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

Ræbild, Anders; Diallo, Boukary O.; Graudal, Lars Ole Visti; Dao, Madjelia; Sanou, Josias

Publication date:
2003

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

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

Trial no. 14 in the arid zone series

by

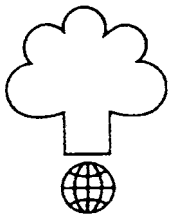
Anders Ræbild[1], Boukary Ousmane Diallo[2], Lars Graudal[1],

Madjelia Dao[2] and Josias Sanou[2]

Institut de l'Environnement et de Recherches Agricoles[2], Burkina Faso

Food and Agriculture Organization, Rome

Danida Forest Seed Centre[1], Denmark



Results and documentation no. 11

Danida Forest Seed Centre

June 2003

Citation:
Anders Ræbild, Boukary Ousmane Diallo, Lars Graudal, Madjelia Dao and Josias Sanou. 2003. Evaluation of a species and provenance trial of *Prosopis* at Gonsé, Burkina Faso. Trial no.14 in the arid zone series. Results and Documentation No. 11. Danida Forest Seed Centre, Humlebaek, Denmark.

ISSN 0902-3224

Cover:
Diagram showing survival in the trial at Gonsé, Burkina Faso. See Figure 1.

This publication can be requested from:

Danida Forest Seed Centre
Krogerupvej 21. DK-3050 Humlebaek, Denmark
Phone: +45-49190500
Fax: +45-49190258
Email: dfsc@sns.dk
Web Site: www.dfsc.dk

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

Technical Editor: Melita Jørgensen

Print:
Toptryk A/S, Graasten

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

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

Preface

This report belongs to a series of analysis reports 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 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.

The report presents the results from a trial 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 to 1994. DFSC is responsible for the reporting of this assessment.

This trial was established and maintained by Institut de l'Environnement et de Recherches Agricoles (INERA, formerly Institut de Recherche en Biologie et Ecologie Tropical, IRBET) in Burkina Faso. The assessment team consisted of Diallo Boukary, Kiemdrébéogo Karim, Kaboré Ousmane, Sawadogo Abel, all from INERA/ IRBET, Traoré Adama and Lambert Ouedraogo from Centre National de Semences Forestières, Agnete Thomsen of FAO, and Lars Graudal from DFSC.

The authors wish to acknowledge the help of the personnel at IRBET 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 Marcus Robbins, consultant to FAO.

Abstract

This report describes results from the analysis of a trial including four provenances of *Prosopis juliflora* and two provenances of *P. limensis* and *P. pallida*, established at Gonsé, Burkina Faso. The provenances were a mixture of original introductions from South and Central America and landraces from Africa. The trial was established in 1986 at a spacing of 4 x 4 metres and assessed after 7 years in 1993. The assessment included survival, height, health and crown area.

The overall survival of the provenances was low, ranging from 10 to 40 %, but the mean height of trees in the largest provenances was 2.5 m. There were significant differences between provenances in survival, height and crown area, and the best choice seemed to be the landrace of *P. juliflora* from Burkina Faso. The provenances of *P. limensis* and *P. pallida* both had a low survival.

Résumé en français

Ce rapport décrit les résultats d'un essai comparatif de six provenances du genre *Prosopis*. *Prosopis juliflora* étais représenté par 4 provenances, et *P. limensis* et *P. pallida* par une provenance chacun. Les provenances sont originaires de l'Amérique latine, et descendants des introductions en Afrique. Cet essai a été mis en place en 1986 à Gonsé au Burkina Faso. Le dispositif est sous forme de placeaux et la densité de plantation est de 4 × 4 m. L'évaluation de l'essai a été faite en 1993 soit 7 ans après la mise en place. La survie, la hauteur, la santé et le diamètre de la cime a été mesuré.

La survie moyenne des provenances était entre 10 et 40 %. La hauteur moyenne de la provenance la plus grande était de 2.5 m. L'analyse a révélé des différences significatives entre les provenances pour les variables survie, hauteur et diamètre de la cime, et la provenance la plus performante était la provenance de *P. juliflora* du Burkina Faso. Le taux de survie pour les provenances de *P. limensis* et *P. pallida* était faible.

Contents

1. Introduction

This report describes the results from trial no. 14 in a large series of provenance trials within the 'International Series of Trials of Arid and Semi-Arid Zone Arboreal Species'. The main goals of the series were to contribute to the knowledge on the genetic variation of woody species, their adaptability and productivity and to give recommendations for the use of the species. The species included in this series of trials are mainly of the genera *Acacia* and *Prosopis*. A more detailed introduction to the series is given by DFSC (Graudal *et al.* 2003).

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.

P. juliflora originates in Northern South America and Central America (ibid.) and is being cultivated across the Sahel due to its tolerance to harsh conditions (von Maydell 1986). In this trial three African seedlots are tested against a new introduction from Honduras. Furthermore two provenances from Peru are included, classified as *P. limensis* and *P. pallida* by the institution collecting the seed. According to Ffolliott & Thames (1983), *P. limensis* is considered part of *P. pallida*, suggesting that the two provenances represent the same species. In this report they are, however, treated as two separate species

2. Materials and methods

2.1 Site and establishment of the trial

The trial is located at Gonsé (12°22′N, 01°19′W) in Burkina Faso at an altitude of 300 m. The mean annual temperature is 28.8, and the mean annual rainfall is 600-800 mm (DFSC 1994). The dry period is approximately eight months. Further information is given in the assessment report (DFSC 1994) and summarised in annex 1.

Seed was sown in April 1986, and the trial was established in July 1986.

2.2 Species and provenances

The trial includes 4 provenances of *P. juliflora*, of which three are landraces from Burkina Faso, Senegal and Nigeria, and one is from Honduras (Table 1). Furthermore two Peruvian provenances of *P. limensis* and *P. pallida* are represented. The provenances have been given identification numbers relating to their geographical origin (name of province or country followed by a number). The original seedlot numbers are provided in annex 2.

2.3 The experimental design

The experimental design is a randomised complete block design with 4 blocks. Within each block, each provenance is represented by 49 trees in a plot, planted in a square of 7 × 7 trees. The trees have a spacing of 4 × 4 m. The layout of the trial is shown in annex 3. Further details are given in DFSC (1994).

2.4 Assessment of the trial

In March 1993 IRBET, CNSF, FAO and DFSC undertook a joint assessment of the trial. The assessment included the characters: survival, vertical height and crown diameter, measured on the 5 × 5 central trees of each plot. 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). The plot data set on which the statistical analyses in this report are performed is shown in annex 4.

Table 1. Species and provenances of *Prosopis* tested in trial no. 14 Gonsé, Burkina Faso.

Provenance identification	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Ann. rain-fall (mm)	No. of mother trees
Burkina20	*P. juliflora*	Bokouma, Soum	Burkina Faso	14° 12' N	00° 43' E	317	400	
Honduras2	*P. juliflora*	Comayagua	Honduras	14° 16' N	16° 57' W	750		
Nigeria1	*P. juliflora*	Gamborungala, Bornou	Nigeria					
Senegal39	*P. juliflora*	Thies	Senegal	14° 48' N	16° 57' W			
Peru04	*P. limensis*	Piura	Peru	5° 25' S	80° 47' W	13	70	
Peru16	*P. pallida*	Sechura (Piura)	Peru	5°33'S	80°48'W	4	25	5

3. Statistical analyses

3.1 Variables

In the report the three variables survival, vertical height and crown area are analysed. A number of health characters were evaluated, but since the trees were generally in good health and only a few trees of block 1 were moderately damaged, these characters are not analysed in the present report. A graphical presentation of the health data is given in annex 5. Survival was analysed as the rate of surviving trees 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 problem with the assessment data is that for trees with heights below 1 metre, no assessment of crown diameter was made. This was the case for 5 of the surviving 134 trees. 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 for these observations have been set to zero. The crown areas for these trees are thus set artificially with the result that the estimates for crown are still slightly biased.

3.2 Statistical model and estimates

Each variable was analysed in two stages. First stage was a test of differences between all provenances, whereas the second stage was an analysis of provenance differences within *P. juliflora*. In both cases 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 fixed effect of provenance number *j*, $block_k$ is the random 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.

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. The test corresponding to the smallest P value (P_1) was considered significant on a 'table-wide' significance level of α if $P_1 < \alpha/n$, where n is the number of tests. The second smallest P value (P_2) was declared significant if $P_2 < \alpha/(n-1)$, and so on (c.f. Kjaer & Siegismund 1996). In this case the number of tests was set to 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 estimates (lsmeans). 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).

The statistical software package used was the 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

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

In the first analysis there were signs of variance heterogeneity, and the data was weighted to fulfil the assumptions of the model.

Results

The overall survival of the trial was low, and there was a large variation in the plot survival within the provenances (Fig. 1). Nigeria1 (*P. juliflora*) and Peru16 (*P. pallida*) both had average survivals close to 10 %, whereas the provenances Burkina20 and Honduras2 of *P. juliflora* had the highest survivals of approximately 40 %. Senegal39 and Peru04 were both intermediate. The differences were significant when analysing all provenances together, but when the analysis was repeated on the provenances of *P. juliflora* only, the differences were significant only at the 10 % level (Table 2).

Table 2. Results from analysis of variance of provenance differences of survival in trial 14.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of provenance differences					
Provenance	5	7.43	6.9	0.002	**
Block	3	9.39	8.7	0.001	
Error	15	1.08			
Prosopis juliflora					
Provenance	3	3.92	3.4	0.07	(*)
Block	3	5.42	4.7	0.03	
Error	9	1.16			

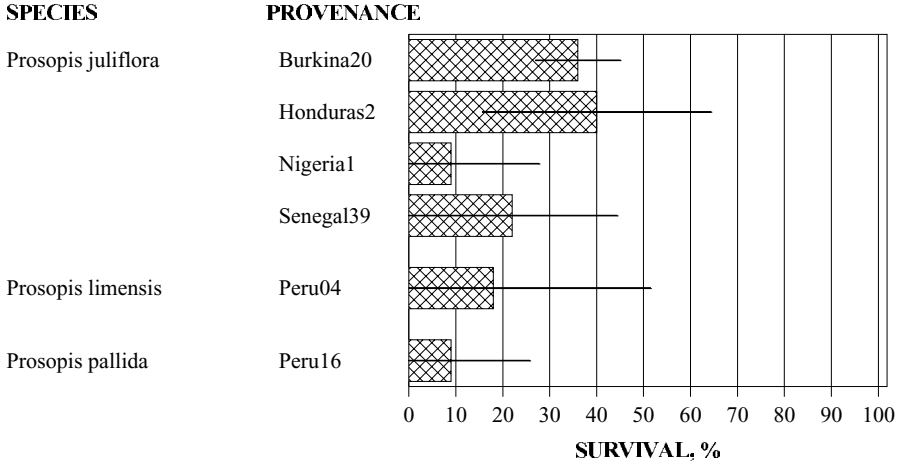


Figure 1. Survival in the *Prosopis* species and provenance trial at Gonsé, Burkina Faso (Trial no. 14 in the arid zone series). Values presented are least square means with 95 % confidence limits. Before analysis the data was weighted with the reciprocal of the variance for the provenances, and the confidence intervals are therefore of different lengths.

4.2 Height

Height is usually considered an important variable in the evaluation of species and provenances. 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. As there have been cases where tall provenances are suddenly affected by stress and die-off, this interpretation need not always be true, however.

Statistical analysis

Again it seemed that the provenances had different variances, and the data was weighted to fulfil model assumptions.

Results

The average heights varied between 1.3 m for Honduras2 and 2.8 m for Senegal39, both of *P. juliflora* (Fig. 2). The variances for Peru04 (*P. limensis*) and especially Peru14 (*P. pallida*) were large, perhaps because of the poor survival, and when all provenances were tested together, no significant differences were found (Table 3). However, when these two provenances were excluded and only *P. juliflora* provenances were tested the differences between provenances were significant, also when adjusting for multiple tests.

Table 3. Results from analysis of variance of provenance differences of vertical height in trial 14.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of provenance differences					
Provenance	5	1.12	2.3	0.12	n.s.
Block	3	0.787	1.6	0.25	
Error	10	0.486			
Prosopis juliflora					
Provenance	3	10.7	9.4	0.01	*
Block	3	2.35	2.1	0.21	
Error	6	1.14			

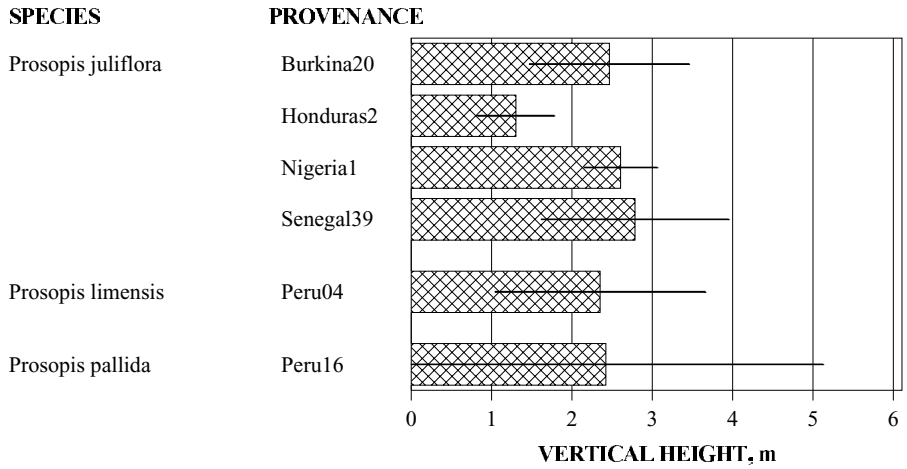


Figure 2. Vertical height in the *Prosopis* species and provenance trial at Gonsé, Burkina Faso (Trial no. 14 in the arid zone series). Values presented are least square means with 95 % confidence limits. Before analysis the data was weighted with the reciprocal of the variance for the provenances, and the confidence intervals are therefore of different lengths.

4.3 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

As in the other two variables there were signs of variance heterogeneity, and the data was weighted. Note that for five of the smallest trees the crown areas have been set to zero (see 3.1).

Results

The average crown area for the provenances varied between 3 and 14 m^2 $tree^{-1}$ with the low and high extremes being Senegal39 and Nigeria1, respectively (Fig. 3). This corresponds to a growth space of 16 m^2 $tree^{-1}$, meaning that the canopy would be closing for Nigeria1, had the survival been higher.

Again the variances were large for Peru04 and Peru16, but for this variable the large variances did not hide the highly significant differences between provenances (Table 4). The provenance effect was significant also when *P. juliflora* was analysed alone.

Table 4. Results from analysis of variance of provenance differences of crown area in trial 14.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of provenance differences					
Provenance	5	49.4	48.0	<0.0001	***
Block	3	14.1	13.7	0.0007	
Error	10	1.0			
Prosopis juliflora					
Provenance	3	28.5	27.0	0.0007	**
Block	3	5.0	4.7	0.05	
Error	6	1.1			

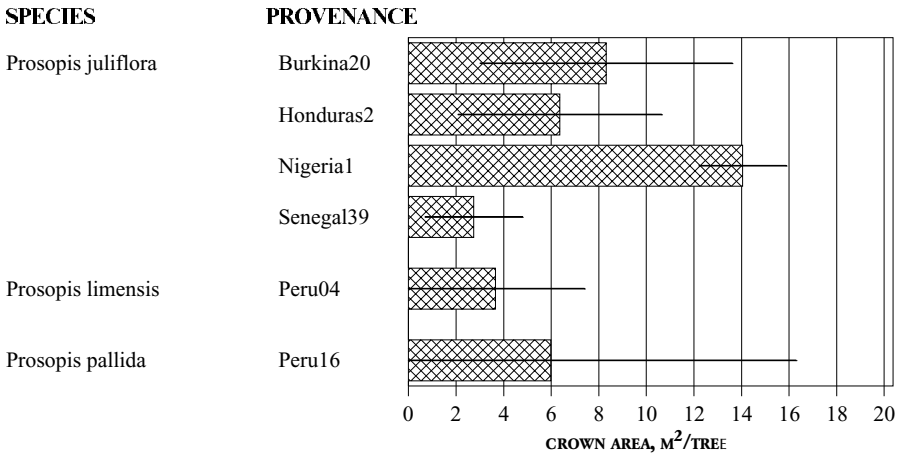


Figure 3. Crown area in the *Prosopis* species and provenance trial at Gonsé, Burkina Faso (Trial no. 14 in the arid zone series). Values presented are least square means with 95 % confidence limits. Before analysis the data was weighted with the reciprocal of the variance for the provenances, and the confidence intervals are therefore of different lengths.

4.4 Results from the multivariate analysis

The multivariate analysis included the three variables analysed in the univariate analyses, and the analysis was performed first on the total data set and then on the provenances of *P. juliflora* only. No account was made for the variance heterogeneity observed in the univariate analyses.

All provenances

The first canonical variate was significant, whereas the second was only significant at the 10 % level (Table 5). In total, the two variates accounted for 94 % of the variation. The differences between the provenances were significant (P-value for Wilk's lambda=0.01, P-value for Pillai's trace=0.01).

In Fig. 4 the canonical scores and 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 in reality have different properties. There is no clear clustering between the provenances, and Peru04 and Peru16 of *P. limensis* and *P. pallida* do not separate from the provenances of *P. juliflora*. The main difference seems to be that Honduras2 is quite distant from the provenances Senegal39, Peru04 and Peru16.

P. juliflora

In this analysis only the first canonical variate was significant, accounting for 79 % of the variation. The differences between provenances were significant at the 5 % level (P for Wilk's lambda=0.04, P for Pillai's trace=0.06, Table 5). The pattern of variation was the same as observed for all provenances analysed together – Honduras2 seemed to be distant from Senegal39 (Fig. 5). Please observe that the confidence regions are based on four replicates for each provenance. Senegal39 and Nigeria1 are only represented with 3 and 2 replicates, which means that the confidence regions should ideally be larger.

Table 5. Results from the canonical variate analyses for the first two canonical variates in trial 14.

Analysis of all provenances						
Canonical variate no.	**1**	**2**				
Proportion of variation accounted for	0.66	0.28				
Significance, P-value	0.01	0.09				
	Raw canonical coefficients		**Standardised canonical coefficients**		**Canonical directions**	
Canonical variate no.	**1**	**2**	**1**	**2**	**1**	**2**
Survival	5.8	-4.2	1.1	-0.8	0.6	-0.8
Height	-1.6	-0.10	-1.3	-0.1	-3.2	0.06
Crown area	0.18	0.25	0.8	1.1	8.5	26.6

Analysis of *P. juliflora*						
Canonical variate no.	**1**	**2**				
Proportion of variation accounted for	0.79	0.20				
Significance, P-value	0.04	0.17				
	Raw canonical coefficients		**Standardised canonical coefficients**		**Canonical directions**	
Canonical variate no.	**1**	**2**	**1**	**2**	**1**	**2**
Survival	0.3	-6.0	0.06	-1.2	0.01	-0.4
Height	-2.3	0.6	-2.0	0.5	-1.5	2.4
Crown area	0.4	0.1	2.0	0.7	6.2	13.3

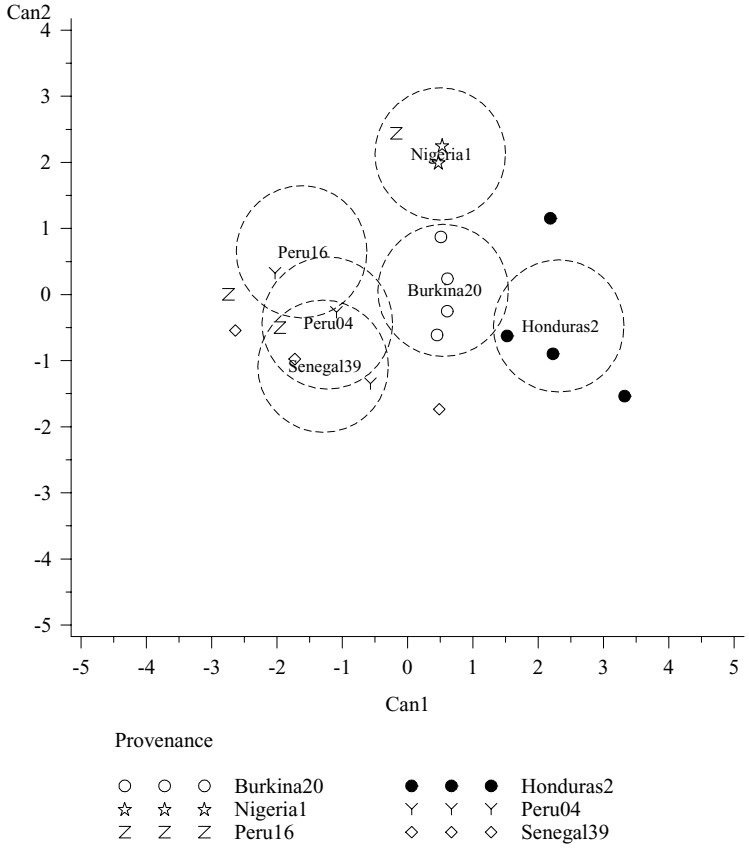


Figure 4. Score plot of the first and the second canonical variate from the canonical variate analysis for the 6 provenances in the *Prosopis* species and provenance trial at Gonsé, Burkina Faso (Trial no. 14 in the arid zone series). The variables survival, height and crown area were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region. Peru04 is *P. limensis*, Peru16 is *P. pallida* and the rest are *P. juliflora*.

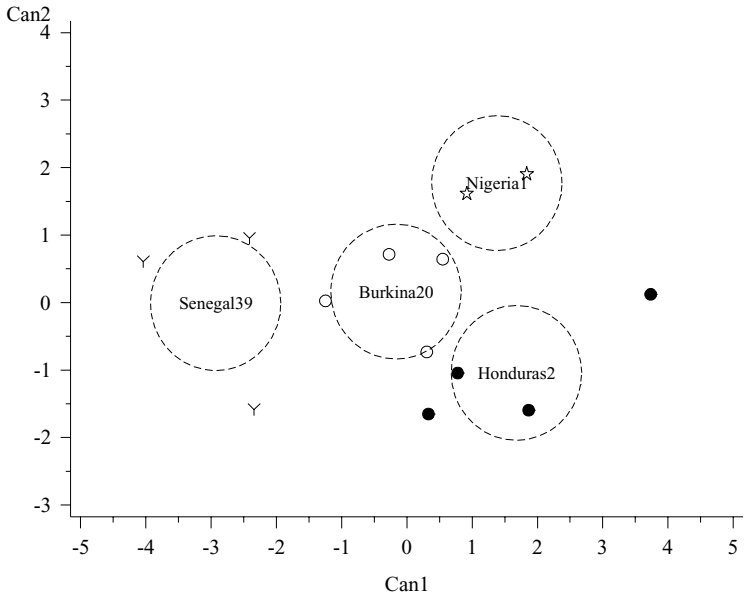


Figure 5. Score plot of the first and the second canonical variate from the canonical variate analysis for *P. juliflora* provenances in the trial at Gonsé, Burkina Faso (Trial no. 14 in the arid zone series). The variables survival, height and crown area were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region. Legend as in Fig. 4.

5. Discussion and conclusions

Productivity

It is difficult to assess the productivity of the trees when no diameters have been measured. It seems that at least the height growth of the best provenances, attaining average heights of 2.5 – 2.8 m, is comparable to the growth in a number of *Acacia* and *Prosopis* species and provenance trials at Gonsé (The trials no. 10-13 in the arid zone series). However, since the survival was quite low for most of the provenances, the productivity must be correspondingly low. The same pattern with poor survival and a relatively fast height growth was observed for *P. chilensis* in the arid zone trial no. 9 at Dori. One cannot exclude the possibility that the productivity could be comparable to the productivity in some of the other species, provided that the problems with low survival are solved.

Provenance differences and recommendations

All provenances had a low survival. Judged from the somewhat sparse material, the best provenance seemed to be the local landrace of *P. juliflora*, Burkina20. This provenance had a relatively high survival and ranked among the best with regards to height growth. Honduras2 also had a relatively high survival, but had a slow height growth. Nigeria1 and Senegal39 had low survivals, but acceptable heights. It is interesting to note that these provenances are very different in the crown areas, representing the largest and the smallest crown areas, respectively. The provenances of *P. limensis* and *P. pallida* both had a poor survival and do not seem apt for the site, even though the height growth of the surviving trees was acceptable.

6. References

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

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

DFSC 1994. Preliminary assessment report – trial no. 14. *Prosopis juliflora* provenance trial, Gonsé, Burkina Faso, joint assessment, March 1993 by IRBET, CNSF, FAO and DFSC. Danida Forest Seed Centre, Humlebæk, Denmark.

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

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

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

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

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

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

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

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

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

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

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

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

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

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: 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.

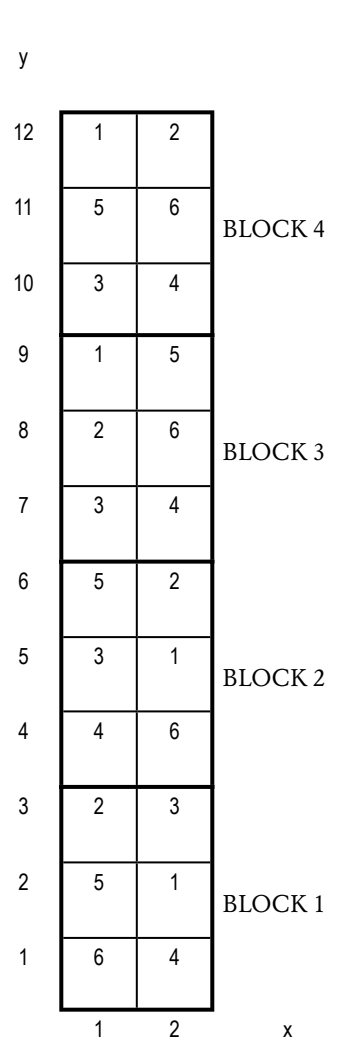
Annex 2. Seedlot numbers

The plot numbers refer to the seedlots in the map of the trial, see annex 3.

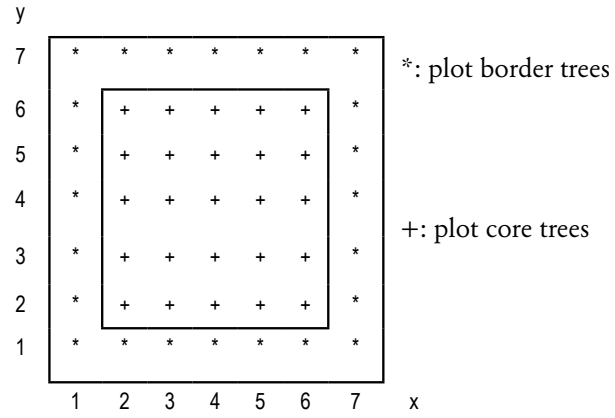
Seedlot numbers				Provenance information							
Provenance identification	**DFSC**	**Country of origin or CTFT**	**Plot**	**Species code**	**Origin**	**Country of origin**	**Latitude**	**Longitude**	**Altitude (m)**	**Rainfall (mm)**	**No. of mother trees**
Burkina20		124 (CNSF)	1	pju	Bokouma, Soum	Burkina Faso	14° 12' N	00° 43' E	317	400	
Honduras2		84/4674N (CTFT)	4	pju	Comayagua (=OFI 49/83 ?)	Honduras	14° 16' N	16° 57' W	750		
Nigeria1		85/5482N (CTFT)	6	pju	Gamborungala, Bornou	Nigeria					
Senegal39		84/4278N (CTFT)	3	pju	Thies (=746/82 ?)	Senegal	14° 48' N	16° 57' W			
Peru04		79/2604N (CTFT)	2	pli	Piura	Peru	5° 25' S	80° 47' W	13	70	
Peru16	1127/83	85/4800N (CTFT)	5	ppa	Sechura (Piura)	Peru	5°33'S	80°48'W	4	25	5

Annex 3. Map 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

Species codes: pju=*P. juliflora*, pli=*P. limensis*, ppa=*P. pallida*.

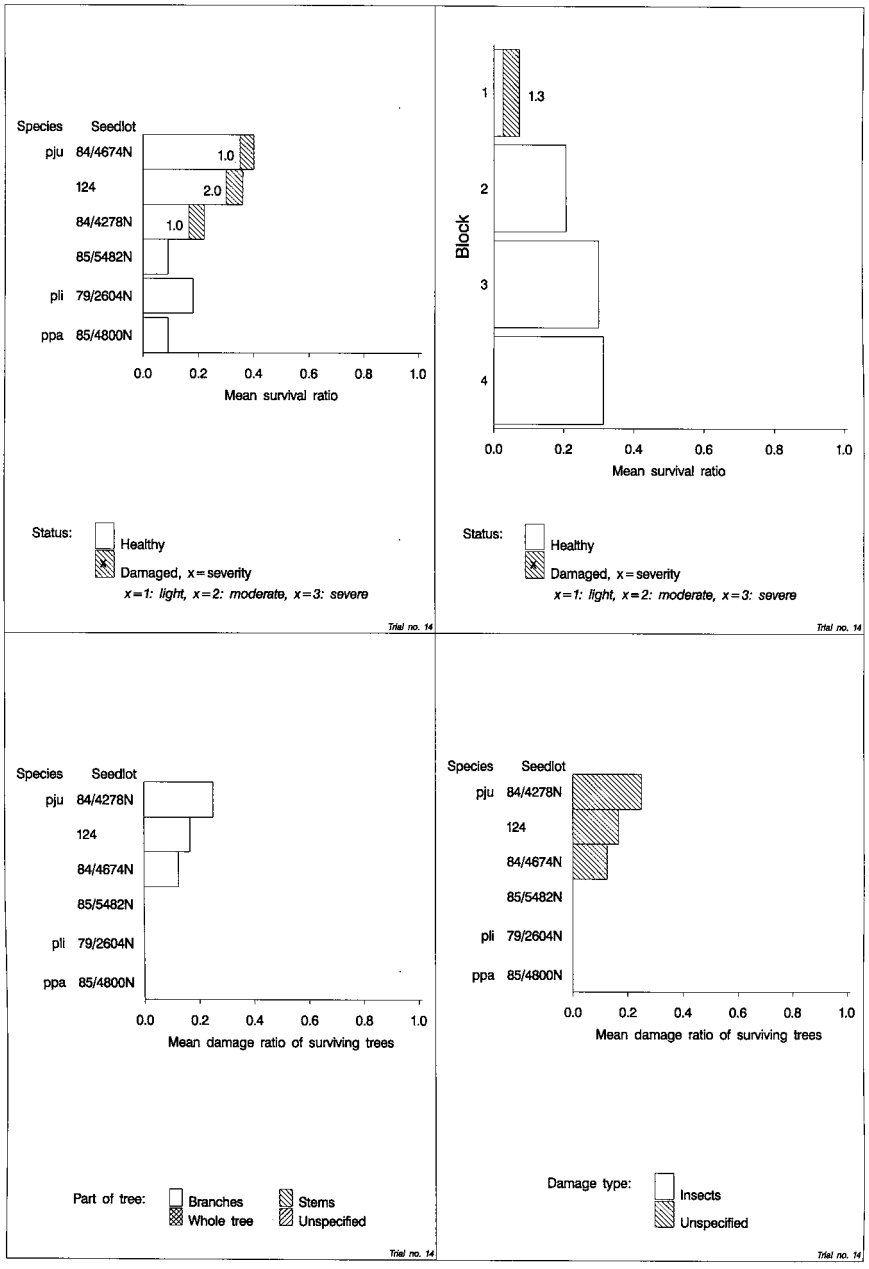
Block	Plot	Plotx	Ploty	Species	Provenance	Survival	Height	Crown area
						proportion	m	m^2 $tree^{-1}$
1	1	2	2	pju	Burkina20	0.12	1.90	3.16
1	2	1	3	pli	Peru04	0.00		
1	3	2	3	pju	Senegal39	0.16	4.15	5.01
1	4	2	1	pju	Honduras2	0.16	1.83	10.90
1	5	1	2	ppa	Peru16	0.00		
1	6	1	1	pju	Nigeria1	0.00		
2	1	2	5	pju	Burkina20	0.36	2.93	11.96
2	2	2	6	pli	Peru04	0.08	1.85	2.22
2	3	1	5	pju	Senegal39	0.40	1.97	1.77
2	4	1	4	pju	Honduras2	0.20	0.68	2.34
2	5	1	6	ppa	Peru16	0.08	2.30	1.46
2	6	2	4	pju	Nigeria1	0.12	2.20	13.17
3	1	1	9	pju	Burkina20	0.48	2.15	6.55
3	2	1	8	pli	Peru04	0.16	2.30	3.52
3	3	1	7	pju	Senegal39	0.32	2.41	1.04
3	4	2	7	pju	Honduras2	0.80	1.62	6.58
3	5	2	9	ppa	Peru16	0.04	1.40	9.62
3	6	2	8	pju	Nigeria1	0.00		
4	1	1	12	pju	Burkina20	0.48	2.88	11.59
4	2	2	12	pli	Peru04	0.48	2.90	5.22
4	3	1	10	pju	Senegal39	0.00		
4	4	2	10	pju	Honduras2	0.44	1.08	5.63
4	5	1	11	ppa	Peru16	0.24	3.57	6.87
4	6	2	11	pju	Nigeria1	0.24	2.42	14.42

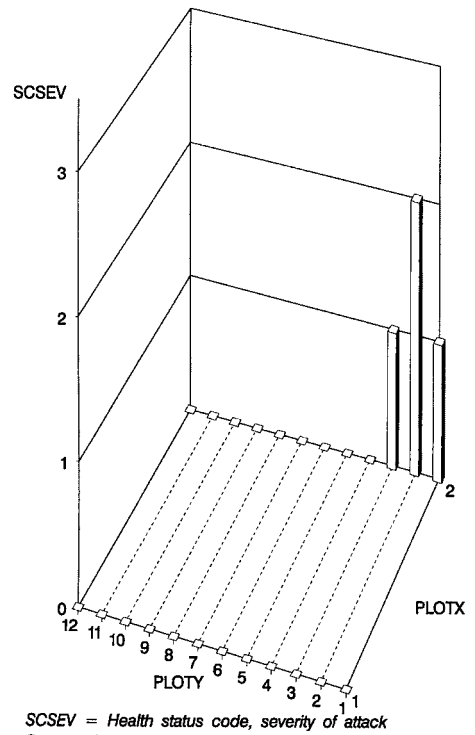
Annex 5. Graphical presentation of the health data

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

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

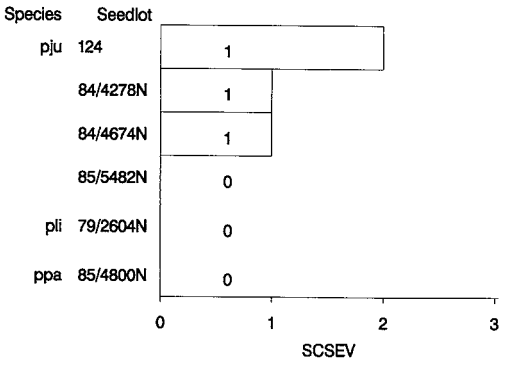
Please note that the seedlot codes correspond to the numbers given in annex 2.





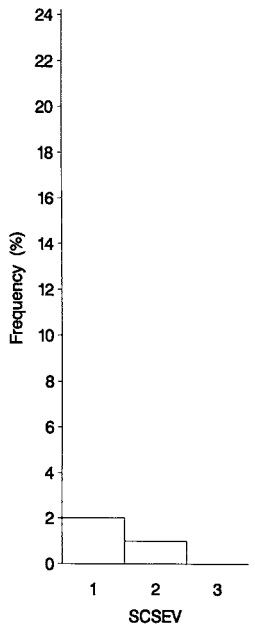
SCSEV = Health status code, severity of attack
Scatter of plot mean values

Trial no. 14



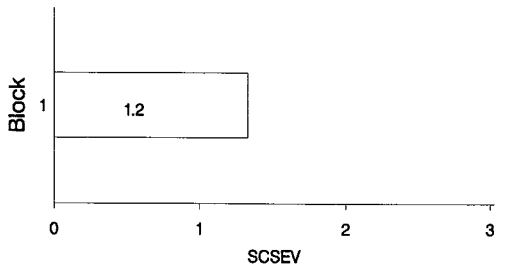
Mean SCSEV of seedlot with error bar line (+/− standard deviation of the mean) and the average number of assessed (living) trees per plot for each seedlot.

Trial no. 14



Frequency distribution of plot mean values

Trial no. 14



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

Trial no. 14