block design with four blocks. Most provenances were represented in all blocks, but some were present in only one, two or three blocks. In one replicate block the provenance is represented by 36 trees in a plot, planted in a square of 6×6 trees. The trees are placed with a spacing of 3×3 m. Only the 16 central trees were assessed. Unfortunately the exact location of the blocks relative to each other is not known, but an attempt at reconstruction is shown in annex 3. Further details are given in DFSC (1994).

2.4 Assessment of the trial

In May 1992 NARI, FRI and DFSC undertook a joint assessment. The assessment included the following characters (DFSC 1994):

- Survival
- Health status
- Length of the stems
- 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 is documented in DFSC (1994). The plot data set on which the statistical analyses in this report are performed is shown in Annex 4. This data set includes directly observed values as well as derived variable values.

Table 1. Species and provenances of *Acacia*, *Leucaena* and *Prosopis* tested in trial no. 20 at Phaltan, India. See text for note on the rainfall data for the Mexican provenances.

Provenance	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
India5	*Acacia nilotica* subsp. *indica*		India					
India8	*Leucaena leucocephala*		India					
NW Frontier1	*Prosopis cineraria*	Darya Khan, Bhakhar	Pakistan	31° 47' N	71° 10' E	200	200	30
Punjab7	*Prosopis cineraria*	Greater Cholistan, Toofan, Bahawalpur	Pakistan	29° -- N	72° – E	160	125	32
Sind09	*Prosopis cineraria*	Islam-Kot, Tharparkar, Registan (Loonio)	Pakistan	24° 40' N	70° 12' E	50	150	25
Yemen4	*Prosopis cineraria*	Khanfar (Aden)	Yemen	13° 00' N	45° 10' E	15	50	20
Chile08	*Prosopis flexuosa*	Barriales Iii	Chile	28° 15' S	70° 32' W	650	15	10
Chile10	*Prosopis flexuosa*	Hacienda Margarita 1	Chile	27° 19' S	70° 40' W		15	11
Mexico03	*Prosopis glandulosa* var. *torreyana*	Concepcion Del Oro	Mexico	24° 49' N	101° 25' W	1650		
Mexico04	*Prosopis glandulosa* var. *torreyana*	Paila, Coahuila	Mexico	25° 28' N	102° 10' W	1150		
Mexico05	*Prosopis glandulosa* var. *torreyana*	Monterrey	Mexico	25° 42' N	100° 20' W	538		
India9	*Prosopis juliflora*							
Peru13	*Prosopis pallida*	Ocucaje (Ica), Zona: Tres Esquinas	Peru	14° 20' S	75° 40' W	420	35	
Peru14	*Prosopis pallida*	Huayuri (Palpa)	Peru	14° 04' S	75° 44' W	391	0	
Peru15	*Prosopis pallida*	San Jacinto De Cachiche, Ica	Peru	13° 45' S	75° 50' W	413	2	
Chile11	*Prosopis sp.*	Colina, Chacabuco	Chile	33° 02' S	70° 45' W	840	306	15
Mexico10	*Prosopis sp.*	Las Posas	Mexico	23° 09' N	110° 04' W		82	
Mexico12	*Prosopis sp.*	El Triunfo, La Paz	Mexico	23° 50' N	110° 12' W		341	
Mexico13	*Prosopis sp.*	San Ignacio	Mexico	27° 15' N	112° 52' W		62	
Chile12	*Prosopis tamarugo*	Bellavista Norte	Chile	19° 55' S	69° 50' W	1150	0	150
Chile13	*Prosopis tamarugo*	La Huayca	Chile	20° 35' S	69° 35' W	1010	0	200
Chile14	*Prosopis tamarugo*	Refresco	Chile	20° 27' S	69° 40' W	978	0	200

3. Statistical analyses

3.1 Variables

In this report the following nine variables are analysed:

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

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

From the assessment data it appeared that for a large number of small trees, predominantly with heights below 1 m, no assessment of diameter, number of stems and crown diameter was made. Of the 711 surviving trees 134 had no measurements of crown area, 224 had no measurements of diameter and 141 had no registration of number of stems. Since omission of these data will produce biased results and lead to an over-estimation of the provenances in question, the values for crown area, basal area and dry weight for these observations have been set to zero. There is no reasonable way to estimate the number of stems of such trees, and no default value has been set for this variable. In any case, the estimates of the variables will be slightly biased, but it is believed that this is to a smaller extent than without the corrections.

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

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

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

$$TreeDW = e^{(2.394\times\ln(basalarea)-2.436)}$$

and for *P. juliflora*

$$TreeDW = e^{(2.466\times\ln(basalarea)-2.036)}$$

Finally, the regression for *P. pallida* was

$$TreeDW = e^{(2.814\times\ln(basalarea)-2.765)}$$

No regressions were available for the other species.

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, σ_e^2).

As some of the blocks were divided into minor blocks, it was tested whether a different arrangement of the blocks (having five instead of four blocks) would improve output for the model. However, for the variable height there were no convincing differences, and it was decided to use the original blocks.

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

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

where X_{jk} is the value of the trait in plot jk, μ is the grand mean, $provenance_j$ is the fixed effect of provenance number j, $block_k$ is the fixed effect of block k, and ε_{jk} is the residual of plot jk and is assumed to follow a normal distribution N(0, σ_e^2). These tests were performed for the species *P. cineraria*, *P. flexuosa*, *P. glandulosa* and *P. pallida*. Because the two provenances of *P. flexuosa* were not present in all blocks, the block effect had to be omitted in the tests for this species. Furthermore a test was performed to see if there were differences between the provenances of the group with unknown species identity (*Prosopis* sp.). This test also followed model (6). No tests were performed for *P. tamarugo*, as only one provenance had surviving trees.

To complement blocks in adjusting for uneven environments, co-variates related to the plot position were included in the initial model. In the initial models, the co-variates were distance along the axes of the blocks, plotx and ploty, and squared values of these distances, plotx2 and ploty2. Since the exact location of the blocks relative to each other was not known, the co-variates were nested within two groups, one consisting of block 1 and 2, the other of block 3 and 4. The co-variates were excluded successively if they were not significant at the 10% level.

Standard graphical methods and calculated standard statistics were applied to test model assumptions of independence, normality and variance homogeneity (Snedecor & Cochran 1980, Draper & Smith 1981, Ræbild *et al.* 2002). Where appropriate, transformations or weighting of data as well as excerption of outliers were performed to fulfil basic model assumptions (ibid., Afifi & Clark 1996). Weighting of data with the inverse of the variance for the seedlots was used to obtain normality of the residuals where the seedlots appeared to have different variances.

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, and the test corresponding to the smallest P value (P_1) was considered significant on a 'table-wide' significance level of α if $P_1 < \alpha/n$, where n is the number of tests. The second smallest P value (P_2) was declared significant if $P_2 < \alpha/(n-1)$, and so on (c.f. Kjær & Siegismund 1996). In this case the number of tests was set to nine, thus equalling the number of variables analysed. The significance levels are indicated by (*) (10%), * (5%), ** (1%), *** (1 ‰) and n.s. (not significant).

Finally the model was used to provide least square means (lsmeans) as estimates for provenance values. A multivariate analysis providing canonical variates, and Wilk's lambda and Pillai's trace statistics, complemented the univariate analyses (Chatfield & Collins 1980, Afifi & Clark 1996, Skovgaard & Brockhoff 1998).

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

4. Results

4.1 Survival

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

Statistical analysis

The analyses were performed on untransformed data. In the test of differences between the provenances with unknown species identity it was necessary to weight the data to obtain variance homogeneity. The co-variates plotx2 and ploty were significant in the test of species differences, but not in any of the other tests.

Results

The provenances had very different survivals. Whereas in *P. tamarugo* almost no trees survived (two of the provenances did not have surviving trees at all), survival was 85-95 % for the three local provenances India5, India8 and India9 (Fig. 1). The analyses of variances demonstrated that the differences between provenances were highly significant, but that within species there were no significant differences within species (Table 2). Only in the test of differences between the provenances with unknown species identity there were signs of significant differences, but following the correction for multiple comparisons this was no longer the case.

The highest survival was found in the local provenances mentioned above, followed by *P. glandulosa*, *P. pallida* and the group of *Prosopis* sp. In *P. cineraria* survival was around 50 %, whereas *P. flexuosa* and especially *P. tamarugo* had low survival.

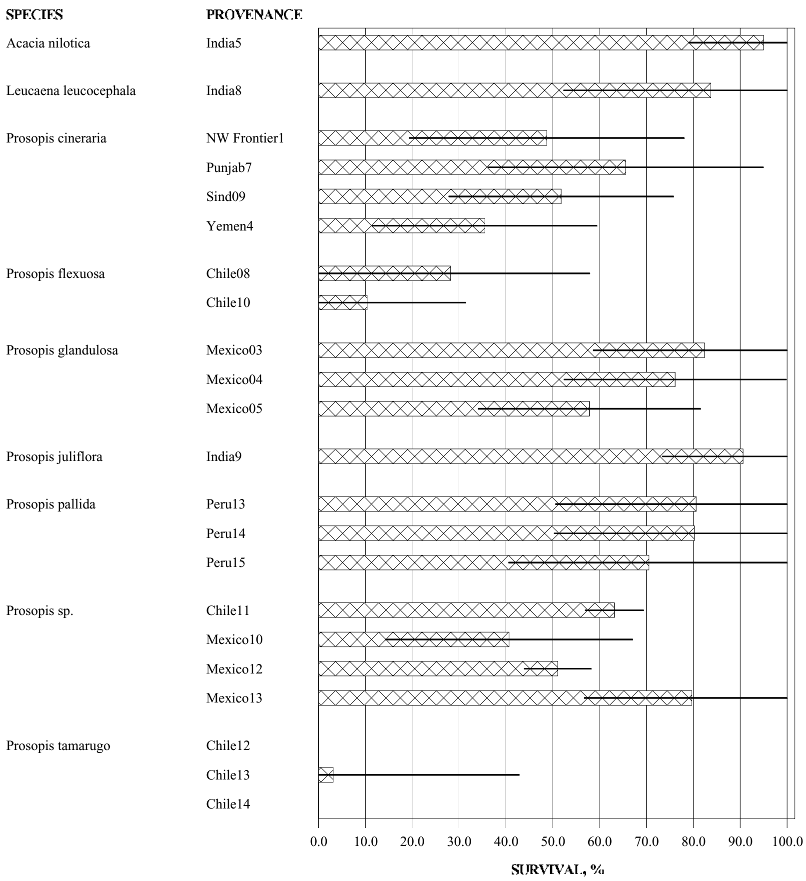

Figure 1. Survival in the *Acacia*, *Leucaena* and *Prosopis* species and provenance trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 2. Results from analysis of variance of species and provenance differences of survival in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 12.7	4348	7.5	0.0009	**
Provenance(species)	13; 47	578	1.7	0.09	
Block	3; 47	1496	4.4	0.01	
Plotx2	2, 47	1392	4.1	0.02	
Ploty	2; 47	2118	6.2	0.004	
Error	47	339			
P. cineraria					
Provenance	3; 7	502	1.2	0.37	n.s.
Block	3; 7	1661	4.0	0.06	
Error	7	411			
P. flexuosa					
Provenance	1; 4	421	1.8	0.25	n.s.
Error	4	230			
P. glandulosa					
Provenance	2; 6	651	1.7	0.25	n.s.
Block	3, 6	251	0.7	0.60	
Error	6	375			
P. pallida					
Provenance	2, 6	130	0.2	0.81	n.s.
Block	3; 6	537	0.9	0.50	
Error	6	600			
Prosopis sp.					
Provenance	3; 9	5.16	5.1	0.03	n.s.
Block	3; 9	16.4	16.2	0.001	
Error	9	1.02			

4.2 Height

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

Statistical analysis

In the analysis of species differences, the observation for India8 in block 4 turned out to be a very distinct outlier. There was no apparent reason for the extremity, but it was nevertheless decided to exclude the observation as it had a large influence on the model. The co-variates plotx2 and ploty were significant in the analysis of species differences and in the test of provenance differences within *P. glandulosa*. The only other significant co-variate was ploty in the test of differences between provenances with unknown species identity.

Results

India8 of *L. leucocephala* was by far the highest provenance with more than 6 m, followed by India5 of *Acacia nilotica* with 3.5 m (Fig. 2). The rest of the provenances were below 3 m, with the highest to be found in *P. glandulosa* and *P. juliflora*, and only small trees in the rest of the provenances. The differences between species were highly significant, but within species there were no significant differences (Table 3).

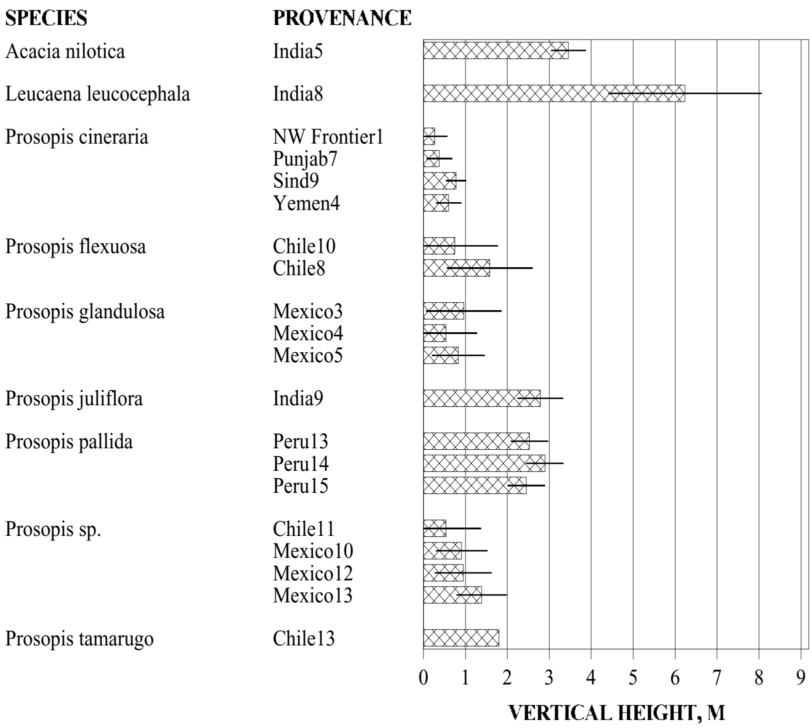

Figure 2. Vertical height in the *Acacia*, *Leucaena* and *Prosopis* species and provenance trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits. There are no confidence intervals for Chile13 because there is only one observation for the provenance.

Table 3. Results from analysis of variance of species and provenance differences of vertical height in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 11.9	14.7	68.1	<0.0001	***
Provenance(species)	11; 41	0.232	3.0	0.005	
Block	3; 41	0.438	5.7	0.002	
Plotx2	2, 41	0.248	3.2	0.05	
Ploty	2; 41	0.798	10.3	0.0002	
Error	41	0.0771			
P. cineraria					
Provenance	3; 6	0.155	4.3	0.06	n.s.
Block	3; 6	0.191	5.3	0.04	
Error	6	0.0361			
P. flexuosa					
Provenance	1; 2	0.687	6.2	0.13	n.s.
Error	2	0.112			
P. glandulosa					
Provenance	2; 2	0.0801	11.2	0.08	n.s.
Block	3; 2	0.0939	13.1	0.07	
Plotx2	2; 2	0.0914	12.7	0.07	
Ploty	2; 2	0.118	16.5	0.06	
Error	2	0.00718			
P. pallida					
Provenance	2, 6	0.224	1.7	0.25	n.s.
Block	3; 6	0.747	5.8	0.03	
Error	6	0.129			
Prosopis sp.					
Provenance	3; 6	0.321	5.3	0.04	n.s.
Block	3; 6	0.145	2.4	0.16	
Ploty	2, 6	0.237	3.9	0.08	
Error	6	0.0601			

4.3 Crown area

The crown area variable gives 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

In the analysis of species differences the plots of residuals demonstrated that the variance increased with increasing crown area, and the data were transformed with the square root to obtain variance homogeneity. The provenance Chile08 was present on only two plots that had quite different average crown areas, and even after the transformation these observations turned out to be outliers. The provenance was therefore excluded in the analysis of species differences. In this analysis plotx, plotx2 and ploty were significant or almost significant. However, in none of the other tests the co-variates were significant.

Note that for a large number of trees, no assessment of crown area was made (section 3.1). Instead the crown area for these trees were set to zero, which may introduce a bias in the analysis. For some provenances all trees were lacking values for crown area, and the least square means for these provenances are therefore zero even though there are live trees for the provenances. This is also the reason for the lack of test of differences between the provenances of *P. flexuosa***.**

Results

The local provenances or landraces were again having the largest values, but this time with India9 of *P. juliflora* as the largest with 10 m² tree⁻¹. India5 and India8 had crown areas between 5 and 6 m² tree⁻¹, followed closely by *P. pallida* with values between 4 and 5 m² tree⁻¹. Most of the other provenances had quite small crown areas (Fig. 3). The differences between species were highly significant, but there were no signs of significant differences within the species (Table 4).

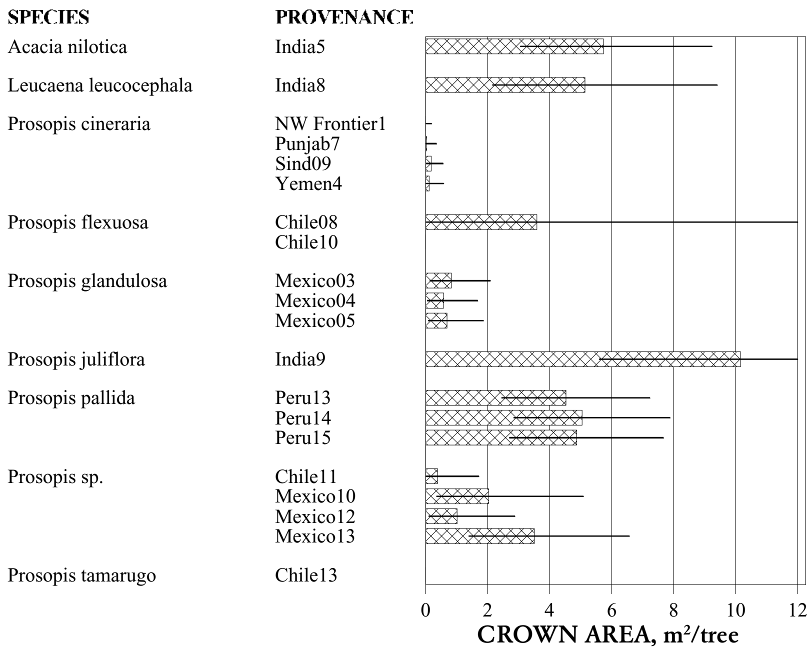

Figure 3. Crown area in the *Acacia*, *Leucaena* and *Prosopis* species and provenance trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits. Due to the square root transformation the upper and lower confidence intervals have different lengths. For Chile08 and India9 the upper confidence intervals were truncated at 12 m² tree⁻¹. There are no confidence intervals for Chile13 because there is only one observation for the provenance.

Table 4. Results from analysis of variance of species and provenance differences of crown area in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 10.6	6.47	12.5	0.0002	***
Provenance(species)	10; 39	0.56	3.9	0.001	
Block	3; 39	0.97	6.7	0.001	
Plotx	3; 39	0.47	2.9	0.07	
Plotx2	2; 39	0.52	3.6	0.04	
Ploty	2; 39	1.68	11.6	<0.0001	
Error	39	0.15			
P. cineraria					
Provenance	3; 6	0.10	1.4	0.32	n.s.
Block	3; 6	0.16	2.2	0.19	
Error	6	0.07			
P. glandulosa					
Provenance	2; 6	0.02	0.1	0.89	n.s.
Block	3; 6	0.26	1.4	0.34	
Error	6	0.19			
P. pallida					
Provenance	2, 6	0.01	0.07	0.93	n.s.
Block	3; 6	0.67	3.2	0.11	
Error	6	0.21			
Prosopis. sp.					
Provenance	3; 8	1.15	3.2	0.08	n.s.
Block	3; 8	0.92	2.6	0.13	
Error	8	0.36			

4.4 Number of stems

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

Statistical analysis

The first analysis demonstrated that there was variance heterogeneity between the provenances, and the data were weighted in the analysis of species differences. This was not necessary in the tests of differences within the species. No co-variates were significant.

It should be noted that a large number of small trees were not assessed, which may introduce a bias in the analysis (section 3.1). For Chile10, no trees were assessed at all, and there is thus no estimate for this provenance.

Results

Many of the species had a large number of stems. In the species *P. flexuosa*, *P. glandulosa*, the group of provenances with unknown species identity and *P. tamarugo*, the number of stems was varying between 5 and 8 stems tree^{-1}. The rest of the provenances had values of 3 stems tree^{-1} or less (Fig. 4). The species differences were highly significant, but within species there were no signs of significant differences (Table 5).

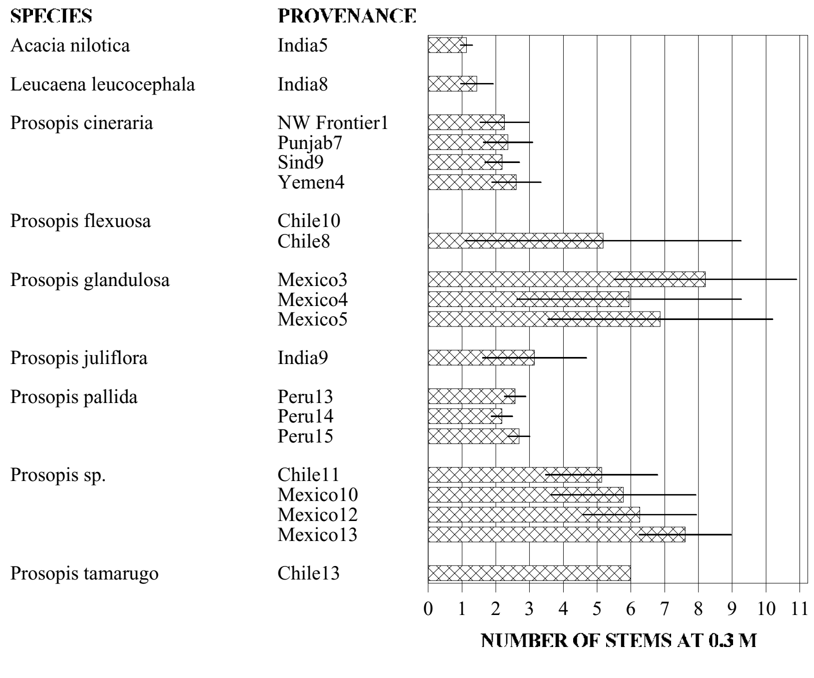

Figure 4. Number of stems in the *Acacia*, *Leucaena* and *Prosopis* species and provenance trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits. There are no confidence intervals for Chile13 because this provenance had only one observation.

Table 5. Results from analysis of variance of species and provenance differences of number of stems in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	7; 6.7	130	23.6	0.0003	***
Provenance(species)	10; 36	3.05	3.1	0.01	
Block	3; 36	73.1	73.3	0.0001	
Error	36	0.998			
P. cineraria					
Provenance	3; 3	0.0678	0.9	0.55	n.s.
Block	2; 3	1.06	13.6	0.03	
Error	3	0.0782			
P. glandulosa					
Provenance	2; 4	4.31	1.1	0.41	n.s.
Block	3, 4	3.49	0.9	0.51	
Error	4	3.79			
P. pallida					
Provenance	2, 6	0.283	4.2	0.07	n.s.
Block	3; 6	0.100	1.5	0.31	
Error	6	0.0672			
Prosopis sp.					
Provenance	3; 5	3.75	3.3	0.11	n.s.
Block	3; 5	2.51	2.2	0.20	
Error	5	1.13			

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

Statistical analysis

The plots of residuals from the first test of species differences demonstrated that the observations for India8 in block 4 and India9 in block 1 could be outliers. However, tests in which these observations were excluded demonstrated that they had only limited effect on the outcome of the model. As the data set revealed no reason for the extremity of the observations, they were kept in the model presented here. No co-variates were significant.

For a large number of smaller trees the diameter was not assessed, and the basal area for these trees were set to zero. This introduces a bias in the analysis (see section 3.1) and explains why some provenances have least square means of zero even though there are still live trees.

Results

The variation in basal area of the mean tree was large, ranging from below 1 cm^2 $tree^{-1}$ in some provenances of *P. cineraria* and *P. glandulosa* to more than 60 cm^2 $tree^{-1}$ in *L. leucocephala* (Fig. 5). The two other local provenances of *A. nilotica* and *P. juliflora* were at second and third place, followed by *P. pallida* having a basal area of the mean tree of approximately 20 cm^2 $tree^{-1}$.

The difference between species was again highly significant. In *P. cineraria*, the analysis of variance indicated that there are significant differences between the provenances, even after correction for multiple comparisons (Table 6). Here the provenance Sind09 seemed to be superior to the rest. In the other species, provenance differences were not significant.

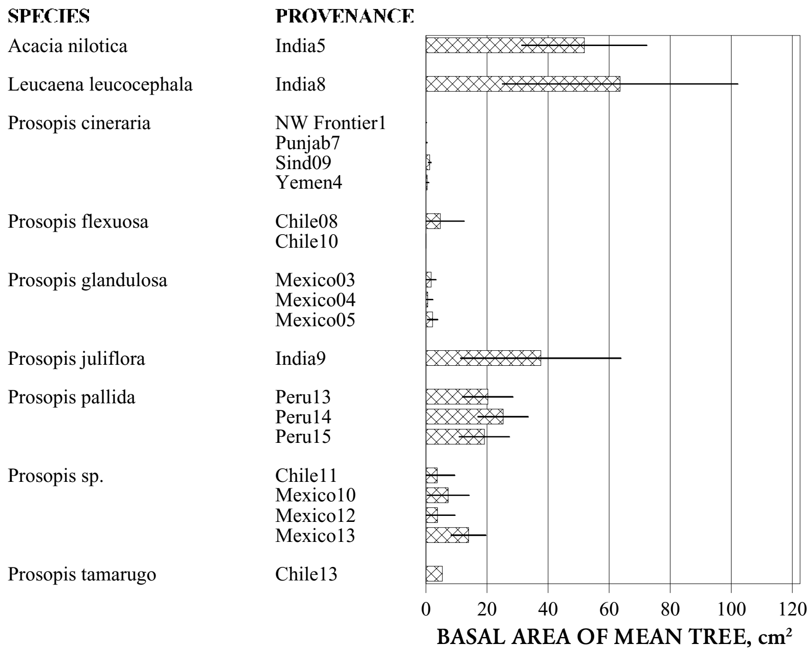

Figure 5. The basal area of the mean tree in the *Acacia*, *Leucaena* and *Prosopis* species and provenance trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits. There are no confidence intervals for Chile13 because this provenance had only one observation.

Table 6. Results from analysis of variance of species and provenance differences of basal area of the mean tree in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 14.7	3081	77.9	<0.0001	***
Provenance(species)	10; 46	36	0.5	0.90	
Block	3; 46	394	5.2	0.004	
Error	46	75			
P. cineraria					
Provenance	3; 6	1.50	12.0	0.006	*
Block	3; 6	1.03	8.3	0.01	
Error	6	0.12			
P. glandulosa					
Provenance	2; 6	2.6	1.4	0.32	n.s.
Block	3; 6	2.3	1.3	0.37	
Error	6	1.8			
P. pallida					
Provenance	2; 6	43	0.9	0.44	n.s.
Block	3; 6	299	6.6	0.03	
Error	6	45			
P. sp.					
Provenance	3; 8	93	3.8	0.06	n.s.
Block	3; 8	63	2.6	0.13	
Error	8	25			

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

The initial analysis demonstrated that there was variance heterogeneity in the data, and in the analysis of species differences the data weighted. No co-variates were significant.

Results

The total basal area followed much the same pattern as for basal area of the mean tree. *L. leucocephala* was the largest with almost 6 m^2 ha^{-1}, followed by *A. nilotica* with 5.4 m^2 ha^{-1}. *P. juliflora* had a total basal area of 4 m^2 ha^{-1}, whereas the provenances of *P. pallida* had values of approximately 2 m^2 ha^{-1}. The other provenances were all below 1 m^2 ha^{-1} (Fig. 6). The differences between species were highly significant, but within species no significant differences were found (Table 7).

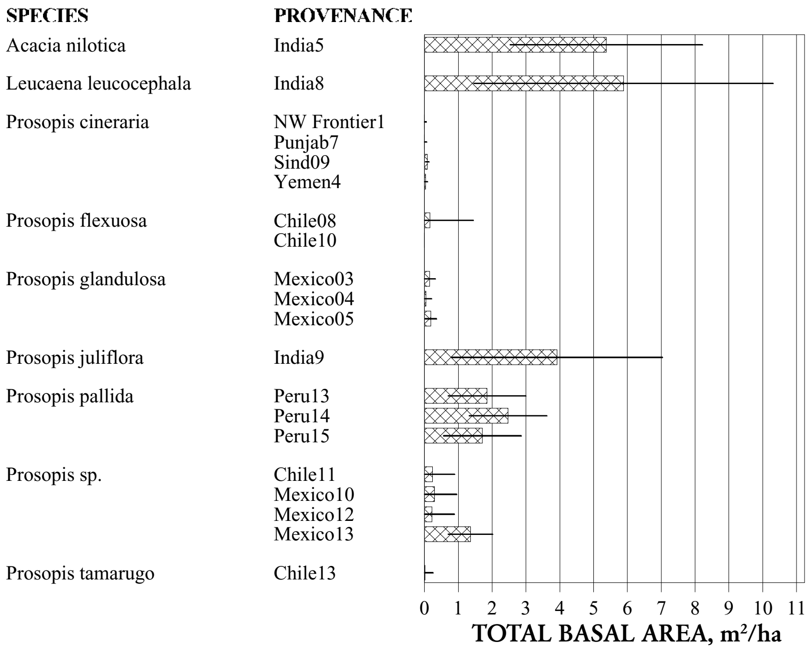

Figure 6. Total basal area in the *Acacia*, *Leucaena* and *Prosopis* species and provenances trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits. There are no confidence intervals for Chile13 because this provenance had only one observation.

Table 7. Results from analysis of variance of species and provenance differences of total basal area in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 32.2	17.1	27.0	<0.0001	***
Provenance(species)	11; 51	0.614	0.9	0.51	
Block	3; 51	2.15	3.3	0.03	
Error	51	0.655			
P. cineraria					
Provenance	3; 7	0.0063	2.7	0.12	n.s.
Block	3; 7	0.0055	2.4	0.16	
Error	7	0.0023			
P. glandulosa					
Provenance	2; 6	0.023	1.2	0.37	n.s.
Block	3, 6	0.019	1.0	0.45	
Error	6	0.019			
P. pallida					
Provenance	2; 6	0.659	0.7	0.51	n.s.
Block	3; 6	3.55	4.0	0.07	
Error	6	0.884			
Prosopis sp.					
Provenance	3; 9	1.23	3.6	0.06	n.s.
Block	3; 9	0.427	1.3	0.35	
Error	9	0.340			

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, as the basis for estimation of the dry weight is the basal area. However, an important difference is that the dry weight include a cubic term (in comparison to basal area having only a square term), meaning that large trees with a large dry mass weight heavily in this variable. The dry weight of the mean tree is thus the best estimate for the production of biomass at the site.

Statistical analysis

This variable was analysed only on the four species for which dry weight estimates are available (section 3.1). There were signs of variance heterogeneity between the provenances, and the data were weighted in the analysis of species differences. In the analyses of provenance differences this was not necessary. No co-variates were significant.

Just as for basal area of the mean tree, the missing measurements of diameter for some trees mean that there is a risk of bias in the tests and estimates. We believe that the worst consequences are avoided by setting the basal areas for these trees to zero (section 3.1).

Results

India5 and India9 of *A. nilotica* and *P. juliflora* were the largest and both had dry weight of the mean tree around 14 kg tree^{-1}. For *P. pallida* the values were ranging between 6 and 8 kg tree^{-1}, whereas *P. cineraria* was the smallest with values below 1 kg tree^{-1} (Fig. 7). According to the analyses of variance there were highly significant differences between species, but within *P. cineraria* and *P. pallida* there were no signs of significant differences between provenances (Table 8).

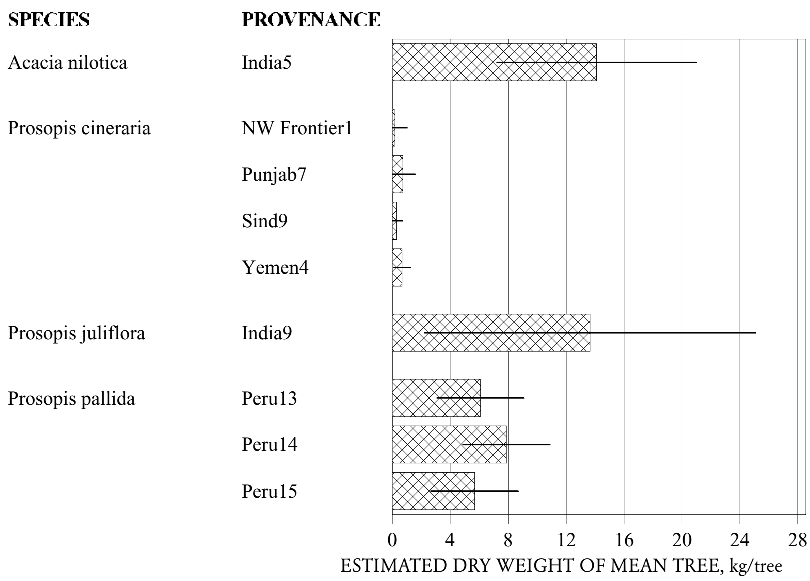

Figure 7. Dry weight of the mean tree in the trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 8. Results from analysis of variance of species and provenance differences of dry weight of the mean tree in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	3; 14.5	38.1	44.7	<0.0001	***
Provenance(species)	5; 21	0.7	0.7	0.64	
Block	3; 21	8.5	8.0	0.0009	
Error	21	1.1			
P. cineraria					
Provenance	3; 1	0.0796	25.7	0.14	n.s.
Block	2; 1	0.0146	4.7	0.31	
Error	1	0.00310			
P. pallida					
Provenance	2, 6	5.51	0.9	0.45	n.s.
Block	3; 6	28.0	4.6	0.05	
Error	6	6.05			

4.8 Total dry weight

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

Statistical analysis

There were signs of variance heterogeneity between the provenances. In the test of species differences the data were weighted, but this was not needed in the tests of differences within the species. No co-variates were significant.

Results

A. nilotica had the largest production of dry weight per ha, amounting to 15 t ha^{-1}. This corresponds to 3 t ha^{-1} y^{-1}. *P. juliflora* were the second largest with 13 t ha^{-1}, whereas *P. pallida* came third with values in the range of 5-7 t ha^{-1}. The production in *P. cineraria* was negligible with less than 100 kg ha^{-1} produced (Fig. 8). Differences between species were highly significant, but there were no significant differences within species (Table 9).

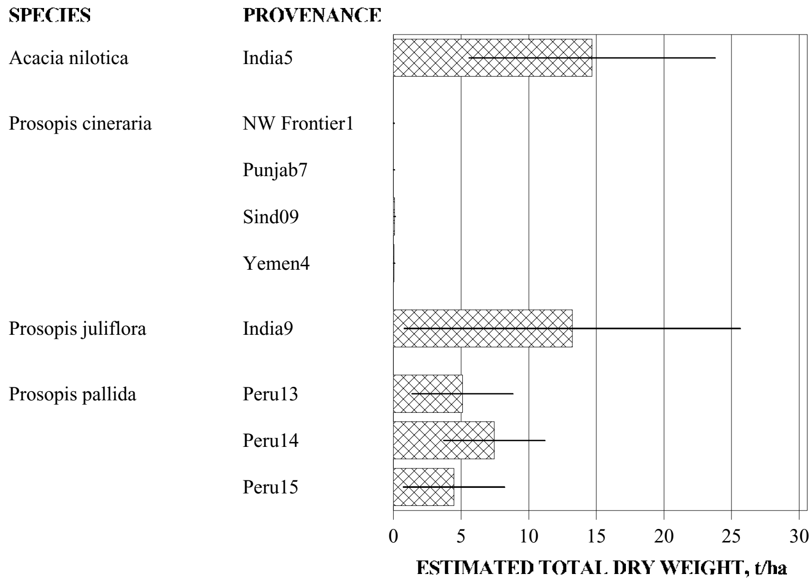

Figure 8. Total dry weight in the trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits.

Table 9. Results from analysis of variance of species and provenance differences of total dry weight in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	3; 22.5	25.8	35.7	<0.0001	***
Provenance(species)	5; 22	0.484	0.5	0.78	
Block	3; 22	4.38	4.4	0.01	
Error	22	0.999			
P. cineraria					
Provenance	3; 7	0.00738	2.7	0.12	n.s.
Block	3; 7	0.00673	2.5	0.14	
Error	7	0.00270			
P. pallida					
Provenance	2, 6	9.84	1.0	0.41	n.s.
Block	3; 6	38.8	4.1	0.07	
Error	6	9.38			

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. About half of the damaged trees were stressed by drought, whereas the reason for damage in the other half was either not recognisable or classified as physical damage (probably grazing by animals).

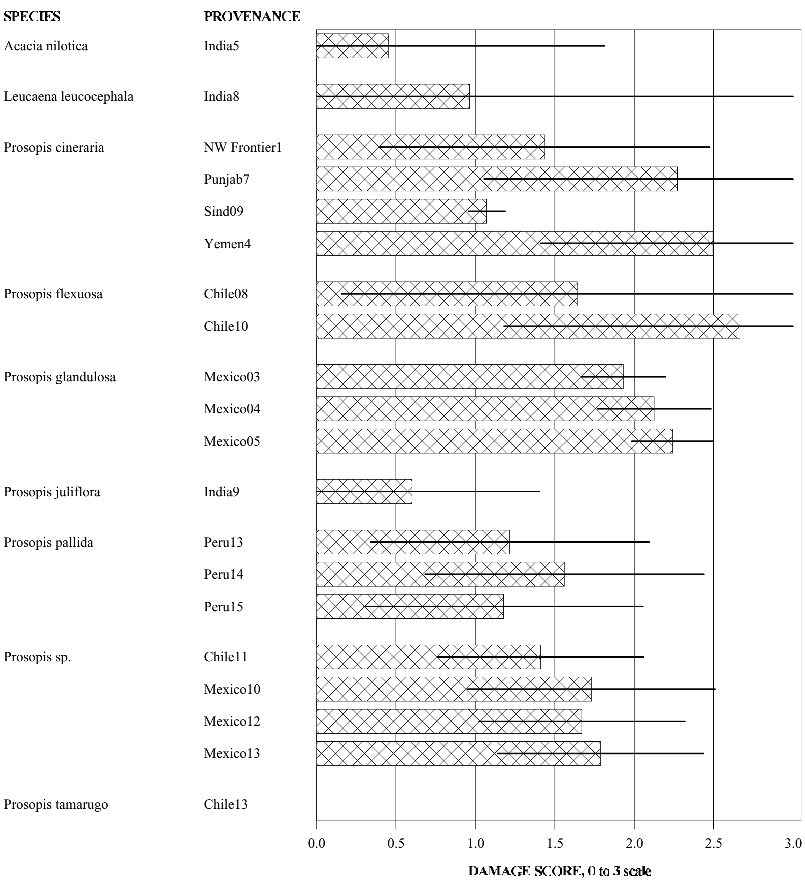

Figure 9. Damage score in the trial at Phaltan, India (Trial no. 20 in the arid zone series). Values presented are least square means with 95 % confidence limits. For Chile13 of *P. tamarugo* there was only one plot where the trees had no damage. Note that large values means that the trees are heavily damaged.

Statistical analyses

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

Also, since there are different stresses involved, it may be difficult to compare the different genetic units, because they may have different susceptibility to the different stresses. The results should therefore be interpreted as the adaptability to the sum of stress factors at the moment of assessment.

The residuals indicated that there was variance heterogeneity in the data, and weight statements were applied in the analysis of species differences and in the analysis of differences within *P. cineraria*. The co-variate ploty was significant in the test of species differences, but not in the other tests.

Results

The three local provenances all had damage scores below 1, indicating that they are only mildly affected by the stresses at the site. On the contrary, all the introduced provenances had damage scores above 1, with certain provenances of P. cinreraria, *P. flexuosa* and *P. glandulosa* as the most severely affected. Among the introduced provenances, *P. pallida* was the least affected (Fig. 9).

The analysis of variance showed that the species were only at the border of being significantly different (Table 10). However, in an additional test of all provenances against each other (excluding the effect of species) there were highly significant differences between the provenances (F=6.6, P<0.0001, data not shown). Within species, there were significant differences in *P. cineraria* and *P. glandulosa*, but the correction for multiple comparisons removed significance, and differences should be interpreted cautiously.

Table 10. Results from analysis of variance of species and provenance differences of damage score in trial 20.

Effect	DF (nominator, denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	8; 12.5	1.26	2.7	0.06	(*)
Provenance(species)	11; 44	0.47	1.2	0.32	
Block	3; 44	3.72	9.4	<0.0001	
Ploty	2; 44	3.02	7.6	0.002	
Error	44	0.40			
P. cineraria					
Provenance	3; 6	5.6	5.5	0.04	n.s.
Block	3; 6	207.4	201.6	<0.0001	
Error	6	1.0			
P. flexuosa					
Provenance	1; 2	1.04	4.4	0.17	n.s.
Error	2	0.24			
P. glandulosa					
Provenance	2; 4	0.08	7.7	0.04	n.s.
Block	3; 4	0.81	80.6	0.0005	
Ploty	2; 4	0.68	67.3	0.0008	
Error	4	0.01			
P. pallida					
Provenance	2; 6	0.18	0.4	0.72	n.s.
Block	3; 6	3.14	6.1	0.03	
Error	6	0.52			
Prosopis sp.					
Provenance	3; 8	0.11	0.3	0.79	n.s.
Block	3; 8	1.65	5.2	0.03	
Error	8	0.32			

4.10 Multivariate analysis of all provenances

In order to get an impression of the differences between the different species, a multivariate analysis including most of the provenances was performed. The three provenances of *P. tamarugo* were excluded because of the poor survival, as was the provenance Chile10 of *P. flexuosa*. Furthermore, of the 68 observations (plots) remaining, 14 were excluded because e.g. the number of stems was not available. In the multivariate analysis all observations with missing values are deleted. Thus the material used for this analysis is scattered. The analysis included the variables survival, height, crown area, number of stems, basal area of the mean tree, total basal area and damage score. The crown area was transformed with the square root before analysis, but apart from this no account was made for the variance heterogeneity observed in the other variables.

The analysis demonstrated that the three first canonical variates were significant (Table 11). In total, the two variates accounted for 94 % of the variation. Differences between the provenances were highly significant (P-values for Wilk's lambda and for Pillai's trace both below 0.0001).

The plots of scores for the three first canonical variates are presented in Fig. 10. 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 provenances have different properties. From the diagrams it appears that especially the provenance India8 (*L. leucocephala*) separates from the rest. The other provenances are located in a cluster with India5 (*A. nilotica*) at the right side. Provenances of the genus *Prosopis* are thus placed together in the diagrams, and only with some difficulty can one observe differences between the species.

We therefore carried out another analysis where all but the provenances of *Prosopis* were excluded, hoping that this would give a better differentiation. In this analysis only two canonical variates were significant, together accounting for 81 % of the variation (Table 12). Plotting the two canonical variates against each other, it turned out that the provenances were located more or less according to species, even though the species were not always separated from each other (Fig.11). The provenances of *P. pallida* were located in a cluster to the right of the diagram together with the provenance of *P. juliflora*. Provenances of *P. cineraria* were located at the bottom, and *P. glandulosa* was to the left. Finally the group of provenances with unknown species identity were at the middle together with the provenance of *P. flexuosa*. This is interesting because the provenances of *Prosopis* sp. have two origins quite far from each other: Chile and Mexico.

Another observation, opening for alternative interpretation of the results, is that the provenances are also grouped according to geographical origin: Provenances from Mexico are located at the same place, as are the provenances from Chile and Peru. The exception is India9, a landrace of *P. juliflora* – however, this is originally a South American species. Because species and geographical origins are confounded, it is impossible to say which factor is dominating in grouping the provenances.

Finally it was attempted to make similar analysis separately for each species. Unfortunately the number of observations was too small to allow for multivariate tests.

Table 11. Results from the canonical variate analyses for the first three canonical variates in trial 20. All provenances included.

Canonical variate no.	1	2	3
Proportion of variation	0.74	0.13	0.06
Significance, P-value	<0.0001	<0.0001	0.002

	Raw canonical coefficients			Standardised canonical coefficients			Canonical directions		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	-0.027	0.011	-0.004	0.6	0.2	-0.1	42	-18	56
Height	3.6	1.95	0.06	5.3	2.8	0.1	10	2	7
Crown area	-1.1	-0.79	2.39	-0.9	-0.7	2.1	3	-3	15
Number of stems	- 0.38	0.83	0.19	-1.0	2.1	0.5	-11	29	7
Basal area, mean tree	-0.029	-0.048	-0.041	-0.6	-1.1	-0.9	132	-42	116
Total basal area	-0.049	-0.16	0.011	-0.1	-0.4	0.02	13	-5	12
Damage score	-0.85	-0.22	0.14	-0.7	-0.2	0.1	-1	2	0.6

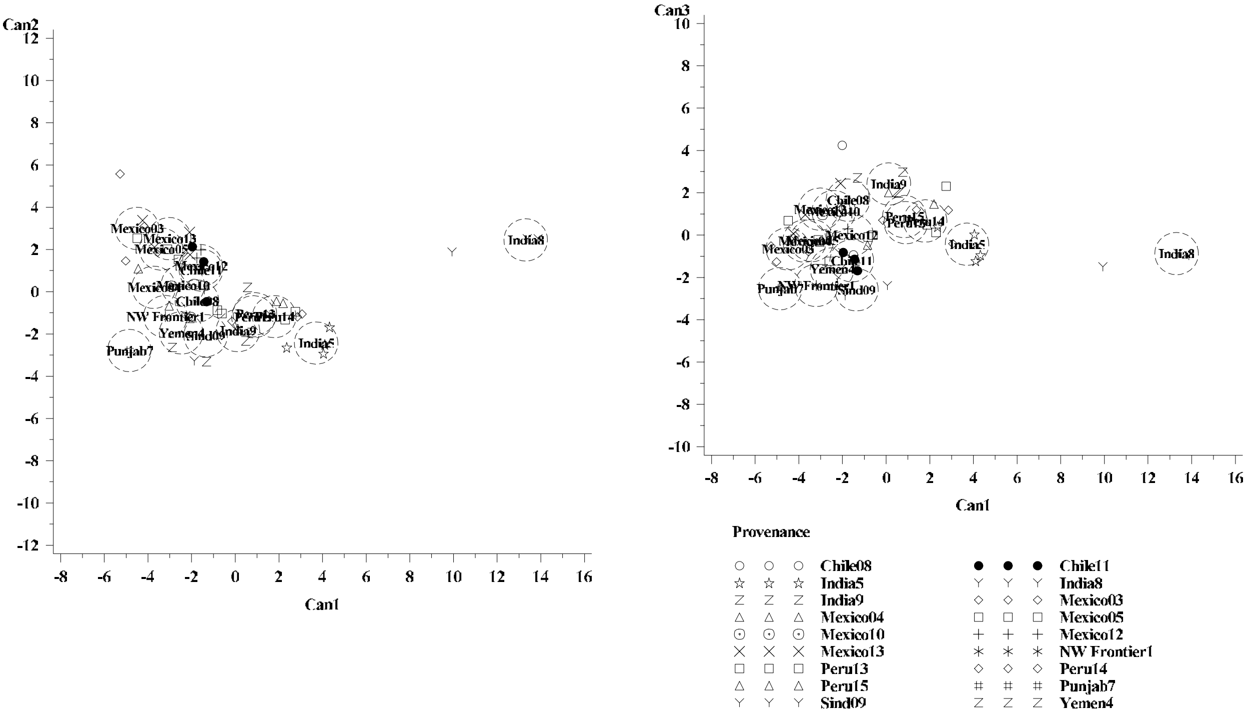

Figure 10. Score plot of the first and the second canonical variate (upper diagram) and the first and the third canonical variate (lower diagram) from the canonical variate analysis for the provenances in the trial at Phaltan, India (Trial no. 20 in the arid zone series). The variables survival, height, 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. India8 is *L. leucocephala* and India5 is *A. nilotica*, the rest are *Prosopis* sp.

Table 12. Results from the canonical variate analyses for the first two canonical variates in trial 20. Only *Prosopis* provenances are included.

Canonical variate no.	**1**	**2**				
Proportion of variation	0.60	0.21				
Significance, P-value	<0.0001	0.001				
	Raw canonical coefficients		**Standardised canonical coefficients**		**Canonical directions**	
Canonical variate no.	**1**	**2**	**1**	**2**	**1**	**2**
Survival	-0.02	0.02	-0.35	0.53	39.0	80.5
Height	3.24	1.29	2.60	1.04	6.7	4.7
Crown area	-0.39	0.28	-0.34	0.25	6.0	5.3
Number of stems	-0.48	0.74	-1.14	1.76	-14.9	24.1
Basal area, mean tree	0.20	0.17	2.68	2.34	97.9	55.6
Total basal area	-1.89	-1.73	-2.76	-2.53	9.8	5.8
Damage score	0.25	0.25	-0.16	0.20	-0.8	0.6

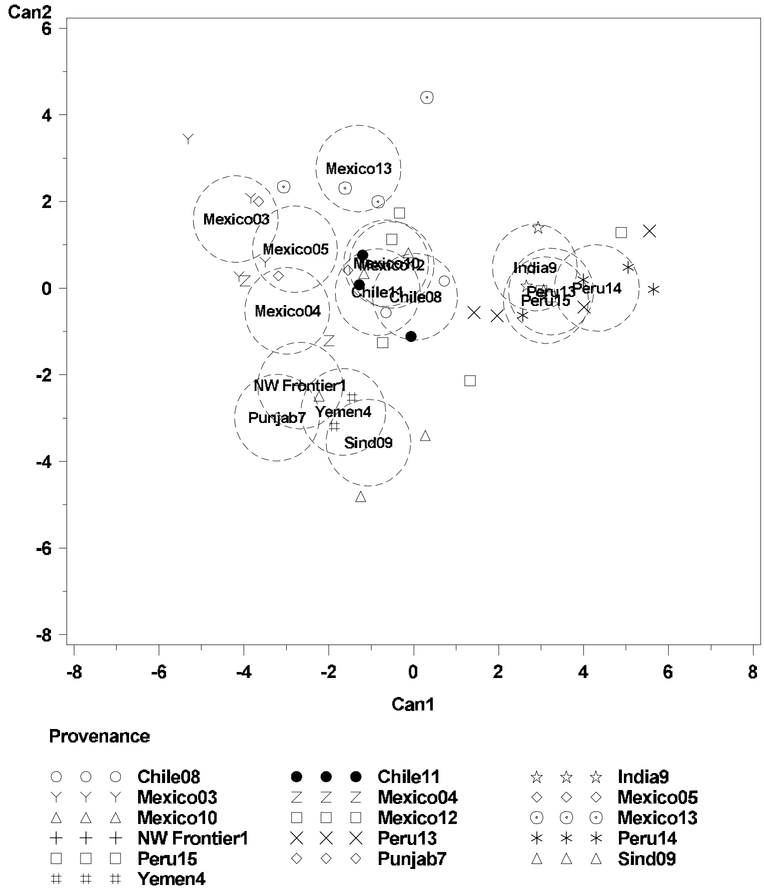

Figure 11. Score plot of the first and the second canonical variate from the canonical variate analysis for the *Prosopis* provenances in the trial at Phaltan, India (Trial no. 20 in the arid zone series). The variables survival, height, crown area, number of stems, basal area of the mean tree, total basal area and damage score were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

5. Discussion and conclusions

Productivity

The fastest producers in the trial were the provenances of *A. nilotica* and *L. leucocephala*, having annual grows of basal areas of approximately 1.1 to 1.2 m^2 ha^{-1} y^{-1}. For *A. nilotica*, this corresponded to an annual production of dry weight of 3 t ha^{-1}. It was not possible to calculate the dry weight for *L. leucocephala*, but it seems probable that it has at least the same production as *A. nilotica*, considering that the basal area was similar, and the height almost double. The annual increase in dry weight was slightly higher in the other trial at Phaltan (trial no. 19). In this trial, the provenance of *A. nilotica* had a growth of 3.5 t ha^{-1} y^{-1}.

The intensive tending and irrigation in the two trials at Phaltan makes it difficult to compare to the other trials in this series, as most trials have been subjected to more extensive care.

Species and provenance differences

The differences between species were conspicuous. *P. tamarugo* had a survival close to zero and seem unapt for the site, but also *P. flexuosa* had a poor survival. With the single exception of the local landrace of *P. juliflora*, the provenances of *Prosopis* had a clearly inferior performance compared to *A. nilotica* and *L. leucocephala*. Among the new introductions of *Prosopis*, the species *pallida* from Peru was the best performer with an acceptable growth in height, basal area and dry weight. This species seem to be the only promising species.

On the basis of this trial the use of local provenances and landraces (India5, India8 and India9) should be recommended. They have the best survival, the largest basal areas and, one must presume, the largest dry weights. Furthermore they were less damaged than the new introductions. However, it should also be noted that these recommendations are based on a trial that has been tended intensively. When such tending does not take place, we cannot exclude the possibility that other provenances would have a better performance.

L. leucocephala differed much from the rest of the provenances in the multivariate analysis. This could indicate, that though being a leguminous plant, the species is relatively different from plants in the genera *Acacia* and *Prosopis*. However, more tests will be needed to verify this. Within the group of *Prosopis* provenances, provenances grouped according to species and geographical origin. This confirms the impression that there in general were few signs of differences within the species.

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Annex 1. Description of the trial site

Name of site:	Village Rajale (Lundy Farm), Phaltan Latitude: 17°55'N Longitude: 74°25'E Altitude: 560 m
Meteorological stations:	Tambmal (Phaltan) Lundy Farm (Rajale)
Rainfall (Rajale):	Annual mean (period): 499 mm/year (1987-1992) Yearly registrations: 1987/88: 587.3 1988/89: 530.4 1989/90: 603.5 1990/91: 467.1 1991/92: 305.9
Month of establishment:	(October 1987): 113.2
Rainy season:	6-10 (June-October) Length (days): 32
Dry months/year:	No. of dry months (< 50 mm): 8-11 No. of dry periods: 1
Temperature (Tambmal):	Annual mean: 25 Coldest month: 11 Hottest month: 41
Topography:	Flat/gentle
Soil:	Type: Vertisols with stone substrate Depth: Shallow/medium
Climatic/agroecological zone:	Semi-arid
Koeppen classification:	BSh

Annex 2. Species and provenances tested in trial no. 20 at Phaltan, India

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

Seedlot numbers				**Provenance information**							
Provenance	DFSC	Country of origin	Plot	Species	Origin	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
India5		Phaltan4	21	*Acacia nilotica* subsp. *indica*		India					
India8		Phaltan3	20	*Leucaena leucocephala*		India					
NW Frontier1	1183/83		8	*Prosopis cineraria*	Darya Khan, Bhakhar	Pakistan	31 47 N	71 10 E	200	200	30
Punjab7	1180/83		7	*Prosopis cineraria*	Greater Cholistan, Toofan, Bahawalpur	Pakistan	29 -- N	72 – E	160	125	32
Sind09	1179/83		6	*Prosopis cineraria*	Islam-Kot, Tharparkar, Registan (Loonio)	Pakistan	24 40 N	70 12 E	50	150	25
Yemen4	1062/82	(1)	5	*Prosopis cineraria*	Khanfar (Aden)	Yemen	13 00 N	45 10 E	15	50	20
Chile08	1456/84		10	*Prosopis flexuosa*	Barriales Iii	Chile	28 15 S	70 32 W	650	15	10
Chile10	1585/86		9	*Prosopis flexuosa*	Hacienda Margarita 1	Chile	27 19 S	70 40 W		15	11
Mexico03	1211/83		11	*Prosopis glandulosa* var. *torreyana*	Concepcion Del Oro	Mexico	24 49 N	101 25 W	1650		
Mexico04	1212/83		12	*Prosopis glandulosa* var. *torreyana*	Paila, Coahuila	Mexico	25 28 N	102 10 W	1150		
Mexico05	1213/83		13	*Prosopis glandulosa* var. *torreyana*	Monterrey	Mexico	25 42 N	100 20 W	538		
India9		Phaltan5	22	*Prosopis juliflora*		INDIA					
Peru13	1156/83	15.7.83	14	*Prosopis pallida*	Ocucaje (Ica), Zona: Tres Esquinas	Peru	14 20 S	75 40 W	420	35	
Peru14	1336/84		15	*Prosopis pallida*	Huayuri (Palpa)	Peru	14 04 S	75 44 W	391	0	
Peru15	1490/85		16	*Prosopis pallida*	San Jacinto De Cachiche, Ica	Peru	13 45 S	75 50 W	413	2	
Chile11	1455/84		1	*Prosopis sp.*	Colina, Chacabuco	Chile	33 02 S	70 45 W	840	306	15
Mexico10	1475/84	35	2	*Prosopis sp.*	Las Posas	Mexico	23 09 N	110 04 W		0.82	
Mexico12	1478/84	37	3	*Prosopis sp.*	El Triunfo, La Paz	Mexico	23 50 N	110 12 W		3.41	
Mexico13	1479/84	38	4	*Prosopis sp.*	San Ignacio	Mexico	27 15 N	112 52 W		0.62	
Chile12	1014/82		17	*Prosopis tamarugo*	Bellavista Norte	Chile	19 55 S	69 50 W	1150	0	150
Chile13	1018/82		18	*Prosopis tamarugo*	La Huayca	Chile	20 35 S	69 35 W	1010	0	200
Chile14	1093/82		19	*Prosopis tamarugo*	Refresco	Chile	20 27 S	69 40 W	978	0	200

Annex 3. Layout of the trial

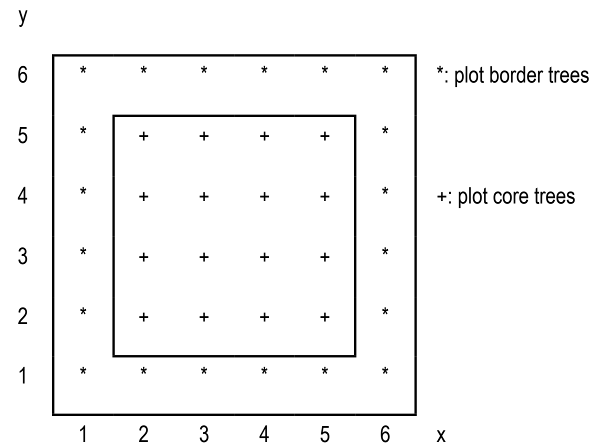
Layout of blocks and plots in the field. Position of blocks relative to each other not verified. Orientation not verified.

BLOCK 1					BLOCK 1	BLOCK 2			
4	20	2	7		9	14	4	12	2
22	18	17	1	no	5	21	16	8	18
19	21	10	13	plant	12	5	7	13	20
14	16	11	3	area	8				
6	15								

11	15	10	6	BLOCK 2
1	22	3	9	

11	12	5	14	4	8	13	20	9	6	BLOCK 3
12	22	15	21	7	2	22	3	16	1	
6	13	1	20	9	11	21	8	15	5	
2	4	16	14	3		BLOCK 4				

Individual tree positions in each plot:



Annex 4. Plot data set

Block	Plot	Plotx	Ploty	Species	Provenance	Surv-ival	Height	Crown area	Number of stems	Basal area, mean tree	Total basal area	Dry weight, mean tree	Total dry weight	Damage score
						%	m	m^2	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	tons ha^{-1}	0-3 scale
1	21	3	3	*Acacia nilotica* subsp. *indica*	India5	100	3.27	3.64	1.00	43.3	4.81	11.54	12.83	0.00
1	20	3	1	*Leucaena leucocephala*	India8	100	7.06	7.03	1.38	68.9	7.65			0.00
1	8	7	4	*Prosopis cineraria*	NW Frontier1	31	0.24	0.00	2.80	0.0	0.00	0.00	0.00	0.80
1	7	5	1	*Prosopis cineraria*	Punjab7	80	0.46	0.16	3.13	0.7	0.04	0.08	0.05	1.88
1	6	2	5	*Prosopis cineraria*	Sind09	44	1.19	0.27	2.83	1.9	0.09	0.21	0.10	0.29
1	5	7	7	*Prosopis cineraria*	Yemen4	69	0.77	0.74	2.91	1.3	0.10	0.15	0.12	0.73
1	10	4	3	*Prosopis flexuosa*	Chile08	13	1.80	8.67	5.50	4.1	0.06			2.00
1	9	7	1	*Prosopis flexuosa*	Chile10	0					0.00			
1	11	4	4	*Prosopis glandulosa* var. *torreyana*	Mexico03	88	1.15	1.24	8.86	2.4	0.23			0.21
1	12	7	3	*Prosopis glandulosa* var. *torreyana*	Mexico04	69	0.81	1.17	7.40	0.7	0.05			0.45
1	13	5	3	*Prosopis glandulosa* var. *torreyana*	Mexico05	75	1.17	1.91	8.75	3.0	0.25			0.75
1	22	2	2	*Prosopis juliflora*	India9	81	2.72	5.99	4.50	17.4	1.70	4.58	4.45	1.23
1	14	2	4	*Prosopis pallida*	Peru13	94	2.77	4.32	2.47	26.7	2.78	7.70	8.03	0.00
1	15	3	5	*Prosopis pallida*	Peru14	65	2.79	2.71	2.36	20.3	1.55	4.61	3.52	1.00
1	16	3	4	*Prosopis pallida*	Peru15	94	2.59	4.04	3.00	16.0	1.66	3.39	3.53	0.00
1	1	5	2	*Prosopis sp.*	Chile11	50	1.38	0.45	4.63	5.4	0.30			1.38
1	2	4	1	*Prosopis sp.*	Mexico10	0					0.00			
1	3	5	4	*Prosopis sp.*	Mexico12	44	1.63	1.64	7.14	5.2	0.25			1.29
1	4	2	1	*Prosopis sp.*	Mexico13	94	2.66	6.26	8.53	27.5	2.87			1.40
1	17	4	2	*Prosopis tamarugo*	Chile12	0					0.00			
1	18	3	2	*Prosopis tamarugo*	Chile13	0					0.00			
1	19	2	3	*Prosopis tamarugo*	Chile14	0					0.00			
2	21	8	2	*Acacia nilotica* subsp. *indica*	India5	100	3.80	7.48	1.25	70.1	7.79	20.27	22.53	0.00
2	20	11	3	*Leucaena leucocephala*	India8	100	6.43	5.51	1.81	76.4	8.49			0.19
2	8	10	2	*Prosopis cineraria*	NW Frontier1	92	0.79	0.18	2.91	0.1	0.01	0.01	0.01	0.92
2	7	9	3	*Prosopis cineraria*	Punjab7	88	0.73	0.26	2.79	0.0	0.00	0.00	0.00	0.21
2	6	10	6	*Prosopis cineraria*	Sind09	94	0.86	0.22	2.73	2.0	0.21	0.21	0.22	0.00
2	5	8	3	*Prosopis cineraria*	Yemen4	36	1.00	0.31	3.50	1.0	0.04	0.13	0.04	1.83

Block	Plot	Plotx	Ploy	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area, mean tree	Total basal area	Dry weight, mean tree	Total dry weight	Damage score
						%	m	m^2	no. $tree^{-1}$	$cm^2\ tree^{-1}$	$m^2\ ha^{-1}$	kg $tree^{-1}$	tons ha^{-1}	0-3 scale
2	10	9	6	*Prosopis flexuosa*	Chile08	44	1.36	0.71	4.86	5.3	0.26			1.29
2	9	10	7	*Prosopis flexuosa*	Chile10	0					0.00			
2	11	7	6	*Prosopis glandulosa* var. *torreyana*	Mexico03	88	1.05	0.75	6.46	2.1	0.21			0.36
2	12	10	1	*Prosopis glandulosa* var. *torreyana*	Mexico04	63	1.12	1.25	4.10	1.7	0.12			1.60
2	13	10	3	*Prosopis glandulosa* var. *torreyana*	Mexico05	31	1.04	0.73	7.50	0.8	0.03			1.20
2	22	8	7	*Prosopis juliflora*	India9	100	3.05	10.39	3.19	57.9	6.43	21.10	23.44	0.00
2	14	8	1	*Prosopis pallida*	Peru13	81	3.19	8.67	2.46	33.4	3.02	9.77	8.82	0.23
2	15	8	6	*Prosopis pallida*	Peru14	78	3.07	6.41	2.36	36.4	3.54	13.18	12.81	0.14
2	16	9	2	*Prosopis pallida*	Peru15	88	3.19	6.21	2.57	31.1	3.02	8.70	8.46	1.29
2	1	7	7	*Prosopis sp.*	Chile11	81	1.48	0.67	5.10	3.7	0.33			0.54
2	2	11	1	*Prosopis sp.*	Mexico10	73	1.81	3.46	4.73	8.7	0.66			1.36
2	3	9	7	*Prosopis sp.*	Mexico12	63	1.89	2.56	6.25	6.9	0.48			1.40
2	4	9	1	*Prosopis sp.*	Mexico13	100	2.08	3.95	5.88	13.3	1.48			1.00
2	18	11	2	*Prosopis tamarugo*	Chile13	6	1.80	0.00	6.00	5.4	0.04			0.00
3	21	4	10	*Acacia nilotica* subsp. *indica*	India5	80	3.25	4.90	1.08	42.3	3.52	10.68	8.90	0.08
3	20	8	9	*Leucaena leucocephala*	India8	60	6.89	6.41	1.50	81.0	5.06			3.00
3	8	6	9	*Prosopis cineraria*	NW Frontier1	60	0.23	0.00		0.0	0.00	0.00	0.00	0.67
3	7	5	10	*Prosopis cineraria*	Punjab7	67	0.42	0.00		0.0	0.00	0.00	0.00	2.80
3	6	6	9	*Prosopis cineraria*	Sind09	57	0.75	0.47	1.00	1.0	0.03	0.11	0.03	1.00
3	5	3	9	*Prosopis cineraria*	Yemen4	38	0.50	0.00		0.0	0.00	0.00	0.00	3.00
3	9	9	9	*Prosopis flexuosa*	Chile10	20	0.50	0.00		0.0	0.00			3.00
3	11	1	9	*Prosopis glandulosa* var. *torreyana*	Mexico03	69	1.10	0.77	11.00	1.5	0.11			1.36
3	12	2	9	*Prosopis glandulosa* var. *torreyana*	Mexico04	88	1.00	0.00		0.0	0.00			1.71
3	13	7	9	*Prosopis glandulosa* var. *torreyana*	Mexico05	88	1.57	1.16	5.33	4.8	0.47			1.79
3	22	7	10	*Prosopis juliflora*	India9	81	2.33	12.62	2.40	38.1	3.44	13.29	12.00	0.62
3	14	4	9	*Prosopis pallida*	Peru13	69	2.13	3.29	2.50	10.3	0.79	2.20	1.68	2.55

Block	Plot	Plotx	Ploty	Species	Provenance	Surv-val	Height	Crown area	Number of stems	Basal area, mean tree	Total basal area	Dry weight, mean tree	Total dry weight	Damage score
						%	m	m^2	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	tons ha^{-1}	0-3 scale
3	15	3	10	*Prosopis pallida*	Peru14	100	3.39	7.62	2.00	33.7	3.98	9.75	11.51	2.65
3	16	9	10	*Prosopis pallida*	Peru15	87	2.52	9.05	2.18	22.9	2.06	6.35	5.73	0.92
3	1	10	10	*Prosopis sp.*	Chile11	71	1.05	0.00		0.0	0.00			2.10
3	2	6	10	*Prosopis sp.*	Mexico10	77	1.53	4.38	5.00	7.5	0.52			1.10
3	3	8	10	*Prosopis sp.*	Mexico12	67	1.41	1.28	4.00	3.0	0.17			1.00
3	4	5	9	*Prosopis sp.*	Mexico13	69	1.70	3.58	7.29	11.0	0.84			2.09
4	21	7	11	*Acacia nilotica* subsp. *indica*	India5	100	3.51	7.40	1.20	51.7	5.38	13.90	14.48	1.73
4	20	4	11	*Leucaena leucocephala*	India8	75	4.57	2.36	1.08	28.0	2.33			0.67
4	6	11	11	*Prosopis cineraria*	Sind09	13	0.30	0.00		0.0	0.00	0.00	0.00	3.00
4	5	10	11	*Prosopis cineraria*	Yemen4	0					0.00		0.00	
4	9	5	11	*Prosopis flexuosa*	Chile10	21	1.00	0.00		0.0	0.00	0.00	0.00	2.33
4	11	6	11	*Prosopis glandulosa* var. *torreyana*	Mexico03	86	0.95	0.59	6.50	0.6	0.05			2.08
4	12	1	10	*Prosopis glandulosa* var. *torreyana*	Mexico04	86	0.93	0.71	5.70	0.0	0.00			1.08
4	13	2	11	*Prosopis glandulosa* var. *torreyana*	Mexico05	38	0.65	0.00		0.0	0.00			2.33
4	22	2	10	*Prosopis juliflora*	India9	100	3.03	12.44	2.50	36.9	4.10	11.69	12.99	0.56
4	14	4	12	*Prosopis pallida*	Peru13	79	2.03	2.80	2.86	10.5	0.80	2.43	1.85	2.09
4	15	9	11	*Prosopis pallida*	Peru14	79	2.32	4.18	2.00	10.6	0.81	2.54	1.94	2.45
4	16	3	12	*Prosopis pallida*	Peru15	14	1.50	1.73	3.00	6.6	0.09	1.18	0.16	2.50
4	1	3	11	*Prosopis sp.*	Chile11	50	1.55	0.94	6.80	5.7	0.32			1.63
4	2	1	12	*Prosopis sp.*	Mexico10	13	0.80	0.00		0.0	0.00			3.00
4	3	5	12	*Prosopis sp.*	Mexico12	31	1.24	0.00		0.0	0.00			3.00
4	4	2	12	*Prosopis sp.*	Mexico13	56	1.44	1.22	8.75	3.9	0.25			2.67