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Evaluation of a species and provenance trial of *Prosopis* at Gonsé, Burkina Faso

Trial no. 13 in the arid zone series

by

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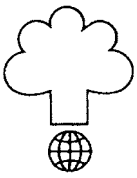

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Cover photo:
Diagram showing survival of four of the provenances in the trial. The 5th provenance had no surviving trees (Fig. 1).

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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 new 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 http://www.dfsc.dk. The scope of the series is in particular the large number of trials from which results have not been made available to the public, and which are not appropriate for publication in scientific journals. We believe that the results from these trials will contribute considerably to the knowledge on genetic variation of tree species in the tropics. Also, the analysis report will allow a more detailed documentation than is possible in scientific journals.

At the same time, the report represents the first results within the framework of the International Series of Trials of Arid and Semi-Arid Zone Arboreal Species, initiated by 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 Centre National de Semences Forestières (CNSF), in Burkina Faso in collaboration with IBN-DLD (Institute for Forest and Nature Research, Wageningen), The Netherlands. The assessment team consisted of Traoré Adama (CNSF), Diallo Boukary, Kiemdrébéogo Karim, Kaboré Ousmane, Sawadogo Abel, all from IRBET (Institut de Recherche en Biologie et Ecologie Tropical, Burkina Faso, now INERA), Agnete Thomsen (FAO) and Lars Graudal (DFSC).

The authors wish to acknowledge the help of the personnel at CNSF 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 Dr. agro. Axel Martin Jensen, and by Marcus Robbins, consultant to FAO.

Abstract

This report describes the results from a trial with five provenances of the genus *Prosopis*. The trial was established at Gonsé, Burkina Faso with a spacing of 4 x 4 metres in 1988, and was measured after five years in 1993. One provenance was from Chile (*P. chilensis*), and the rest (one provenance of *P. glandulosa* and three provenances with unknown species identity) were from Mexico.

The survival in the trial was below 10%, and there were no significant differences between the provenances in the analysed variables (survival, height and crown area). The largest provenance had attained an average height of 1.9 m. Based on the trial none of the provenances are recommended at Gonsé.

Résumé en français

Le présent rapport décrit les résultats obtenus d'un essai comparatif de cinq (5) provenances d'espèces du genre *Prosopis*. Une provenance est originaire du Chilie (*P. Chilensis*) et les quatres autres du Mexique une provenance de *P. glandulosa* et trois d'une espèce dont l'identité n'était pas connue. L'essai a été mis en place en 1988 à Gonsé (Burkina Faso) suivant un écartement de 4 x 4 mètres. Les mensurations ont eu lieu en 1993, soit cinq (5) ans après l'implantation de l'essai.

Moins de 10 % de survivants existaient et il n'y avait pas de différences significatives entre les provenances pour les variables analysées (taux de survie, hauteur et surface de houppier). La provenance la plus haute atteignait une moyenne de 1,9 m. Sur la base de cet essai, aucune des provenances ne peut être recommandée pour le site de Gonsé.

Contents

1. Introduction

This report describes the results from trial no. 13 in a large series of species and provenance trials within the 'International Series of Trials of Arid and Semi-Arid Zone Arboreal Species'. The main goals of the series were to contribute to the knowledge on the genetic variation of woody species, their adaptability and productivity and to give recommendations for the use of the species. The species included in this series of trials are mainly of the genera *Acacia* and *Prosopis*. A more detailed introduction to the series is given by DFSC (Graudal *et al.* 2003).

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 (Ffolliott & Thames 1983). It has therefore been suggested to test Neotropical species of the genus in similar zones (in particular the Sahel) in Africa. The current trial includes five provenances of the genus *Prosopis*, one of Chilean and four of Mexican origin. The provenance from Chile is of *P. chilensis*, and one of the provenances from Mexico is *P. glandulosa*. The species identity of the three remaining provenances is not known with certainty, partly because the taxonomy of *Prosopis* is still a matter of debate (cf. Ffolliott & Thames 1983).

2. Materials and methods

2.1 Site and establishment of the trial

The trial is placed at Gonsé (12°22′N, 01°19′W) in Burkina Faso at an altitude of 300 m. The mean annual temperature is 28.1°C, and the annual rainfall is 600-800 mm with a dry period of eight months. Further information is given in the assessment report, available from DFSC (DFSC 1994), and are summarised in appendix 1.

In order to facilitate the water infiltration the soil was scarified by sub-soiling with a bulldozer to a depth of 60 cm in July before planting. Seed was sown in April 1988, and the trial was established in August 1988. Beating up took place only in the first 4 weeks after establishment. The trial was weeded once a year.

2.2 Species and provenances

The trial includes one provenance of *Prosopis chilensis*, one provenance of *P. glandulosa* var. *juliflora*, and three provenances of *Prosopis*, whose exact botanical classification is not known (Table 1). One of the provenances, Mexico08, is a mixture of two seedlots of the same origin. The provenance of *P. chilensis* is from Chile, whereas the other provenances are from Mexico. For convenience, the provenances are given names relating to the geographical origin. The original seedlot numbers are provided in appendix 2.

The original rainfall data supplied from the seed collectors in Mexico was 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 provenances Mexico09 and Mexico11 given in table 1 are the original data multiplied by 100, which brings them within the range observed elsewhere in Baja California. Still the data should be considered with care.

2.3 The experimental design

The experimental design is a randomised complete block design with 4 blocks. Within each block, 25 trees planted in a square of 5×5 trees represent each provenance. The trees were planted with a spacing of 4×4 m. The layout of the trial is shown in appendix 3. Further details are given in DFSC (1994).

2.4 Assessment of the trial

In March 1993 CNSF, IRBET, FAO and DFSC undertook a joint assessment. The assessment included the characters survival, vertical height and crown diameter, measured on all trees on the plots. A detailed account of the assessment methods is given by DFSC (Graudal *et al.* 2003), and the raw data from the assessment are documented in DFSC (1994). For reference the plot data set on which the statistical analyses are performed is shown in annex 4.

Table 1. Provenances of *Prosopis* tested in trial no. 13 at Gonsé, Burkina Faso. See text for comment on the rainfall data of Mexico09 and Mexico11.

Provenance identification	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Ann. rainfall (mm)	No. of mother trees
Chile06	*P. chilensis*	Pama, Limari	Chile	31°09'S	71°04'W	650	160	8
Mexico02	*P. glandulosa* var. *juliflora*	La Muralla, Coahuila	Mexico	26°45'N	101°32'W	880		
Mexico08	*Prosopis sp.*	El Triunfo, La Paz, Bcs	Mexico	23°50'N	110°12'W			25
Mexico09	*Prosopis sp.*	San Ignacio	Mexico	27°15'N	112°52'W		100	25
Mexico11	*Prosopis sp.*	Rancho S. Juan, Loreto, Bcs	Mexico	25°48'N	101°15'W		47	25

3. Statistical analyses

3.1. Variables

In the report the three variables: survival, vertical height and crown area are analysed. Survival was analysed as the rate of surviving trees compared to the total number of trees per plot, whereas height and crown area were analysed as the mean of surviving trees for each plot.

A special problem with the assessment data is that for trees with heights below 1 m, no assessment of crown diameter was made. This was the case for as many as 10 trees out of the 45 surviving trees. Since omission of these data will lead to biased results and result in over-estimation of the provenances in question, the values for crown area for these observations have been set to zero. The estimates of crown area are thus slightly biased.

3.2 Statistical model and estimates

The statistical software package used was the Statistical Analysis System (SAS 1988a, 1988b, 1991, Littell *et al.* 1996). The variables were analysed according to the following model:

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

where X_{jk} is the value of the trait in question (e.g. height) in plot *jk*, μ is the grand mean, $provenance_j$ is the effect of provenance number *j*, $block_k$ is the effect of block *k* in the trial, and ε_{jk} is the residual of plot *jk* which is assumed to follow a normal distribution $N(0, \sigma_e^2)$. In the initial models, the co-variates were distances along the two axes of the trial, plotx and ploty, and squared values of these, plotx2 and ploty2. The co-variates were excluded successively if they were not significant at the 10% level. The P-values from the tests of provenance differences were corrected for the effect of multiple comparisons by the sequential tablewide Bonferroni method.

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.*; Afifi & Clark 1996).

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 three, 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, Skovgård & Brockdorf 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 given in the results section.

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 survival reflects only the conditions experienced during the first year's growth of the trial and not necessarily the climatic extremes and conditions that may be experienced during the life-span of a tree in the field.

Statistical analysis

The provenance Chile06 had a survival of zero and was excluded from the analysis. There were signs of variance heterogeneity between the remaining provenances, and the data was weighted.

Results

Of the 500 trees originally planted, only 45 were alive at the time of the assessment. The average survival of the provenances ranged from 0 in Chile06 to 12-15 % in the provenances Mexico08 and Mexico11. Since none of the trees from Chile06 (*P. chilensis*) had survived, the provenance is not included in Fig. 1. According to the analysis of variance without Chile06 (Table 2) there were no significant differences between the provenances. Note that the co-variate plotx2 was significant. Even with Chile06 included, the variation within the provenances was too large to make the provenance effect significant (data not shown).

Table 2. Results from analysis of variance of provenance differences of survival in trial 13.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
Provenance	3	0.5	0.43	0.73	n.s.
Block	3	3.6	3.3	0.08	
Plotx2	1	10.1	9.4	0.02	
Error	8	1.1			

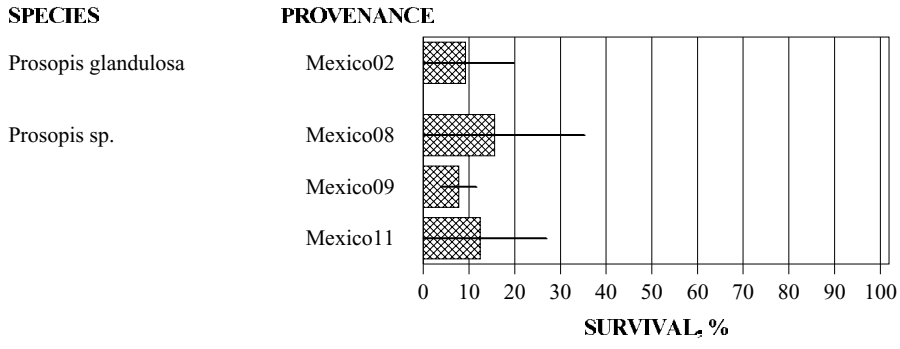

Figure 1. Survival in the *Prosopis* species and provenance trial at Gonsé, Burkina Faso (Trial no. 13 in the arid zone series). Values presented are least square means with 95 % confidence limits. Before analysis the data was weighted with the reciprocal of the variance for the provenances, and the confidence intervals are therefore of different lengths.

4.2 Height

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

Statistical analysis

The data was analysed without transformations or weights.

Results

The average vertical height ranged from 1.4 m in the provenance Mexico11 to 1.9 m in the Mexico02 (Fig. 2). In the analysis of variance there were no signs that the provenances differed with respect to height (Table 3).

Table 3. Results from analysis of variance of provenance differences of vertical height in trial 13.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
Provenance	3	0.088	0.2	0.87	n.s.
Block	3	0.376	1.0	0.48	
Error	4	0.734			

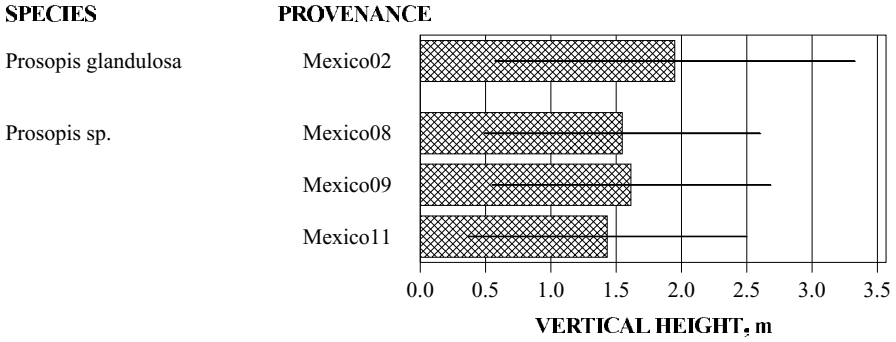

Figure 2. Vertical height in the *Prosopis* species and provenance trial at Gonsé, Burkina Faso (Trial no. 13 in the arid zone series). Values presented are least square means with 95 % confidence limits.

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 analysis was performed without transformations or weights. Note, as explained above, that the 10 smallest out of the 45 surviving trees were not assessed, and have been set to a default crown area of zero. This may introduce a bias in the analysis.

Results

The average crown area for the provenances varied between 2.2 m^2 $tree^{-1}$ (Mexico09) and 5.3 m^2 $tree^{-1}$ (Mexico02, Fig. 3). Compared to the initial growth space of 16 m^2 $tree^{-1}$, the trees would still be far from covering the area even if the survival was higher.

The differences between the provenances were not clear enough to become significant (Table 4).

Table 4. Results from analysis of variance of provenance differences of crown area in trial 13.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
Provenance	3	3.2	0.2	0.89	n.s.
Block	3	9.8	0.6	0.63	
Error	4	15.2			

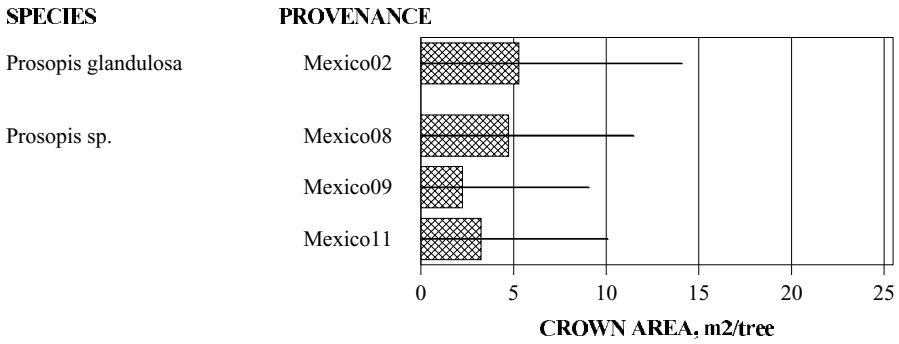

Figure 3. Crown area in the *Prosopis* species and provenance trial at Gonsé, Burkina Faso (Trial no. 13 in the arid zone series). Values presented are least square means with 95 % confidence limits.

5. Discussion and conclusions

The heights of the surviving trees were comparable to those attained by *Acacia* species in similar trials at the Gonsé (Trial nos. 10-14 in the aridzone series). Mexico02 had an average height of 1.9 m, whereas the best provenances of *A. nilotica, A. senegal, A. seyal* and *A. tortilis* in the trials 10 and 12 had heights of 2.2 m, 2.5 m, 2.9 m and 2.0 m respectively. This indicates that the growth potential of the surviving trees is within an acceptable range.

However, the very low survival of the trees in this trial quite clearly indicates that none of the provenances are adapted to the site. The low survival could be due to problems with the establishment technique, but this seems to be ruled out by comparing with results from a trial at Dori, Burkina Faso. The three provenances with unknown species identity, Mexico08, Mexico09 and Mexico11 are also represented in this trial (arid zone trial no. 9) and have survivals in the range of 50-70 %. Since the two trials were established by CNSF at the same time we thus conclude that the low survival at Gonsé is due to a poor adaptation to the site conditions. One may hypothesize that the rainfall at Gonsé is too high for the trees, originating from areas with extremely low precipitation.

Unfortunately there were no significant differences between provenances in the trial, which makes it difficult to evaluate the efficiency of selection of better provenances. Even in a multivariate analysis, including all three variables, there were no significant differences between the provenances (P for Wilk's lambda = 0.51, P for Pillai's trace = 0.70, analysis not shown).

Combined with the poor survival this means that none of the 5 provenances in the trial are recommended. For future use it seems more relevant to choose other species, which have demonstrated that they are able to grow at the site.

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Annex 1. Description of the site

Name of site:	Gonsé, Burkina Faso (Bureau National des Sols, 1990): Latitude: 12°22'N Longitude: 01°19'W Altitude: 300 m
Meteorological stations:	Region de Gonsé (Bureau National des Sols, 1990) Ouagadougou (12°21'N, 01°31'W, 306 (FAO 1984, Bureau National des Sols, 1990)
Rainfall:	Annual mean (period): 862 mm (FAO 1984) 678.55 (1985-88 (Bureau National des Sols, 1990)) Yearly registrations: 1985: 633.5 1986: 695.55 1987: 626.1 1988: 759.45 Month of establishment: 226.77
Potential evapotranspiration	(Oct.-Apr., Penman (Bureau National des sols 1990)): 1985: 1057.8 1986: 1119.6 1987: 1021.8 1988: 1052.8
Rainy season: June-September	Type: Normal with dry period
Dry months/year:	No. of dry months (<50 mm): 8 No. of dry periods: 1
Temperature (°C (FAO 1984)):	Annual mean: 28.1 Coldest month: 15.8 (mean minimum) Hottest month: 38.5 (mean maximum)
Wind: Prevailing directions:	L'harmattan (March-April) Speed at 2 m: 2.3 m/s (FAO 1984)
Topography:	Flat
Soil:	Type: Ferruginous tropical leached soil, sandy with some clay/leached gravel soil Depth: varying (Shallow-deep) (> 1 m)
Climatic/agroecological zone:	Semi-arid, Sudano-Sahelian zone.
Dominant natural vegetation:	Woody savanna (Butyrospermum parkii, Terminalia avicennoides).
Koeppen classification:	BSh.

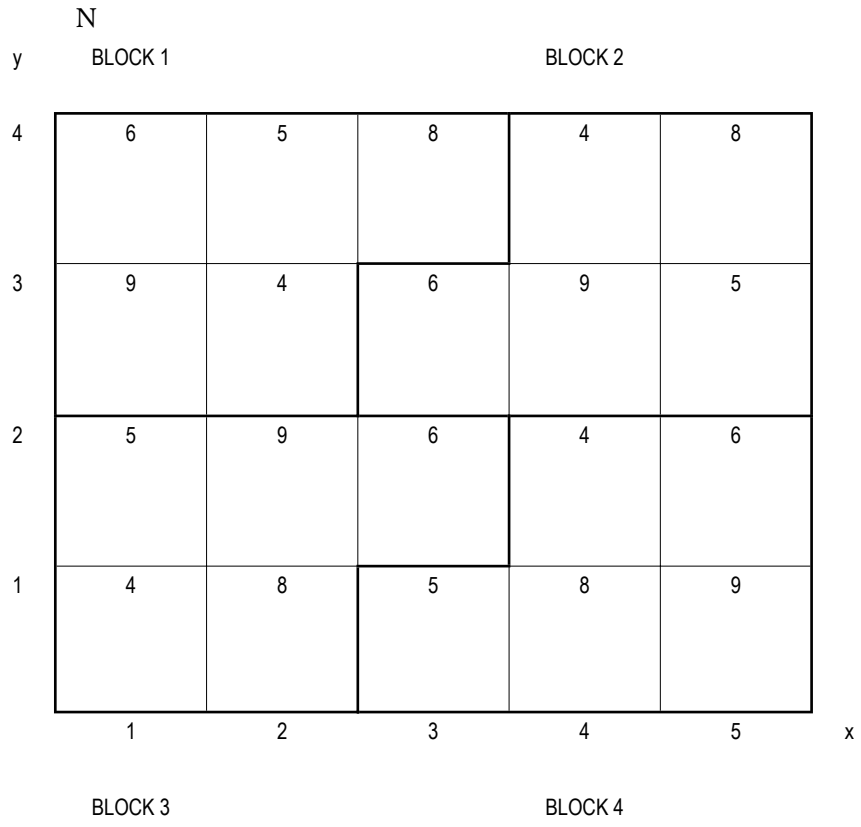
Annex 2. Provenances of *Prosopis* tested in trial no. 13 at Gonsé, Burkina Faso

The species codes are as follows: pch=*P. chilensis*, pglju=*P. glandulosa* var. *juliflora*, psp=*Prosopis sp.* See text for comment on the rainfall data of Mexico09 and Mexico11. The plot numbers refer to the seedlots in the map of the trial, see annex 3.

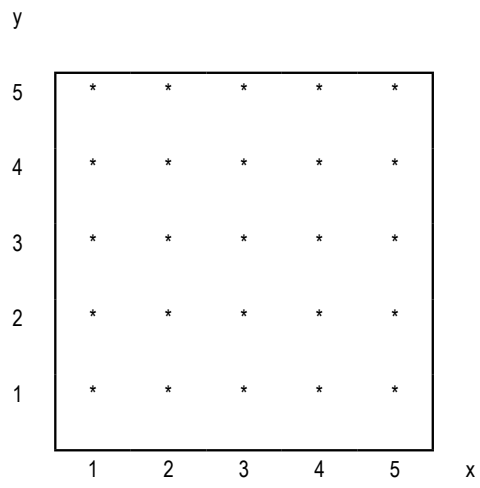
Seedlot numbers				**Provenance information**							
Provenance identification	DFSC	Country of origin	Plot	Species code	Provenance origin	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
Chile06	1419/84		8	pch	Pama, Limari	Chile	31°09'S	71°04'W	650	160	8
Mexico02	1205/83		9	pglju	La Muralla, Coahuila	Mexico	26°45'N	101°32'W	880		
Mexico08	1280 and 1478/84		6	psp	El Triunfo, La Paz, Bcs	Mexico	23°50'N	110°12'W			25
Mexico09	1281/84	38	4	psp	San Ignacio	Mexico	27°15'N	112°52'W		100	25
Mexico11	1476/84	39	5	psp	Rancho S. Juan, Loreto, Bcs	Mexico	25°48'N	101°15'W		47	25

Annex 3. Layout of the trial

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



Individual tree positions in each plot:



Annex 4. Plot data set, used for the analyses

Block	Plot	Plotx	Ploty	Species	Provenance	Survival %	Height m	Crown area m^{-2} $tree^{-1}$
1	4	2	3	*Prosopis sp.*	Mexico09	0		
1	5	2	4	*Prosopis sp.*	Mexico11	0		
1	6	1	4	*Prosopis sp.*	Mexico08	36	1.51	4.3
1	8	3	4	*P. chilensis*	Chile06	0		
1	9	1	3	*P.glandulosa var. juliflora*	Mexico02	12	1.27	2.9
2	4	4	4	*Prosopis sp.*	Mexico09	8	1.60	1.5
2	5	5	3	*Prosopis sp.*	Mexico11	40	2.60	10.0
2	6	3	3	*Prosopis sp.*	Mexico08	0		
2	8	5	4	*P. chilensis*	Chile06	0		
2	9	4	3	*P.glandulosa var. juliflora*	Mexico02	0		
3	4	1	1	*Prosopis sp.*	Mexico09	8	1.70	4.0
3	5	1	2	*Prosopis sp.*	Mexico11	4	0.70	0
3	6	3	2	*Prosopis sp.*	Mexico08	16	1.15	0.2
3	8	2	1	*P. chilensis*	Chile06	0		
3	9	2	2	*P.glandulosa var. juliflora*	Mexico02	0		
4	4	4	2	*Prosopis sp.*	Mexico09	8	1.90	2.5
4	5	3	1	*Prosopis sp.*	Mexico11	8	1.35	1.1
4	6	5	2	*Prosopis sp.*	Mexico08	8	1.40	6.6
4	8	4	1	*P. chilensis*	Chile06	0		
4	9	5	1	*P.glandulosa var. juliflora*	Mexico02	32	2.40	6.6