Evaluation of a species and provenance trial of *Prosopis cineraria, P. pallida* and *Acacia senegal* at Djibo, Burkina Faso

Trial no. 6 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

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Cover:
Diagram showing survival in the *Prosopis cineraria*, *P. pallida* and *Acacia senegal* species and provenance trial at Djibo, 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

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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 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, Karim Kiendrebeogo, Tamboura Saïdou, Tamboura Adama, Tamboura Amadou, Adama Douramani, all from INERA/IRBET, Traoré Adama 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 the results from a trial with the two species *Prosopis cineraria* and *P. pallida*, established in 1985 with a spacing of 4 x 4 metres at Djibo, Burkina Faso. The assessment took place 8 years later in 1993. The provenances of *P. cineraria* were from India, Pakistan and Yemen, whereas the provenances of *P. pallida* were from Peru. A local provenance of *Acacia senegal* was included as a control.

The growth of *P. cineraria* was very poor, and only survival was registered. For the other species, a number of growth parameters were measured. There were no significant differences between the provenances, but from the raw data it seemed that the provenance of *A. senegal* had a considerably larger basal area of the mean tree as well as dry weight of the mean tree than had the rest of the provenances. The dry weight production of the largest provenance was approximately 0.8 t ha^{-1} y^{-1}. The lack of significance is in part due to the poor survival and the low number of replicates.

Planting of *P. cineraria* can thus not be recommended, and before commencing plantations of *P. pallida,* a larger number of provenances should be tested.

Résumé en français

Ce rapport décrit les résultats issus d'essai de provenances de deux espèces *Prosopis cineraria* et *Prosopis pallida.* Cet essai a été mis en place en juin 1985 à Djibo au Burkina Faso. Le dispositif est sous forme de placeaux et la densité de plantation est de 4 m × 4 m. L'évaluation de l'essai a été faite en 1993 soit 8 ans après la mise en place. Les provenances de *P. cineraria* sont originaires d'Inde, du Pakistan, du Yémen alors que celles de *P. Pallida* viennent du Pérou. Le témoin est une provenance de *Acacia senegal.*

La croissance de *P. cineraria* étant très faible, seul le taux de survie a été mesuré. Chez les provenances des deux autres espèces un certain nombre de paramètres de croissance a été mesuré. Les analyses montrent qu'il n'y a pas de différences significatives entre les provenances de *Prosopis*. Cependant la provenance de *A. senegal* a une surface de recouvrement et une matière sèche plus élevées. La production de matière sèche pour la plupart des provenances est de l'ordre de 0.8 t ha^{-1} an^{-1}. La faible différence est due à la forte mortalité et à un nombre de répétitions limité.

La plantation de *Prosopis cineraria* ne peut pas être recommandée dans cette zone et les plantations de *Prosopis pallida* doivent être précédées par des essais de plusieurs provenances.

Contents

1. Introduction

This report describes the results from trial no. 6 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). *P. cineraria* has a widespread distribution including Arabia, Pakistan and India (Leakey & Last 1978). So far it has found only limited use on the African continent, and in the present trial a number of provenances is examined.

It has also been suggested to test Neotropical species of the genus in dry zones (in particular the Sahel) in Africa. *P. pallida* is a drought-tolerant species native to Peru, Colombia and Ecuador (Ffolliott & Thames 1983), and two Peruvian provenances are on trial in this experiment. As a local control a provenance of *Acacia senegal* is included.

2. Materials and methods

2.1 Site and establishment of the trial

The trial is placed at Djibo (14°06′N, 01°37′W) in Burkina Faso. The annual average rainfall decreased from 570 mm in 1961-1970 to 300 mm in 1981-1987 (references in DFSC 1994), and the dry period varies from eight to ten months.

Before planting the soil was scarified in the planting rows by a single tooth sub-soiling to a depth of 60 cm. The trial was planted in July 1985 and beaten up two weeks after with the same provenances as originally planted. The conditions were unfavourable during the first years, the rainfall for 1985, 1986 and 1987 being only 175 mm, 299 mm and 298 mm, respectively. Further information is given in the assessment report (DFSC 1994) and summarised in annex 1.

2.2 Species and provenances

The trial include one provenance of *A. senegal*, five provenances of *Prosopis cineraria* from Pakistan, India and Yemen, and finally two provenances of *P. pallida* from Peru (Table 1). The provenances are given names relating to the geographical origin (name of province or country followed by a number). The original seedlot numbers are provided in annex 2.

2.3 Experimental design

The trial is a randomised complete block design with three blocks. Within each block, each provenance is represented by 49 trees in a plot, planted in a square of 7 × 7 trees with 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

In March 1993 INERA/IRBET, FAO, CNSF and DFSC undertook a joint assessment. Three plots of one of the blocks no longer existed at the time and therefore are not included in the analysis. Furthermore, the survival and growth of *P. cineraria* was poor, and only survival was registered for this species. For the other species, the assessment included the following characters: survival, vertical height, diameter at 0.3 m, number of stems at 0.3 m and crown diameter. Only the 5 × 5 central trees of each plot were evaluated. A detailed account of the assessment methods is given by DFSC (Graudal *et al.* 2003).

Table 1. Species and provenances tested in trial no. 6 at Djibo, Burkina Faso.

Provenance identification	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
Burkina08	*Acacia senegal*	Mogtedo	Burkina Faso					
Ahmedabad2	*Prosopis cineraria*	Sumarsar (Naik Wali), Kutch (Bhuj)	India	23°50'N	69°48'E	80	348	25
NW Frontier3	*Prosopis cineraria*	Bhakkar (Darya Khan Or Goharwala)	Pakistan	31°40'N	71°08' E	200	200	30
Sind10	*Prosopis cineraria*	Saeed-Abad, Hyderabad	Pakistan	25°25'N	68°24 E	30	157	25
Sind11	*Prosopis cineraria*	Islam-Kot, Tharparkar, Registan (Loonio)	Pakistan	24°40'N	70°12 E	50	150	25
Yemen5	*Prosopis cineraria*	Khanfar (Aden)	Yemen	13°00'N	45°10'E	15	50	20
Peru06	*P. pallida*	Puerte Del Vice, Piura	Peru	05°25'S	80°47'W	13	70	18
Peru12	*P. pallida*	Sechura (Piura)	Peru	05°33'S	80°48'W	4	25	5

3. Statistical analyses

3.1 Variables

In the report the following eight variables are analysed:

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

Survival was analysed as the rate of surviving trees to the total number of trees per plot, whereas height, crown area, number of stems, basal area and dry weight was analysed as the mean of the surviving trees for each plot. The area-related measures, total basal area and total dry weight, were calculated as the sum of the variables for each block and provenance and then related to the growth space of the trees, expressing the variables on an area basis.

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. senegal* the regression is

$$TreeDW = e^{(2.474\times\ln(basalarea)-2.233)}$$

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. pallida* the regression is

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

Since *P. cineraria* was too small to be measured, no calculation of dry weight was made for this species.

3.2 Statistical model and estimates

For survival, the variables were analysed according to a model including only the effect of provenance and blocks to find general effects of the provenances. Second, species differences were analysed by a model with the main effects of species, provenance and blocks. The final step was to analyse provenance differences within the species for each of the species *P. cineraria* and *P. pallida*. This was done according to a model including only the effect of provenance and blocks.

For the other variables, which were analysed only on *A. senegal* and *P. pallida*, the first step was to test provenance differences according to a model including the effect of provenance and blocks. The second step was to test provenance differences within *P. pallida* according to the same model.

Thus, the test of species differences was based on the model:

$$X_{ijk} = \mu + species_i + provenance(species)_{ij} + block_k + \varepsilon_{ijk}$$

where X_{ijk} is the value of the trait (e.g. height) in plot *ijk,* μ is the grand mean, $species_i$ is the fixed effect of species number *i,* $provenance(species)_{ij}$ is the effect of provenance number *j* nested within species *i,* assumed to be a random effect with an expected value of zero and variance σ_{pr}^2, $block_j$ is the effect of block (replication) *k* in the trial, assumed to be a random effect (or, in the case of calculating least square means, a fixed effect), and ε_{ijk} is the residual of plot *ijk*, and is assumed to follow the normal distribution $N(0, \sigma_e^2)$. This test was performed using the Satterthwaite method for calculation of the degrees of freedom (SAS 1988b).

The test of significant differences between provenances was based on the model:

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

where X_{jk} is the value of the trait in plot *jk,* μ is the grand mean, $provenance_j$ is the fixed effect of provenance number *j*, $block_k$ is the fixed effect of block *k*, and ε_{jk} is the residual of plot *jk* and is assumed to follow a normal distribution $N(0, \sigma_e^2)$.

In the initial models, the co-variates were distances along the two axes of the trial, plotx and ploty. The co-variates were excluded successively if they were not significant at the 10% level. In none of the analyses the co-variates were significant, and no further reference is made to this.

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.* 2001). Where appropriate, transformations were performed to fulfil basic model assumptions (ibid.; Afifi & Clark 1996). Where large provenances tended to have larger variances than small provenances, a logarithmic transformation was used to stabilise variance. In the case of survival, an arcsine transformation was used.

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. Kjaer & Siegismund 1996). In this case the number of tests was set to eight, thus equalling the number of variables analysed. The significance levels are indicated by (*) (10%), * (5%), ** (1%), *** (1 ‰) and N.S. (not significant).

Finally the model was used to provide least square means (lsmeans) as estimates for provenance values. No multivariate analysis was performed in this trial, because the number of replicates was too small to allow for an analysis.

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. 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 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 analysis was first performed on un-transformed data, but the residuals did not follow the normal distribution. An arcsine transformation improved the distribution of the residuals, and this transformation was used to present the data.

Results

The average survival for the provenances varied between 20 and 88 % when calculated on the raw data. Due to the arcsine transformation, the least square means are biased, meaning that the range in Fig. 1 is only 20 to 80 %. However, the values depicted in Fig. 1 still give the best illustration of the differences between the provenances and can be used to compare the performance of the provenances.

The analysis of variance demonstrated that there were significant differences between the provenances (Table 2). Note that these differences were no longer significant when the P-value was corrected for multiple comparisons. However, when trying to decipher the differences in more detail, it turned out that there were differences neither between species nor between provenances within the species. Thus the significant differences must be due to differences between provenances of the different species.

The provenances with high (>50 %) survival included Ahmedabad2 and Sind10 of *P. cineraria* and the two Peruvian provenances of *P. pallida*. The *A. senegal* provenance Burkina08 and the *P. cineraria* provenances NW Frontier3, Sind11 and Yemen5 all had low survival.

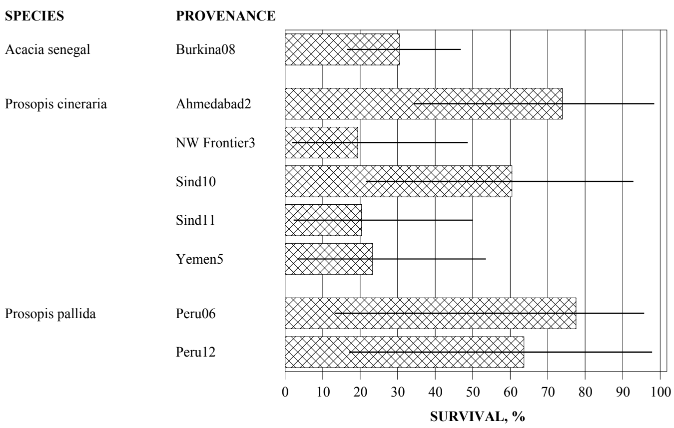

Figure 1. Survival in the *Prosopis cineraria, P. pallida* and *Acacia senegal* species and provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Before analysis data was transformed with the arcsine transformation. Values presented are back-transformed least square means with 95 % confidence limits. Due to the transformation, the upper and lower confidence intervals have different lengths.

Table 2. Results from analysis of variance of species and provenance differences of survival in trial 6.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of provenance differences					
Provenance	7; 11	0.18	3.6	0.03	n.s.
Block	2; 11	0.35	7.0	0.01	
Error	11	0.05			
Test of species differences					
Species	2; 4.8	0.29	2.1	0.23	n.s.
Provenance(species)	5; 11	0.13	2.7	0.08	
Block	2; 11	0.34	7.0	0.01	
Error	11	0.05			
Prosopis cineraria					
Provenance	4; 6	0.15	3.0	0.11	n.s.
Block	2; 6	0.33	6.6	0.03	
Error	6	0.05			
Prosopis pallida					
Provenance	1; 1	0.023	5.1	0.27	n.s.
Block	2; 1	0.133	28.8	0.13	
Error	1	0.005			

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. As there have been cases where the tallest provenances are suddenly affected by stress and die-off, this interpretation need not always be true.

Statistical analysis

The analysis was straightforward, and no transformations were used. It should be noted that due to missing plots and since only 3 provenances are represented, no more than eight observations are included in the analysis of all provenances. In the analysis of differences between provenances of *P. pallida* only five observations are included, meaning that the number of degrees of freedom is too small to include the block effect in the model.

Results

The average height varied between 2.5 and almost 4 m (Fig. 2). Differences between provenances were not significant, neither between all provenances nor when *P. pallida* was analysed only (Table 3). The tallest provenance was Peru06 of *P. pallida* with almost 4 m. The provenances of *P. cineraria* were all below one m and were not assessed for height, or the other characteristics.

Table 3. Results from analysis of variance of provenance differences of height in trial 6.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
All provenances					
Provenance	2	1.1	5.0	0.11	n.s.
Blocks	2	0.4	1.8	0.31	
Error	3	0.2			
P. pallida					
Provenance	1	2.0	5.4	0.10	n.s.
Error	3	1.1			

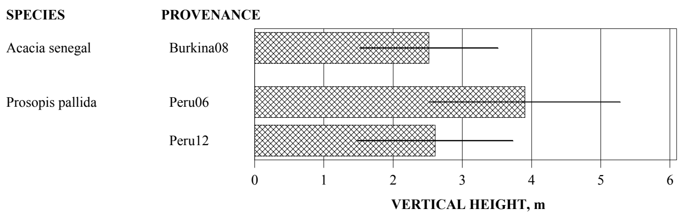

Figure 2. Vertical height in the species/provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.3 Crown area

The crown area variable indicates the ability of the trees to cover the ground. This 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 on un-transformed data. Please note that only 8 observations are included in the analysis.

Results

The average crown areas were 8 to 9 m^2 $tree^{-1}$ for the *P. pallida* provenances and 12 m^2 $tree^{-1}$ for the *A. senegal* provenance (Fig. 3). Since the growth space amounts to 16 m^2 $tree^{-1}$ it means that the canopy was about to close for the largest provenance. The differences between provenances were not consistent enough to become significant (Table 4).

Table 4. Results from analysis of variance of provenance differences of crown area in trial 6.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
All provenances					
Provenance	2	11.4	1.7	0.32	n.s.
Blocks	2	11.1	1.6	0.33	
Error	3	6.8			
P. pallida					
Provenance	1	0.47	0.85	0.42	n.s.
Error	3	0.55			

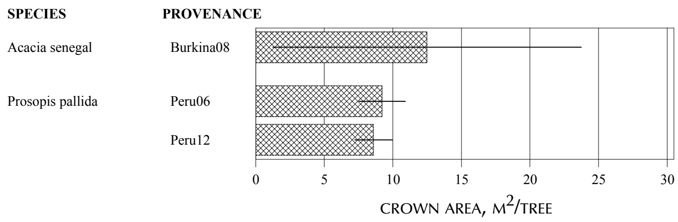

Figure 3. Crown area in the provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.4 Number of stems

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

Statistical analysis

With the very limited number of observations it is difficult to assess whether the assumptions for analysis of variance are violated, and the analysis was performed on data without transformation. In the analysis of differences between the provenances of *P. pallida*, the residual degrees of freedom were too small to allow for analysis of the block effect, which was therefore omitted.

Results

The average number of stems was between 2.1 and 2.3 for the three provenances (Fig. 4). There were no signs of significant differences in the analysis of variance (Table 5).

Table 5. Results from analysis of variance of provenance differences of number of stems in trial 6.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
All provenances					
Provenance	2	0.04	0.13	0.88	n.s.
Blocks	2	0.03	0.10	0.91	
Error	3	0.32			
P. pallida					
Provenance	1	0.0001	0.00	0.99	n.s.
Error	3	0.80			

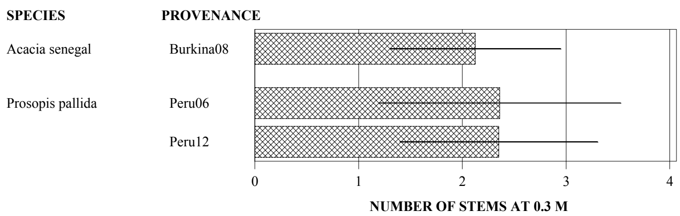

Figure 4. Number of stems in the and provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.5 Basal area of the mean tree

The basal area is often used as a measure of the productivity of stands, since it is correlated with the production of wood. The basal area of the mean tree is calculated on the live trees only and can be interpreted as the potential basal area production of the provenance provided that all trees survive.

Statistical analysis

There were signs of variance heterogeneity in the data, and the analysis was performed on values transformed with the natural logarithm.

Results

The basal area of the mean tree varied from 16 to 67 cm^2 $tree^{-1}$. Due to the logarithmic transformation, the estimates presented in Fig. 5 are biased towards the low end, but the differences between the provenances are depicted correctly. In the analysis of variance there were some signs of differences between provenance, at least when considering all three provenances (Table 6). The differences were close to being significant, but when the correction for multiple comparisons was applied, significance disappeared. However, on a graph of the plot values of basal area of the mean tree (not shown) it was quite clear that Burkina08 (*A. senegal*) had a much larger value of this variable than the provenance Peru12. Thus even though the statistical analysis did not show significant differences, we conclude that the provenances are most likely different, but that the sample number was not sufficient to detect this.

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

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
All provenances					
Provenance	2	1.4	7.6	0.07	n.s.
Blocks	2	0.12	0.7	0.57	
Error	3	0.19			
P. pallida					
Provenance	1	0.60	3.8	0.15	n.s.
Error	3	0.47			

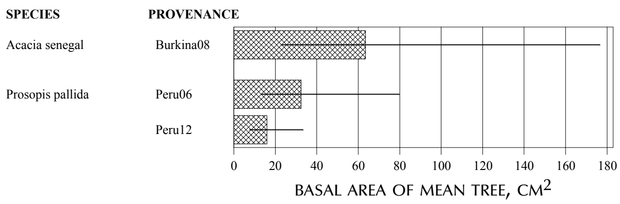

Figure 5. The basal area of the mean tree in the provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Before analysis the data was transformed with the natural logarithm. The values presented are least square means with 95 % confidence limits. Due to the transformation, the upper and lower confidence intervals are of unequal length.

4.6 Total basal area

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

Statistical analysis

The analyses were performed on un-transformed data. Note that due to lack of error degrees of freedom, the block effect was omitted in the analysis of provenance differences within *P. pallida*.

Results

The total basal area ranged from 0.7 to 2.0 m^2 ha^{-1} (Fig. 6). For the provenance with the largest diameter growth, Peru06, this corresponds to an annual basal area increment of 0.25 m^2 ha^{-1}. However, the variation within the provenances was too big to detect significant differences with the limited number of observations (Table 7).

Table 7. Results from analysis of variance of provenance differences of total basal area in trial 6.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
All provenances					
Provenance	2	0.94	1.9	0.30	n.s.
Blocks	2	0.48	0.9	0.48	
Error	3	0.50			
P. pallida					
Provenance	1	2.1	2.8	0.19	n.s.
Error	3	0.7			

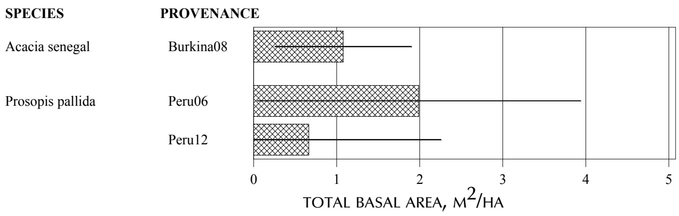

Figure 6. Total basal area in the provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.7 Dry weight of the mean tree

The dry weight of the mean tree is comparable to the basal area of the mean tree in that they both are calculated on the live trees only and thus serve as a measure of the potential production at the site, provided that all trees survive. Furthermore, the two variables are linked closely together since the basis for estimation of the dry weight is the basal area. However, an important difference is that the dry weight includes a cubic term (in comparison to basal area having only a square term), meaning that large trees with a large dry mass are weighted heavily in this variable. The dry weight of the mean tree is thus the best estimate for the potential production of biomass at the site.

Statistical analysis

Although not seen directly in the test of model assumptions of the model with un-transformed data, a plot of raw data indicated that there was variance heterogeneity. Therefore the data was transformed with the natural logarithm before analysis. Note that only five observations are included in the analysis of *P. pallida*, and that the block effect is omitted.

Results

The range for the provenance means of dry weight of the mean tree was 3.7 to 20 kg tree^{-1}, slightly higher than the back-transformed least square means illustrated in Fig. 7, which are biased due to the transformation. However, the values give the best representation of the differences between provenances. According to the analysis of variance, the differences between provenances were close to being significant, but when taking into account the effect of multiple comparisons, the significance decreased (Table 8). As with the analysis of basal area of the mean tree, a plot of the raw data clearly indicated that Burkina08 was consistently larger than Peru12, and that the lack of significance was due to the small number of replicates.

Table 8. Results from analysis of variance of provenance differences of average dry weight in trial 6.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
All provenances					
Provenance	2	2.1	6.6	0.08	n.s.
Blocks	2	0.2	0.7	0.56	
Error	3	0.3			
P. pallida					
Provenance	1	1.2	4.0	0.14	n.s.
Error	3	0.3			

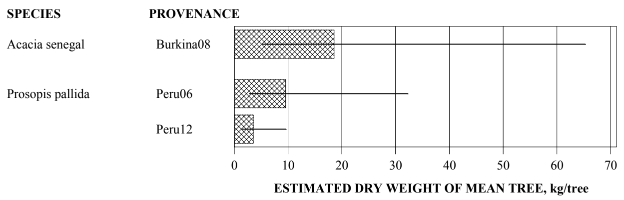

Figure 7. Dry weight of the mean tree in the provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Before analysis, the data was transformed with the natural logarithm. Values presented are back-transformed least square means with 95 % confidence limits. Due to the transformation the upper and lower confidence intervals have different lengths.

4.8 Total dry weight

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

Statistical analysis

The analysis was performed on data without transformations. Note that due to the small number of replicates the effect of block is omitted in the test of differences between the provenances of *P. pallida*.

Results

The total dry weight was estimated to 1.5, 3.2 and 6.4 t ha^{-1} for the provenances Peru12, Burkina08 and Peru06, respectively (Fig. 8). For Peru06 this corresponds to an average annual increment of 0.8 t ha^{-1}. Even though there were large apparent differences between the provenances, there was much variation within the provenances, and with the number of replicates the differences were far from being significant (Table 9).

Table 9. Results from analysis of variance of provenance differences of average dry weight in trial 6.

Effect	DF	MS	F-value	P-value	Bonferroni sequential tablewide correction
All provenances					
Provenance	2	13.4	1.9	0.29	n.s.
Blocks	2	6.7	0.9	0.48	
Error	3	7.1			
P. pallida					
Provenance	1	28.1	2.7	0.20	n.s.
Error	3	10.4			

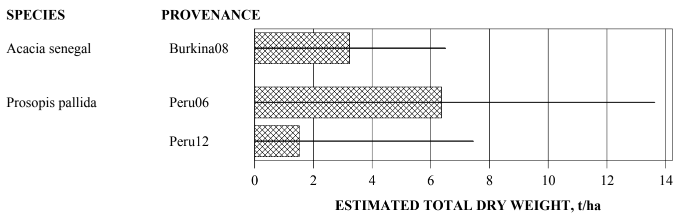

Figure 8. Total dry weight in the provenance trial at Djibo, Burkina Faso (Trial no. 6 in the arid zone series). Values presented are least square means with 95 % confidence limits.

5. Discussion and conclusions

Productivity

The highest producing provenance in the trial, Peru06, had an average production of 0.8 t dry weight ha^{-1} y^{-1}. This corresponds to the 1.4 t ha^{-1} y^{-1} obtained by the provenance Niger1 in the nearby trial of *A. senegal* (Trial no. 5 in the arid zone series, also located at Djibo). Comparisons between trials should always be treated with caution because of possible differences in environment between the trials, but the higher production in trial no. 5 may indicate that the full potential of the site is not used by the provenances in the current trial. Another indication that a higher production is possible is the fact that the provenance Burkina08 (*A. senegal*) in this trial had higher dry weights of the mean trees than the other provenances. Only because of a low survival did the provenance not rank high in total productivity.

Species and provenance differences

None of the provenances of *P. cineraria* in the trial had a satisfactory growth, and were thus only assessed for survival. It would be tempting to conclude that the species is not apt for cultivation at sites like Gonsé. It must be noted, however, that provenances from only a part of the natural distribution of the species are included, and that provenances from other areas, such as the southern and central India, might have a better performance. However, until this is proven it seems worthwhile to invest more energy in the testing of other species.

There were no significant differences between the three provenances representing *A. senegal* and *P. pallida*. Nevertheless, as mentioned above, there were signs that Burkina08 had a larger average dry weight for the surviving trees, indicating that if survival of the provenance was improved, the production potential would be larger. The largest total production was found in the provenance Peru06, and so it is difficult to give recommendations regarding choice of species and provenances. The growth of *A. senegal* may be better evaluated in the other trial at Djibo (no. 5), and if *P. pallida* is to be used, it may be necessary to test a larger array of provenances before giving recommendations. Of the two *P. pallida* provenances it seems, however, that Peru06 (representing the origin with the highest rainfall) may be the most productive, even though no significant differences were found.

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Annex 1. Description of the trial site

Name of site:	Djibo, Burkina Faso Latitude: 14°06'N Longitude: 01°37'W
Meteorological station:	Djibo (14°06'N, 01°37'W (Graf et al. 1989))
Rainfall:	Annual mean (period): 574 mm (1961-70)(Graf et al. 1989)) 410.1 (1971-80 (Graf et al. 1989)) 298 (1981-87 (Graf et al. 1989)) Yearly registrations: 1981: 457.7 1982: 308.8 1983: 322 1984: 226.5 1985: 174.7 1986: 298.5 1987: 297.6
Rainy season:	June-September Type: Normal with dry period
Dry months/year:	No. of dry months (<50 mm): 8-10 No. of dry periods: 1
Wind:	Prevailing directions: L'harmattan ENE (dry season) La mousson SSW
Topography:	Flat
Soil:	Type: Sandy, some clay in depth Depth: Deep (> 1 m)
Climatic/agroecological zone:	Semi-arid, Sahelian zone.
Dominant natural vegetation:	Shrub/woody savanna (*Acacia raddiana, Acacia albida, Acacia seyal).*
Koeppen classification:	BSh

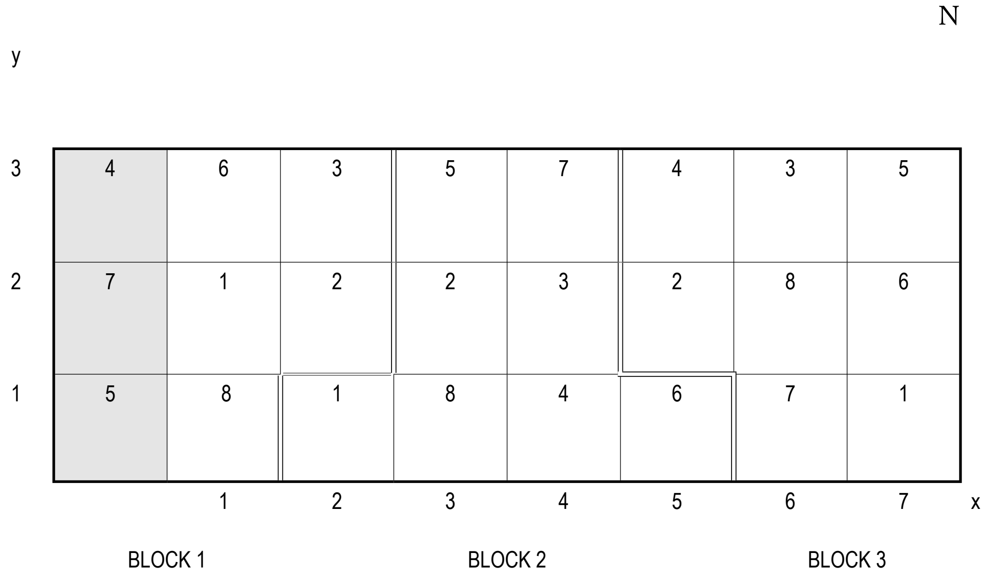
Annex 2. Seedlot numbers for the provenances tested in trial no. 6 at Djibo, Burkina Faso

The plot numbers correspond to the seedlots in the map of the trial, see Annex 3.
Species codes: ase=*Acacia senegal*, pci=*Prosopis cineraria*, ppa=*P. pallida*.

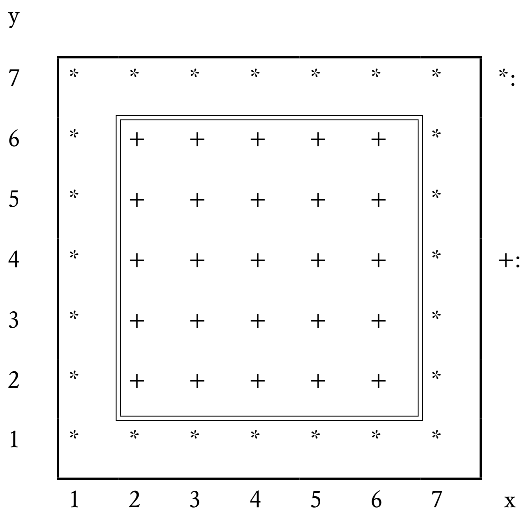
Seedlot numbers				**Provenance infomation**							
Provenance identification	DFSC	Country of origin or CTFT	Plot	Species	Origin	Country of origin	Latitude	Longitude	Altitude (m)	Ann. rainfall (mm)	No. of mother trees
Burkina08		201(CNSF)	8	ase	Mogtedo	Burkina Faso					
Ahmedabad2	1228/83	4794 (CTFT)	5	pci	Sumarsar (Naik Wali), Kutch (Bhuj)	India	23°50'N	69°48'E	80	348	25
NW Frontier3	1183 or 1184/84	4797 (CTFT)	1	pci	Bhakkar (Darya Khan Or Goharwala)	Pakistan	31°40'N	71°08' E	200	200	30
Sind10	1182/83	4796 (CTFT)	4	pci	Saeed-Abad, Hyderabad	Pakistan	25°25 N	68°24 E	30	157	25
Sind11	1179/83	4795 (CTFT)	3	pci	Islam-Kot, Tharparkar, Registan (Loonio)	Pakistan	24°40 N	70°12 E	50	150	25
Yemen5	1204/83	1(Yemen) 4798 (CTFT)	2	pci	Khanfar (Aden)	Yemen	13°00'N	45°10'E	15	50	20
Peru06	1119/83	4799 (CTFT)	7	ppa	Puerte Del Vice, Piura	Peru	05°25'S	80°47'W	13	70	18
Peru12	1127/83	15 03 83(Peru), 4800 (CTFT)	6	ppa	Sechura (Piura)	Peru	05°33'S	80°48'W	4	25	5

Annex 3. Layout of the trial

Layout of blocks and plots in the field
The numbers correspond to the seedlots given in Annex 2
Shaded areas were abandoned and are not included in the assessment



Individual tree positions in each plot:



Annex 4. Plot data set

Species codes: ase=*Acacia senegal*, pci=*Prosopis cineraria*, ppa=*P. pallida*.

Block	Plotx	Ploty	Plot	Species	Provenance	Survival	Height	Crown area	Number of stems	Basal area of mean tree	Total basal area	Dry weight of mean tree	Total dry weight
						%	m	m^2 tree^{-1}	no tree^{-1}	cm^2 tree^{-1}	m^2 ha^{-1}	kg tree^{-1}	tons ha^{-1}
1	1	1	8	ase	Burkina08	32	2.55	17.64	2.50	97.2	1.46	31.55	4.73
1	1	2	1	pci	NW Frontier3	12							
1	1	3	6	ppa	Peru12	32	2.35	8.68	1.75	12.0	0.24	2.43	0.49
1	2	2	2	pci	Yemen5	12							
1	2	3	3	pci	Sind11	8							
2	2	1	1	pci	NW Frontier3	16							
2	3	1	8	ase	Burkina08	36	2.10	9.16	1.88	42.8	0.86	11.51	2.30
2	3	2	2	pci	Yemen5	28							
2	3	3	5	pci	Ahmedabad2	36							
2	4	1	4	pci	Sind10	28							
2	4	2	3	pci	Sind11	12							
2	4	3	7	ppa	Peru06	80	3.20	8.31	2.26	21.3	1.01	5.36	2.54
2	5	1	6	ppa	Peru12	60	2.79	8.66	3.00	18.5	0.69	4.24	1.59
3	5	2	2	pci	Yemen5	32							
3	5	3	4	pci	Sind10	96							
3	6	1	7	ppa	Peru06	96	4.62	10.11	2.46	49.4	2.96	16.97	10.18
3	6	2	8	ase	Burkina08	24	2.90	10.65	2.00	61.5	0.92	17.63	2.64
3	6	3	3	pci	Sind11	48							
3	7	1	1	pci	NW Frontier3	32							
3	7	2	6	ppa	Peru12	92	2.68	8.40	2.30	18.5	1.06	4.33	2.49
3	7	3	5	pci	Ahmedabad2	100							