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Evaluation of a provenance trial of *Acacia nilotica, A. seyal* and *A. tortilis* at Dori, Burkina Faso

Trial no. 7 in the arid zone series

by

Anders Ræbild[1], Lars Graudal[1] and Lambert Georges Ouedraogo[2]

Centre National de Semences Forestières[2], Burkina Faso

Food and Agriculture Organization, Rome

Danida Forest Seed Centre[1], Denmark

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A plot of *Acacia seyal* in the trial. Phot: Agnete Thomsen. 1993.

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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 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 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 to 1994. DFSC is responsible for the reporting of this assessment.

This trial was established and maintained by the 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, Sanogo-Moussa, Hama Hadsou, Hama Hamidou, Derra Hamado, Amadou Mamadou, Sambaré, all from CNSF, 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, 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 provenance trial with eleven provenances of *Acacia nilotica*, *A. seyal* and *A. tortilis* in Dori, Burkina Faso. The trial was established in 1988 with a spacing of 4 x 4 metres, and assessed in 1993 at an age of 5 years. Apart from two provenances of *A. tortilis* from India and Sudan, all provenances were from Burkina Faso.

The three species were significantly different in survival, height, crown area and basal area of the mean tree. *A. seyal* had the poorest survival, but the largest heights, crown areas and basal areas of the mean tree. The only signs of provenance differences within the species were seen in the number of stems of *A. nilotica* and *A. tortilis*, and a multivariate analysis gave no clear separation of the provenances either. The estimated dry weight production of the fastest growing provenances was approximately 3 t ha^{-1}, or 0.6 t ha^{-1} $year^{-1}$.

Résumé en français

Le présent rapport décrit les résultats obtenus d'un essai comparatif de onze (11) provenances de trois espèces: *Acacia nilotica, A. seyal* et *A.tortilis*. En dehors des deux (2) provenances de *A. tortilis* issues de l'Inde et du Soudan, toutes les autres sont du Burkina Faso. L'essai a été mis en place en 1988 à Dori (Burkina Faso) suivant un écartement de 4 x 4 m entre les arbres.

Les mensurations ont eu lieu en 1993, soit cinq (5) ans après l'implantation de l'essai.

L'analyse des données au niveau espèce a révélé une différence significative pour le taux de survie, la hauteur, la surface du houppier et la surface terrière de l'arbre moyen. *A seyal* avait le plus faible taux de survie, mais les plus grandes hauteurs, surfaces du houppier et surfaces terrières de l'arbre moyen. La seule différence observée au niveau provenances au sein des espèces est relative au nombre de tiges chez *A. nilotica* et *A. tortilis*. Même une analyse multivariable n'a pu clairement distinguer les provenances. Le poids estimé de la production en matière sèche des provenances à croissances les plus rapides était approximativement de $3tha^{-1}$ soit une productivité de 0,6t an^{-1}.

Contents

1. Introduction

This report describes the results from trial no. 7 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).

The present trial includes 11 provenances of the species *Acacia nilotica*, *A. seyal* and *A. tortilis*. *A. nilotica* is a very variable species with a natural distribution covering large tracts of tropical and subtropical Africa and Asia (Ross 1979). The two subspecies included in this trial, subsp. *adansonii* (which is also commonly called subsp. *adstrigens*) and subsp. *tomentosa* differ in their ecological requirements even though they both prefer moist conditions. Subsp. *adansonii* is found predominantly on deep sandy-loamy soils such as fossil dunes, and on lateritic and calcareous sites. Subsp. *tomentosa* tolerates inundation and is often found on clay or alluvial soils along depressions or riverbeds (von Maydell 1986, Ross 1979, Fagg & Barnes 1990).

The species *A. seyal* is found in the Sahel and the eastern and south-central Africa (von Maydell 1986, Ross 1979). *A. tortilis* is widespread in the Sahel, East Africa and Arabia (von Maydell 1986, Ross 1979, Fagg & Barnes 1990). Several subspecies are recognised, but in the current trial only the subspecies *raddiana* is included together with a landrace from India. The landrace from India was introduced from Israel, also of the subspecies *raddiana* (Fagg & Barnes 1990). It should be noted that in the French literature, the subspecies is often referred to as a separate species, *A. raddiana*. See Fagg & Greaves (1990a and b) for annotated bibliographies of *A. nilotica* and *A. tortilis*.

2. Materials and methods

2.1 Site and establishment of the trial

The trial is located at Dori (14°02‘ N, 00°01‘ W) in Burkina Faso at an altitude of 275 m. The mean annual temperature is 28.8 °C, and the annual average rainfall is approximately 400-600 mm, depending on the source (DFSC 1994). The dry period is about eight months. Further information is given in the assessment report (DFSC 1994) and summarised in Annex 1.

The soil at the site is sandy, with some clay at depth. In order to facilitate water infiltration the soil was scarified by sub-soiling with a bulldozer, and manual planting-holes were prepared in June-July before planting. Seed were 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 three provenances of *A. nilotica*, four provenances of *A. seyal* and four provenances of *A. tortilis* (Table 1). Most of the provenances are from Burkina Faso, but there are two provenances of *A. tortilis* from Sudan and India. Two subspp. *adansonii* and *tomentosa*, of *A. nilotica* were represented, whereas the provenances of *A. tortilis* were all supposedly of the subspecies *raddiana* (see Introduction). The provenances have been given names relating to the geographical origin (name of country or province followed by a number). The original seedlot numbers are provided in Annex 2.

It should be mentioned that two sets of provenances are collected on the same site: Burkina05 (*A. nilotica*) and Burkina16 (*A. seyal*), as well as Burkina04 (*A. nilotica*) and Burkina02 (*A. tortilis*).

Table 1. Species and provenances tested in trial no. 7 at Dori, Burkina Faso. The provenance information is taken from sheets delivered with the seed by the original seed suppliers.

Provenance	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
Burkina04	*A. nilotica* subsp. *adansonii*	Boukouma	Burkina Faso	14°12’N	00°43’E	317	400	27
Burkina05	*A. nilotica* subsp. *adansonii*	F.C. Barrage, Kossodo, Ouaga	Burkina Faso	12°20’N	01°30’W	341	700	100
Burkina06	*A. nilotica* subsp. *tomentosa*	Falagountou	Burkina Faso	14°22’N	00°11’E	250	400	27
Burkina14	*A. seyal*	Bodole H, Djibo	Burkina Faso	14°06’N	01°37’W	274	380	76
Burkina15	*A. seyal*	Route Sao-Tcheriba, Vers Lery	Burkina Faso	12°15’N	03°12’W	293	700	47
Burkina16	*A. seyal*	F.C. Barrage , Kossodo, Ouaga	Burkina Faso	12°20’N	01°30’W	300	700	26
Burkina17	*A. seyal*	Lery	Burkina Faso	12°49’N	03°12’W	293	700	35
Burkina02	*A. tortilis* subsp. *raddiana*	Boukouma	Burkina Faso	14°12’N	00°43’W	320	400	27
Burkina19	*A. tortilis* subsp. *raddiana*	Markoye	Burkina Faso	14°38’N	00°21’N	295	400	27
Rajasthan06	*A. tortilis*	Ramgaon, Barmer	India	25°45’N	71°23’E	194	310	50
Sudan18	*A. tortilis* subsp. *raddiana*	Elbashiri Oasis, Northern Kordofan	Sudan	13°48’N	30°12’E	400	300	25

2.3 The experimental design

The trial is a randomised complete block design with 6 blocks. Within each block, each provenance is represented by 36 trees in a plot, planted in a square of 6 × 6 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 CNSF, IRBET, FAO and DFSC undertook a joint assessment. The assessment included the following characters: survival, vertical height, diameter at 0.3 m, number of stems at 0.3 m, crown diameter and health, measured on the 4 × 4 central trees. A detailed account of the assessment methods is given by DFSC (Graudal *et al* 2003). Due to limited time only four blocks were measured. For reference the plot data set on which the statistical analyses in this report are performed is shown in annex 4.

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 at 0.3 m
- Total basal area at 0.3 m
- Dry weight of the mean tree
- Total dry weight

Furthermore a number of health characters were evaluated, but since the trees were generally in good health and there were only small apparent differences between the provenances, these characters are not analhe present report. Instead a graphical presentation of the health data is given in Annex 5.

Out of the 767 trees originally planted, 580 were still alive at the assessment. 43 of the trees were below 1 m height. A special problem with the assessment data is that for trees with heights below 1 m, no assessment of diameter, number of stems and crown diameter was made. Since the omission of these data will produce biased results and lead to an over-estimation of the provenances in question, the values for crown area, basal area and dry weight for these observations were set to zero. There is no reasonable way to estimate the number of stems of such trees, and no default value has been set for this variable. In any case, the estimates of the variables will be slightly biased, but this has probably only limited importance.

Another problem is that in every block, one provenance (a different one in each block) is represented twice (i.e. on two plots, see Annex 3). This makes the design imbalanced and introduces a bias in the test of provenance differences, because the block effect becomes confounded with the provenance effect. Therefore the two plots representing the same provenance in a block were averaged before analysis. The values for the co-variates were calculated as averages of the values for the two plots.

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

$$TreeDW = e^{(2.58 \times \ln(basalarea) - 2.52)}$$

where *TreeDW* is the dry weight of the tree in kg tree^{-1}, and *basalarea* is the basal area of the tree in cm^{-2}. For *A. tortilis*, the corresponding regression is

$$TreeDW = e^{(2.47 \times \ln(basalarea) - 2.07)}$$

No regression is available for *A. seyal*, and hence no dry weights were calculated for this species.

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 a two-stage approach, with the first stage consisting of a test of species differences, and the second stage consisting of a test of provenance differences within species. The model for the first stage (test of species differences) is

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

where X_{ijk} is the value of the trait in question (e.g. height) in plot *ijk*, μ is the overall mean, $species_i$ is the fixed effect of species number *i*, $provenance(species)_{ij}$ is the random effect of provenance number *j* nested within species *i*, $block_k$ is the random effect of block *k* in the trial, and ε_{ijk} is the residual of plot *ijk* which is assumed to follow the normal distribution $N(0, \sigma_e^2)$. The test of species differences was performed using the Satterthwaite method for calculation of degrees of freedom (SAS 1988b).

The second stage, the test of significant differences between provenances, was performed separately for each species, based on the 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 a 10% level.

Standard graphical methods and calculated standard statistics were applied to test model assumptions of independence, normality and variance homogeneity (Snedecor & Cochran 1980, Draper & Smith 1981, Ræbild *et al.* 2002). Where appropriate, weighting of data and exclusion of outliers have been performed to fulfil basic model assumptions (*ibid.*; Afifi & Clark 1996, Ræbild *et al.* 2002). Weighting of data with the inverse of the variance for the seedlots was used to fulfil the assumption of normality.

The P-values from the tests of provenance differences were corrected for the effect of multiple comparisons by the sequential table-wide 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 eight, thus equalling the number of variables analysed. For the analyses of differences within *A. seyal* the number was set to six, as no estimates for the dry weight were available. 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 & Brockhoff 1998).

A more detailed description of the statistical 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 growth of the first few year's 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

Survival was analysed without transformations. There were slight signs of variance heterogeneity, the *A. nilotica* provenances having less variation than provenances from the two other species. A weight statement did not change the conclusions, and the original analysis was used.

Results

The average survival for the provenances varied between 50 and 95 % (Fig. 1). There were significant differences between the three species, *A. nilotica* having the highest survival, *A. seyal* the lowest and *A. tortilis* an intermediate survival (Table 2, Fig. 1). Within each species, the differences between provenances were small and far from significant.

Table 2. Results from analysis of variance of species and provenance differences of survival in trial 7.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	2; 8.0	3696	12.2	0.004	*
Provenances (species)	8; 29	302	1.1	0.36	
Block	3; 29	390	1.5	0.24	
Error	29	264			
A. nilotica					
Provenance	2; 6	91	0.60	0.58	n.s.
Block	3; 6	90	0.59	0.64	
Error	6	151			
A. seyal					
Provenance	3; 9	449	1.5	0.29	n.s.
Block	3; 9	887	2.9	0.10	
Error	9	309			
A. tortilis					
Provenance	3; 8	269	1.7	0.23	n.s
Block	3; 8	327	2.1	0.18	
Error	8	154			

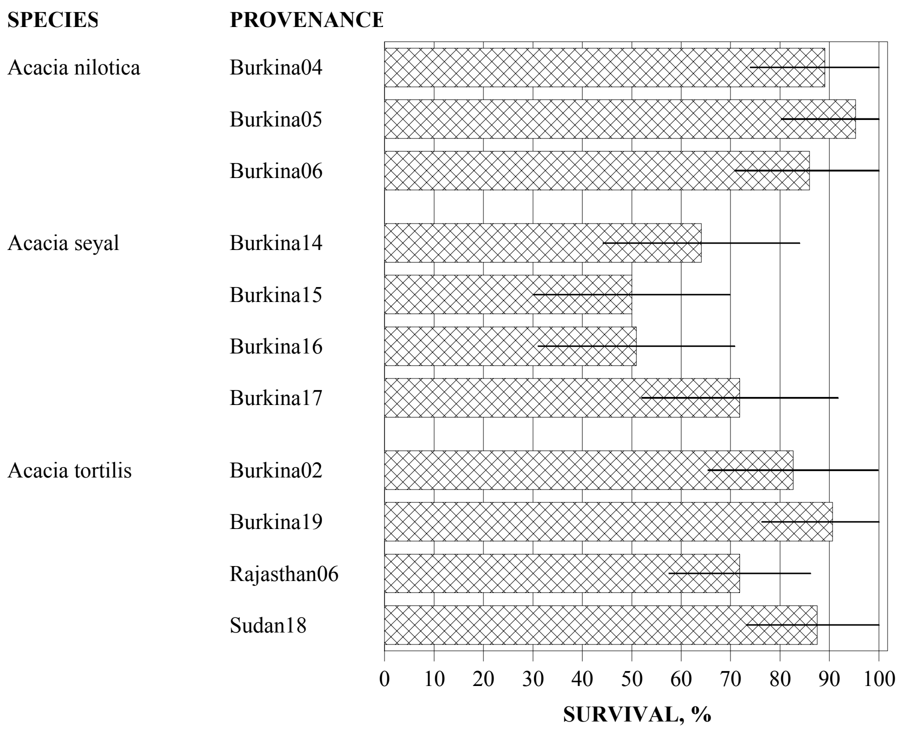


Figure 1. Survival in the *Acacia* species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits. Confidence limits above 100 % were truncated.

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. This interpretation need not always be true, however: Cases have been observed where the tallest provenances are suddenly affected by stress with a subsequent death of the trees.

Statistical analysis

In the analysis of species differences, the assumptions of anova models were fulfilled on the data without transformation. However, in the analysis of provenance differences in *A. seyal* there appeared to be an outlier that could not be explained by examination of the original data. This observation (Burkina17, block 2) had a marked influence on the outcome of the model, and if it was excluded from the data set, the effect of provenance was significant (P=0.02). Since we cannot explain the outlier tendency, the outlier is included in the tests and estimates presented in Table 3 and Fig. 2. The analyses of provenance differences in the other species proceeded without problems.

Results

There were highly significant differences between the heights of the three species (Table 3). The provenances of *A. seyal* were the highest with an average of 2.3 m. The provenance Burkina14 even had a height of 2.6 m (Fig. 2). The *A. tortilis* provenances had the lowest heights with an average of 1.55 m, whereas *A. nilotica* was intermediate with an average height of 2.0 m. There were no significant differences between the provenances of any of the species (Table 3). Note, however, that an outlier in *A. seyal* had a large influence on the significance levels (see above).

Table 3. Results from analysis of variance of species and provenance differences in height for trial 7.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	2; 7.88	2.30	24.1	0.0004	**
Provenances (species)	8; 28	0.10	1.2	0.32	
Block	3; 28	0.53	6.8	0.001	
Ploty	1; 28	0.58	7.5	0.01	
Error	28	0.08			
A. nilotica					
Provenance	2; 6	0.029	0.66	0.55	n.s.
Block	3; 6	0.099	2.23	0.19	
Error	6	0.044			
A. seyal					
Provenance	3; 8	0.22	2.5	0.13	n.s.
Block	3; 8	0.45	5.0	0.03	
Ploty	1; 8	0.59	6.6	0.03	
Error	8	0.09			
A. tortilis					
Provenance	3; 8	0.034	0.32	0.81	n.s.
Block	3; 8	0.066	0.62	0.62	
Error	8	0.107			

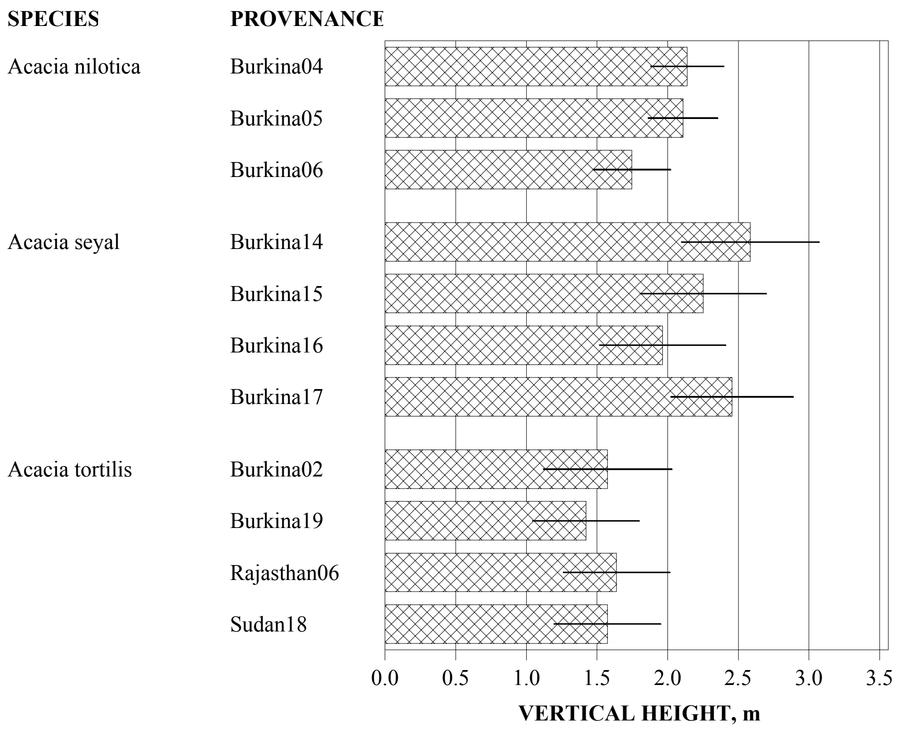


Figure 2. Vertical height in the *Acacia* species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits.

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 the protection of the soil against erosion.

Statistical analysis

The analyses of both species and provenance differences were straightforward, and no transformations were used. Note that for trees below 1 m height, the crown area was set to 0 m^2.

Results

The average crown area for the provenances varied between 3.5 and 10.5 m^2 $tree^{-1}$. As the growth space is 16 m^2 $tree^{-1}$ there was still some time left at the time of the assessment before the trees covered the area.

Again there were highly significant differences between the species (Table 4). *A. seyal* had the largest crown areas with an average of 9.3 m^2 $tree^{-1}$, whereas *A. tortilis* was the smallest with 3.9 m^2 $tree^{-1}$ (Fig. 3). *A. nilotica* was intermediate with 5.3 m^2 $tree^{-1}$. Within the species, there were no significant differences between the provenances of *A. nilotica* and *A. tortilis*. In *A. seyal*, the provenance effect was almost significant, but this disappeared when accounting for multiple comparisons (the Bonferroni P-value). Thus the differences could be due to random variation. The provenances Burkina14 and Burkina17 had the largest crown areas.

Table 4. Results from analysis of variance of species and provenance differences of crown area in trial 7.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	2; 7.77	130.0	80.7	<0.0001	***
Provenances (species)	8; 28	1.6	0.6	0.75	
Block	3; 28	23.6	9.1	0.0002	
Ploty	1; 28	12.8	4.9	0.03	
Error	28				
A. nilotica					
Provenance	2; 6	3.1	2.3	0.18	n.s.
Block	3; 6	4.5	3.3	0.10	
Error	6	1.3			
A. seyal					
Provenance	3; 8	3.3	3.9	0.06	n.s.
Block	3; 8	28.6	33.7	<0.0001	
Ploty	1; 8	36.4	42.9	0.0002	
Error	8	0.8			
A. tortilis					
Provenance	3; 8	0.4	0.2	0.92	n.s.
Block	3; 8	3.4	1.4	0.30	
Error	8	2.4			

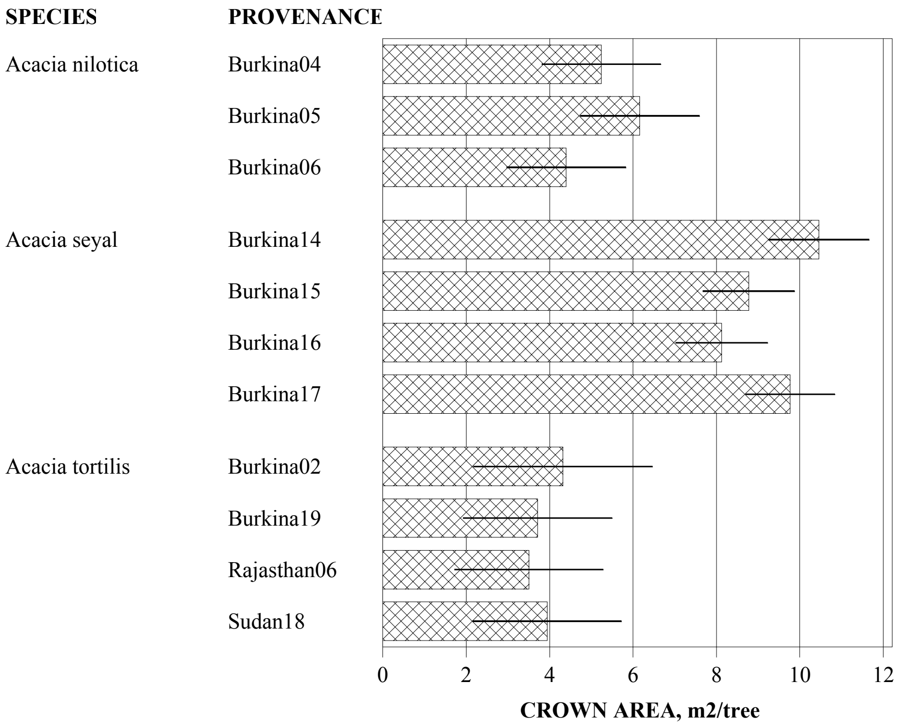


Figure 3. Crown areas in the *Acacia* species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.4 Number of stems

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

Statistical analysis

According to the first analysis of species differences there were signs of different variance between the provenances. A weight statement was used to correct this. In the analyses of differences between provenances within the species, similar weight statements were used.

It should be noted that trees below 1 m were not assessed, which introduces a bias in the analysis. It is difficult to extrapolate the number of stems for such small trees from the larger trees, and the small trees have been omitted from the analysis. Therefore the estimates presented do not represent values for all trees, but only for trees above 1 m height. Seven percent of the trees were below 1 m.

Results

The average numbers of stems were 3.1 and 3.0 in the provenances Sudan12 and Burkina02 (both *A. tortilis*) but only 1.7 and 1.8 in the provenances Burkina06 (*A. nilotica*) and Rajasthan06 (*A. tortilis*) (Fig. 4). The rest of the provenances were intermediate in this character.

An analysis of variance with provenances and blocks as the only two effects demonstrated that there were highly significant differences in number of stems between the provenances in the trial (not shown, F-value=9.0, P<0.0001). The differences between species were not significant, but in *A. nilotica* and *A. tortilis*, there were significant differences between the provenances (Table 5). Even after accounting for the effect of making multiple comparisons (The Bonferroni P-value), the differences were almost significant.

Table 5. Results from analysis of variance of species and provenance differences of number of stems in trial 7.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	2; 10.8	2.5	0.7	0.52	n.s.
Provenances (species)	8; 29	6.0	5.5	0.0003	
Block	3; 29	14.5	13.4	<0.0001	
Error	29	1.1			
A. nilotica					
Provenance	2; 6	10.3	10.2	0.01	(*)
Block	3; 6	17.5	17.2	0.002	
Error	6	1.0			
A. seyal					
Provenance	3; 9	1.6	1.4	0.31	n.s.
Block	3; 9	2.9	2.5	0.12	
Error	9	1.1			
A. tortilis					
Provenance	3; 8	10.5	7.9	0.009	(*)
Block	3; 8	5.0	3.8	0.06	
Error	8	1.3			

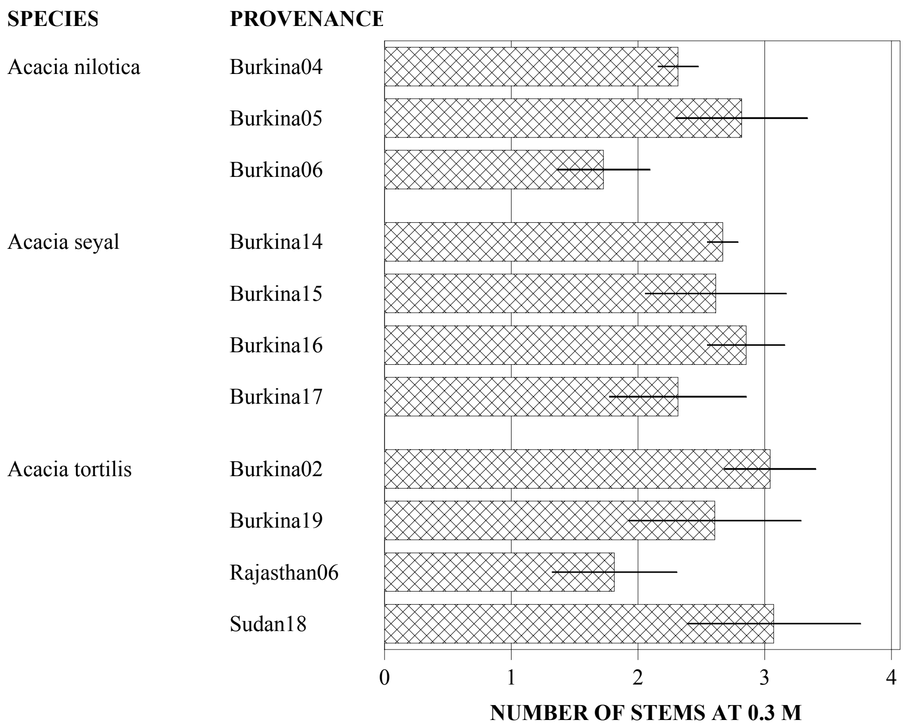


Figure 4. Number of stems in the *Acacia* species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analyses the observations were weighted with the reciprocal of the variance for the provenances, and the confidence intervals are therefore of unequal lengths.

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

The analyses of this variable were based on data without any transformations.

Results

There were significant differences between the species in the trial, but within the species only the provenances of *A. nilotica* were significantly different from each other (Table 6). Furthermore, the significance in *A. nilotica* disappeared when accounting for multiple comparisons.

The basal area of the mean tree varied from 13 to 36 cm^2 $tree^{-1}$, meaning that the fastest growing provenance (Burkina14 of *A. seyal*) had a yearly growth corresponding to 7 cm^2 $tree^{-1}$. *A. seyal* was the fastest growing species with average values of 30 cm^2 $tree^{-1}$, whereas *A. nilotica* and *A. tortilis* had average values of 21 and 15.5 cm^2 $tree^{-1}$, respectively. The provenances Burkina19 of *A. tortilis* and Burkina06 of *A. nilotica* had the smallest basal areas, but the two exotic provenances, Rajasthan06 and Sudan18, were also in the low range.

Table 6. Results from analysis of variance of species and provenance differences of basal area of the mean tree in trial 7.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	2; 7.91	1093	14.1	0.003	*
Provenances (species)	8; 28	77	1.5	0.19	
Block	3; 28	298	6.0	0.003	
Ploty	1; 28	220	4.4	0.04	
Error	28	50			
A. nilotica					
Provenance	2; 6	199	5.6	0.04	n.s.
Block	3; 6	87	2.4	0.16	
Error	6	35			
A. seyal					
Provenance	3; 8	94	1.4	0.32	n.s.
Block	3; 8	293	4.3	0.04	
Ploty	1; 8	490	7.1	0.03	
Error	8	69			
A. tortilis					
Provenance	3; 8	16	0.7	0.59	n.s.
Block	3; 8	36	1.5	0.28	
Error	8	24			

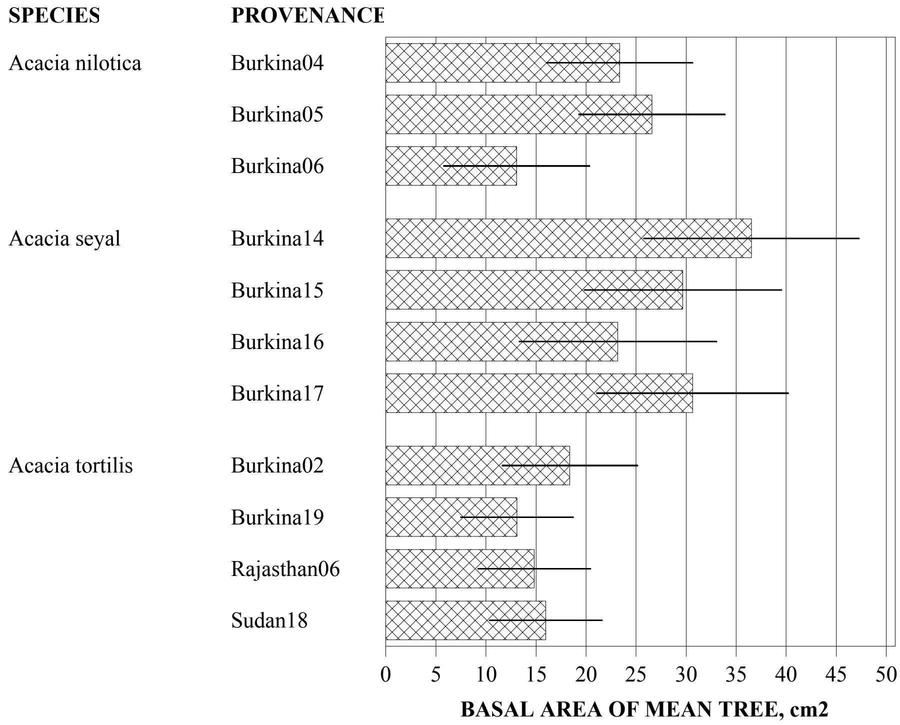


Figure 5. The basal area of the mean tree in the *Acacia* species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.6 Total basal area

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

Statistical analysis

In the analysis of species differences, the residuals demonstrated that there was variance heterogeneity between the provenances. A weight statement solved this. In the analyses of provenance differences, no weight statements were used.

Results

The total basal area varied from an average of 0.5 m^2 ha^{-1} in the provenance Rajasthan06 (*A. tortilis*) to almost 1.5 m^2 ha^{-1} in Burkina05 (*A. nilotica*) (Fig. 6). This corresponds to an annual growth of 0.3 m^2 ha^{-1} for Burkina05.

The analysis of variance demonstrated that there were significant differences between the species (Table 7). Since the significance disappeared when correcting for multiple comparisons, this conclusion should be interpreted cautiously, and it also appears from Fig. 6 that there are no clear differences, perhaps except for the tendency of *A. tortilis* to have low total basal areas. The differences between provenances within the species were not significant – even though *A. nilotica* was close with a P-value of 0.08, this pattern changed when making the Bonferroni correction for multiple tests.

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

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	2; 11.9	8.2	4.6	0.03	n.s.
Provenances (species)	8; 29	2.1	2.0	0.09	
Block	3; 29	8.5	7.8	0.0006	
Error	28	1.1			
A. nilotica					
Provenance	2; 6	0.71	4.0	0.08	n.s.
Block	3; 6	0.29	1.6	0.28	
Error	6	0.18			
A. seyal					
Provenance	3; 9	0.28	1.3	0.33	n.s.
Block	3; 9	0.70	3.3	0.07	
Error	9	0.21			
A. tortilis					
Provenance	3; 8	0.059	0.71	0.57	n.s.
Block	3; 8	0.008	0.10	0.96	
Error	8	0.083			

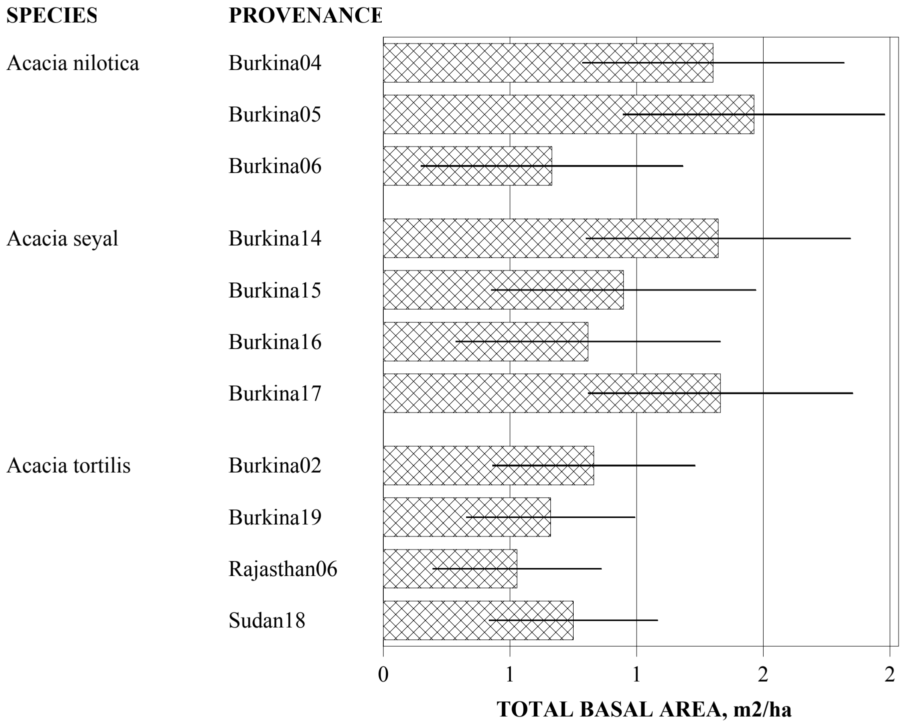


Figure 6. Total basal area in the *Acacia* species and provenances trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.7 Dry weight of the mean tree

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

Statistical analysis
No transformations or weight statements were necessary for this variable, and the analyses were performed on un-transformed data. Due to the lack of biomass regression for *A. seyal*, this species is not included in the analysis.

Results
The average dry weights of the mean tree varied from 2.2 to 5.7 kg $tree^{-1}$, corresponding to a growth of 1.1 kg annually for a tree in the largest provenance (Burkina05, *A. nilotica*) (Fig. 7). The differences between species were far from significant and only in *A. nilotica* were there weak signs of differences between provenances (Table 8). However, the close-to-significance disappeared when correcting for multiple tests, and it is difficult to make conclusions about provenance differences in the growth of the mean trees based on this trial. Acknowledging this precaution it seemed that Burkina06 had a rather low increment of the mean tree, whereas the Burkina04 and Burkina05 had higher growth rates. The provenances of *A. tortilis* were all in between these extremes.

Table 8. Results from analysis of variance of species and provenance differences of average dry weight in trial 7.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	1; 4.97	4.0	0.8	0.41	n.s.
Provenances (species)	5; 17	4.9	2.1	0.12	
Block	3; 17	7.8	3.3	0.05	
Error	17	2.4			
A. nilotica					
Provenance	2; 6	11.0	4.9	0.05	n.s.
Block	3; 6	5.8	2.6	0.15	
Error	6	2.3			
A. tortilis					
Provenance	3; 8	1.0	0.34	0.79	n.s.
Block	3; 8	2.9	0.95	0.46	
Error	8	3.0			

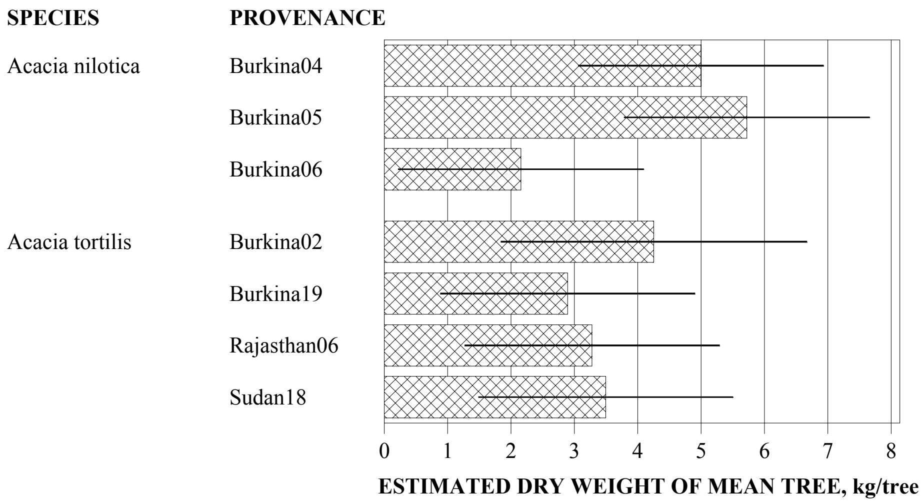


Figure 7. Dry weight of the mean tree in the *Acacia* species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.8 Total dry weight

As with the total basal area, the total dry weight accounts for survival (since missing trees are included in the plot sum) and thus gives the best measure of the total production on the site.

Statistical analysis

The analyses of total dry weight were straightforward, and no transformations were used. Note that *A. seyal* is not included; this is because no biomass regression is available.

Results

As with the analysis of dry weight of the mean tree, the highest and lowest values were found in the provenances of *A. nilotica* (Fig. 8). Burkina04 and Burkina05 had average productions of 2.9 and 3.2 t ha^{-1}, respectively, whereas Burkina06 had an average dry weight production of only 1.3 t ha^{-1}. The yearly production of Burkina05 thus amounts to 0.6 t ha^{-1}. The provenances of *A. tortilis* were all intermediaries in this character. However, since the variation within the provenances was large, the differences between species and provenances were not significant (Table 9), and recommendations based on this variable should be treated with caution.

Table 9. Results from analysis of variance of species and provenance differences of total dry weight in trial 7.

Effect	DF (nominator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Species differences					
Species	2; 5.0	3.4	1.8	0.24	n.s.
Provenances (species)	5; 17	1.9	2.2	0.10	
Block	3; 17	1.4	1.7	0.21	
Error	17	0.8			
A. nilotica					
Provenance	2; 6	4.4	3.8	0.09	n.s.
Block	3; 6	2.1	1.8	0.25	
Error	6	1.1			
A. tortilis					
Provenance	3; 8	0.37	0.58	0.65	n.s.
Block	3; 8	0.13	0.20	0.89	
Error	8	0.64			

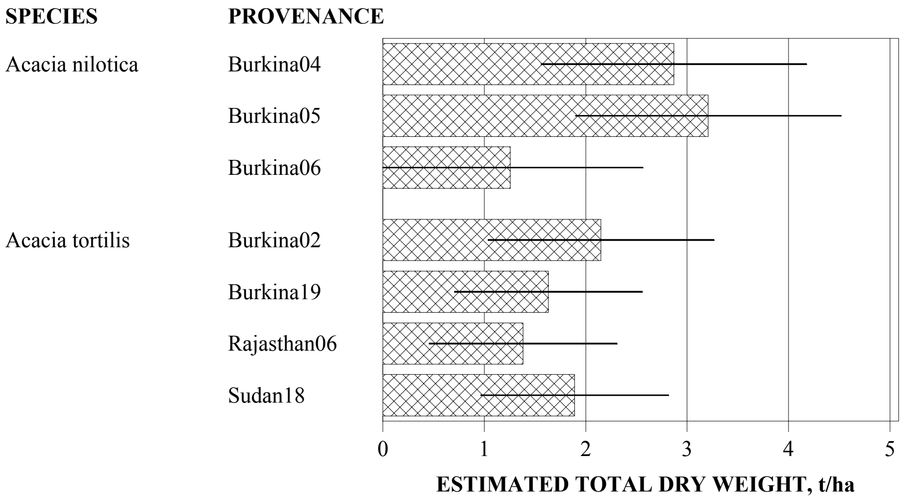


Figure 8. Total dry weight in the *Acacia* species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). Values presented are least square means with 95 % confidence limits.

4.9 Multivariate analysis

The multivariate analyses were performed in two stages, in a similar way to the univariate analyses. The first stage was an analysis of provenance differences in the whole material (all species), whereas the second stage was an analysis of provenance differences within each species separately. The analyses included the eight variables analysed in the univariate analyses. Since there were no estimates for biomass for *A. seyal*, the dry weight variables were not included in the analysis of all provenances and in the analysis of provenance differences within *A. seyal. A. nilotica* could not be analysed separately, because the number of provenances were too few to allow an analysis.

All provenances

In the analysis, the two first canonical variates were significant, and the third was close to being significant (Table 10). This justifies plotting the canonical variates as plots of the second canonical variate against the first, and of the third canonical variate against the first (Fig. 9). In total, the three first canonical variates accounted for 93 % of the variation. The differences between the provenances were highly significant (P-value for Wilk's lambda and Pillai's trace both below 0.0001).

The plots of the canonical scores are given in Fig. 9. Apart from the scores, the mean values for the provenances are given together with their approximate 95 % confidence regions. In the diagram, provenances that are far apart are interpreted as being very different, and if the confidence regions do not overlap, it is likely that the two provenances in reality have different properties.

There appears to be two major groups in the diagrams. The provenances of *A. seyal* form their own cluster separated from the other group, which consist of the provenances of *A. nilotica* and *A. tortilis*. Provenances from the two latter species overlap, and from the diagrams there are no clear differences between the two species. There were only minor differences between the separation of provenances in the two diagrams.

Provenance differences within species

Except for number of stems variable, the univariate analyses gave no convincing signs of provenance differences within the species. The multivariate analyses, integrating many variables, were therefore expected to provide an answer as to whether there were significant differences between the provenances. As mentioned above, only three provenances of *A. nilotica* were included, which is too few to perform a multivariate analysis.

The analysis of *A. seyal* demonstrated that the first canonical variate (accounting for 92 % of the variation) was almost significant (data not shown). The multivariate tests gave no clear conclusion with regard to the possible differences between provenances, since the significance of the provenance effect varied with the test used (P for Wilk's lambda=0.07, P for Pillai's trace=0.18). In the plots of scores (Fig. 10) the provenances were clearly separated, but as the tests do not give unequivocal answers, nothing can be concluded.

According to the test of *A. tortilis*, the provenances of this species were far from being significantly different (data not presented). The first canonical variate accounted for 83 % of the variation but was not significant, and the provenance effect was also far from being significant (P for Wilk's lambda=0.67, P for Pillai's trace=0.63). It is therefore concluded that the provenances are not significantly different.

Table 10. Results from the canonical variate analysis of provenance differences for the first three canonical variates in trial 7. In this analysis data for all three species were included.

Canonical variate no.	**1**	**2**	**3**						
Proportion of variation accounted for	0.69	0.16	0.08						
Significance, P-value	0.0001	0.001	0.07						
	Raw canonical coefficients			**Standardised canonical coefficients**			**Canonical directions**		
Canonical variate no.	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Survival	0.082	0.008	-0.029	1.7	0.2	-0.6	141	-58	101
Height	0.26	-4.2	0.16	0.1	-1.8	0.1	-3.2	-2.5	5.4
Crown area	-1.5	0.52	-0.46	-4.5	1.6	-1.4	-27	5.3	25
Number of stems	0.78	1.8	0.46	0.5	1.1	0.3	0.094	9.0	6.2
Average basal area	0.38	0.011	0.055	4.0	0.1	0.6	-71	5.9	154
Total basal area	-3.6	-0.42	3.1	-1.9	-0.2	1.6	-1.3	-1.1	10.0

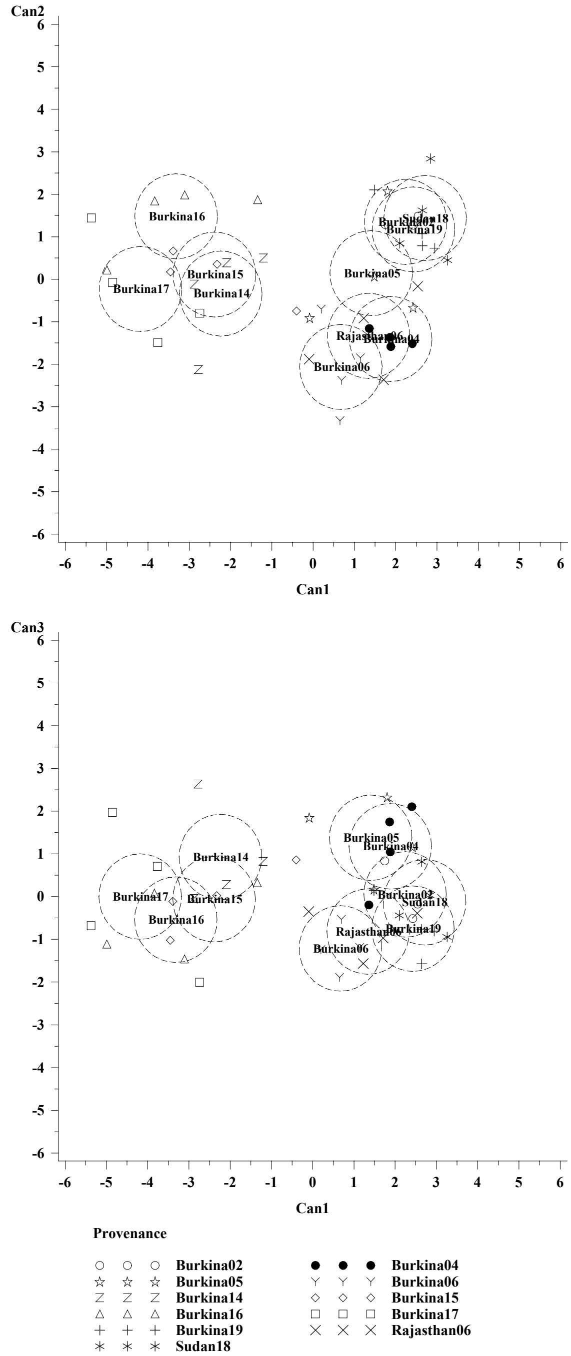


Figure 9. Score plot of the first and the second canonical variate (upper diagram) and of the first and the third (lower diagram) from the canonical variate analysis for the provenances in the species and provenance trial at Dori, Burkina Faso (Trial no. 7 in the arid zone series). The variables survival, height, crown area, number of stems, basal area of the mean tree and total basal area. Each provenance is marked at the mean value and surrounded by a 95 % confidence region. The provenances Burkina14 to Burkina 17 are *A. seyal*, the provenances Burkina04 to Burkina06 are *A. nilotica*, and Burkina02, Burkina19, Rajasthan06 and Sudan18 are *A. tortilis*.

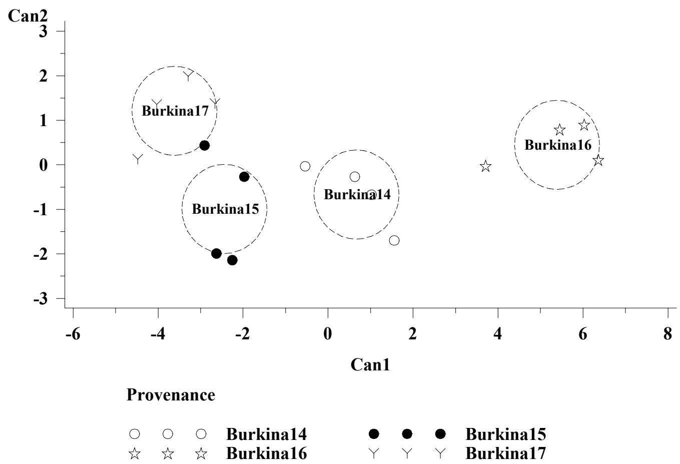


Figure 10. Score plot of the first and the second canonical variate from the canonical variate analysis for *A. seyal* at Dori, Burkina Faso (Trial no. 7 in the arid zone series). The variables survival, height, crown area, number of stems, basal area of the mean tree and total basal area were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region. Note: The second canonical variate was not significant.

5. Discussion and conclusions

Productivity

A parallel trial (Trial no. 10, with the same provenances) exists in Gonsé, approximately 180 km south of Dori. Burkina05 (*A. nilotica*) had the highest dry weight production in both trials. In the current trial, Burkina05 had an average annual production of 0.64 t ha^{-1}, whereas it produced 1.4 t ha^{-1} over a five-year period at Gonsé, approximately double its production in this trial. Correspondingly, the height growth of Burkina05 was smaller, being 2.2 m in this trial but 2.9 m in Gonsé. The average annual rainfall is approximately 300 mm higher at Gonsé than at Dori.

Compared with the *A. senegal* trial in Dori (Trial no. 8), the maximum production was almost the same, but the *A. senegal* had grown to a height of only 1.6 m.

Species differences

Both the univariate and the multivariate analyses revealed that the major differences between the provenances in the trial were due to differences between the three species. In the multivariate analysis *A. seyal* was clearly separated from *A. nilotica* and *A. tortilis*, and the univariate analyses demonstrated that *A. seyal* had the smallest survival but on the other hand the largest heights, crown areas and basal areas of the mean tree. Thus the conclusions would be that *A. seyal* has a more tree-like growth habit than the two other species, may be less adapted to the harsh conditions of the site (poor survival) but nevertheless has the largest increment in basal area. The differences between the two other species were smaller, and in the multivariate analysis the two species could not be separated.

Unfortunately it was not possible to estimate the dry weight of *A. seyal*, and thus the production of biomass between the species cannot be compared. This would have been interesting since the low survival and the large basal areas of the mean tree of *A. seyal* tend to counteract each other. However, the analysis of total basal area gave no clear differences between the species, which may indicate that the dry weight production does also not differ much. The wood density of *A. seyal* in studies in Burkina Faso was 711-749 kg m^{-3} (Nygård & Elfving 2000). Other parts of this study (Graudal *et al.* in prep.) has shown that the specific gravity for *A. nilotica* varied from 610 to 800 kg m^{-3} with a mean value of 700 kg m^{-3}. For *A. tortilis*, the mean specific gravity was 660 kg m^{-3} at one site (Bandia, Senegal) and 770 kg m^{-3} at another (Jodhpur, India).

Provenance differences

The differences between provenances of the individual species were not as clear. Even though there were significant or almost significant differences between the provenances of *A. nilotica* in the number of stems and the basal area and biomass variables, these differences disappeared when correcting for the effect of multiple comparisons. Unfortunately the number of provenances did not allow a multivariate analysis, and the final conclusion can thus not be drawn. It is noteworthy that the provenance Burkina06 of the variety *tomentosa* tends to grow less vigorously than the two provenances of the variety *adansonii*. It would be tempting to explain the apparent difference by adaptation to the soil type (subsp. *adansonii* preferring sandy soil types), but this may be taking interpretation too far.

Apart from the univariate analyses which indicated that there could be differences in the number of stems within the provenances of *A. tortilis*, no convincing differences were found. This impression was confirmed by the multivariate analysis. Similarly, the provenances of *A. seyal* did not separate clearly in the univariate analyses, and the multivariate analysis gave no clear answer either.

Even though the tests did not demonstrate clear significant differences between the provenances, this does not exclude the possibility that there are differences in the material. When making recommendations on the choice of planting material it is therefore natural to choose the provenances that have had the best performance, even if they are not significantly different from the other provenances. However, results from the trial should be verified by later measurement to ensure that the ranking of the provenances has not changed, and that no false recommendations are given. Based on the total basal area it seems that the best provenances would be Burkina04 and Burkina05 (*A. nilotica*) and Burkina14 and Burkina17 (*A. seyal*). The provenances of *A. tortilis* appear to be somewhat more slow growing (always with the reservation that the differences are on the border of significance), but with the best provenances being Burkina02 and Sudan18.

Comparing the origin of the provenances with the conditions of the site no clear picture emerges. One would expect that a match between climate at the origin and climate at the site would be beneficial, but the data does not clearly support this. For *A. nilotica*, it appears that the provenance from Ouagadougou, Burkina05, performs as well as the two provenances from the north. For *A. seyal*, the two northernmost provenances are the leaders, but there are no clear differences between the provenances, and in the multivariate analysis the provenances were scattered among each other, not confirming the trend. The four provenances of *A. tortilis* seem to behave quite similarly, but they represent no gradients in rainfall.

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. 7. Acacia species/provenance trial, Dori, Burkina Faso, joint assessment, March 1993 by CNSF, IRBET, FAO and DFSC. Unpublished working document, 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.

Fagg, C.W. and R.D. Barnes. 1990. African Acacias: Study and acquisition of the genetic resources. Final report, ODA Research Scheme R.4348, Oxford Forestry Institute, UK. 170 pp.

Fagg, C.W. and A. Greaves. 1990a. *Acacia nilotica*. Annotated bibliography no. F42. CAB International, 77 pp.

Fagg, C.W. and A. Greaves. 1990b. *Acacia tortilis*. Annotated bibliography no. F41. CAB International, 36 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, Humlebæk, Denmark.

Graudal, L. *et al.* (in prep.): Biomass regressions for some species of *Acacia* and *Prosopis*.

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.

Nygård, R. and B. Elfving. 2000. Stem basic density and bark proportion of 45 woody species in young savanna coppice forests in Burkina Faso. Ann. For. Sci. 57, 143-153.

Ross, J.H. 1979. A conspectus of the African Acacia species. Memoirs of the Botanical Survey of South Africa, 44, 155 pp.

Ræbild, A., C.P. Hansen and E.D. Kjaer. 2002. Analysis of species and provenance trials. Technical Note No.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 trial site (from DFSC 1994)

Name of site:	Dori, Burkina Faso Latitude: 14°02'N Longitude: 00°01'W Altitude: 275 m
Meteorological stations:	Dori (14°02'N, 00°03'W, 277 m (FAO 1984))
Rainfall:	Annual mean (period): 563 mm (FAO 1984) 410.1 (1971-80 (DSM)) Yearly registrations (DSM): 1981: 457.7 1982: 308.8 1983: 322 1984: 226.5
Rainy season:	June-September (FAO 1984) Type: Normal with dry period (FAO 1984) Length (days): Intermediate 55, wet 36 (FAO 1984)
Dry months/year:	No. of dry months (<50 mm): 8 No. of dry periods: 1
Temperature (°C (FAO 1984)):	Annual mean: 28.8 Coldest month: 13.1 (mean minimum) Hottest month: 41.5 (mean maximum)
Wind:	Speed at 2 m: 2.2 m/s (FAO 1984)
Topography:	Flat
Soil:	Type: Sandy, some clay in depth Depth: Deep (> 1 m) (Soil maps should be consulted for verification/additional information - Bureau National des Sols, Ougadougou).
Climatic/agroecological zone:	Semi-arid, Sahelian zone
Dominant natural vegetation:	Shrub/woody savanna (*Acacia raddiana, Acacia albida, Acacia seyal*)
Koeppen classification:	BSh

Annex 2. Seedlots tested in trial no. 7 at Dori, Burkina Faso

The codes are as follows: aniada: *A. nilotica* subsp. *adansonii*, anito: *A. nilotica* subsp. *tomentosa*, asey: *A. seyal*, ato: *A. tortilis*, atora: *A. tortilis* subsp. *raddiana*. The plot number refers to the seedlots in the map of the trial, see Annex 3.

Seedlot numbers				**Provenance information**							
Provenance	DFSC	Plot	Country of origin	Species code	Origin	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall mm	No. of mother trees
Burkina04		1	885	aniada	Boukouma	Burkina Faso	14°12' N	00°43' E	317	400	27
Burkina05		2	921	aniada	F.C. Barrage, Kossodo, Ouaga	Burkina Faso	12°20' N	01°30' W	341	700	100
Burkina06		3	926	anito	Falagountou	Burkina Faso	14°22' N	00°11' E	250	400	27
Burkina14		9	27	asey	Bodole H, Djibo	Burkina Faso	14°06' N	01°37' W	274	380	76
Burkina15		11	369	asey	Route Sao-Tcheriba, Vers Lery	Burkina Faso	12°15' N	03°12' W	293	700	47
Burkina16		10	909	asey	F.C. Barrage , Kossodo, Ouaga	Burkina Faso	12°20' N	01°30' W	300	700	26
Burkina17		12	916	asey	Lery	Burkina Faso	12°49' N	03°12' W	293	700	35
Rajasthan06	1085/82	8		ato	Ramgaon, Barmer	India	25°45' N	71°23' E	194	310	50
Sudan18	1240/84	7	6/1983	atora	Elbashiri Oasis, Northern Kordofan	Sudan	13°48' N	30°12' E	400	300	25
Burkina02		6	868	atora	Boukouma	Burkina Faso	14°12' N	00°43' W	320	400	27
Burkina19		5	920	atora	Markoye	Burkina Faso	14°38' N	00°21' N	295	400	27

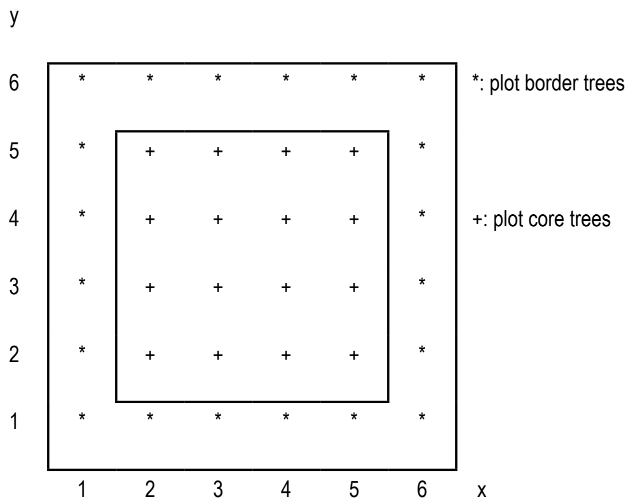
The numbers correspond to the seedlots given in Annex 2.

Annex 3. Layout of the trial

N

y	BLOCK 1			BLOCK 2			BLOCK 3		
8	8	3	11	12	2	6	6	3	7
7	10	6	12	3	9	7	5	1	10
6	1	5	2	5	8	1	11	12	9
5	7	9	5	10	11	10	9	2	8
4	11	9	3	2	9	8	12	1	5
3	1	2	10	11	1	7	2	10	9
2	12	8	5	12	10	5	5	8	7
1	6	7	3	3	6	2	12	3	11
x	1	2	3	4	5	6	7	8	9
	BLOCK 4			BLOCK 5			BLOCK 6		

Individual tree positions in each plot::



Annex 4. Plot data set, used for the analyses

Block	Plot	Plotx	Ploty	Species	Provenance	Survival Propor-tion	Height	Crown area	Number of stems	Basal area, mean tree	Total basal area	Dry weight, mean tree	Total dry weight
							m	m^2	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	tons ha^{-1}
2	1	6	6	aniada	Burkina04	0.75	2.28	5.54	3.00	25.57	1.10	5.07	2.38
2	2	5	8	aniada	Burkina05	1.00	2.13	6.69	4.25	27.68	1.73	5.97	3.73
2	3	4	7	anito	Burkina06	0.79	1.69	6.42	2.22	18.76	0.66	2.59	1.31
2	5	4	6	atora	Burkina19	0.88	1.24	3.00	2.55	8.93	0.38	1.60	0.87
2	6	6	8	atora	Burkina02	0.70	1.83	5.66	3.50	23.35	1.09	5.84	2.97
2	7	6	7	atora	Sudan18	0.87	1.62	5.09	4.18	17.69	0.76	3.57	1.95
2	8	5	6	ato	Rajasthan06	0.82	1.84	4.87	1.90	18.00	0.70	3.37	1.84
2	9	5	7	asey	Burkina14	0.80	3.08	11.03	2.92	42.82	2.17	0.00	0.00
2	10	4	5	asey	Burkina16	0.55	2.28	10.36	3.09	29.28	1.26	0.00	0.00
2	10	6	5	asey	Burkina16	0.19	2.47	10.42	2.33	31.65	0.37	0.00	0.00
2	11	5	5	asey	Burkina15	0.21	2.94	12.79	3.40	49.08	0.96	0.00	0.00
2	12	4	8	asey	Burkina17	0.88	1.85	6.76	1.86	15.07	0.82	0.00	0.00
4	1	1	3	aniada	Burkina04	1.00	2.23	6.92	2.13	29.67	1.85	6.90	4.31
4	2	2	3	aniada	Burkina05	0.94	2.30	8.95	2.07	33.34	1.95	8.06	4.72
4	3	3	1	anito	Burkina06	0.81	2.11	4.96	1.45	17.01	0.73	2.74	1.39
4	3	3	4	anito	Burkina06	0.56	1.67	4.37	2.11	9.25	0.33	1.54	0.54
4	5	3	2	atora	Burkina19	0.93	1.57	5.05	2.36	14.90	0.81	3.45	2.02
4	6	1	1	atora	Burkina02	0.63	1.35	5.31	2.50	19.67	0.61	4.21	1.64
4	7	2	1	atora	Sudan18	0.75	1.66	6.06	2.60	18.82	0.74	4.21	1.97
4	8	2	2	ato	Rajasthan06	0.50	2.21	6.94	1.88	23.85	0.75	6.86	2.15
4	9	2	4	asey	Burkina14	0.75	2.36	10.09	2.58	30.31	1.42	0.00	0.00
4	10	3	3	asey	Burkina16	0.60	1.93	9.37	2.67	21.98	0.77	0.00	0.00
4	11	1	4	asey	Burkina15	0.25	2.46	9.38	2.40	34.25	1.34	0.00	0.00
4	12	1	2	asey	Burkina17	0.50	2.65	13.96	2.75	39.83	1.24	0.00	0.00
5	1	5	3	aniada	Burkina04	1.00	2.07	5.75	2.06	27.16	1.70	6.10	3.81
5	2	4	4	aniada	Burkina05	1.00	1.83	4.26	2.07	18.16	1.06	3.29	2.06
5	2	6	1	aniada	Burkina05	1.00	2.23	6.75	2.93	30.82	1.81	6.37	3.98
5	3	4	1	anito	Burkina06	0.94	2.17	4.35	1.47	10.87	0.64	1.85	1.08
5	5	6	2	atora	Burkina19	0.88	1.62	5.24	3.07	18.61	1.02	4.90	2.68
5	6	5	1	atora	Burkina02	0.94	1.65	4.45	2.93	14.82	0.81	3.44	2.02
5	7	6	3	atora	Sudan18	0.94	1.43	3.34	2.31	12.59	0.64	2.60	1.52
5	8	6	4	ato	Rajasthan06	0.56	1.01	1.81	1.25	6.38	0.10	0.63	0.22
5	9	5	4	asey	Burkina14	0.63	2.13	8.50	2.50	32.99	1.29	0.00	0.00
5	10	5	2	asey	Burkina16	0.56	2.27	10.88	2.89	35.26	1.24	0.00	0.00
5	11	4	3	asey	Burkina15	0.81	2.08	8.48	2.15	21.99	1.12	0.00	0.00

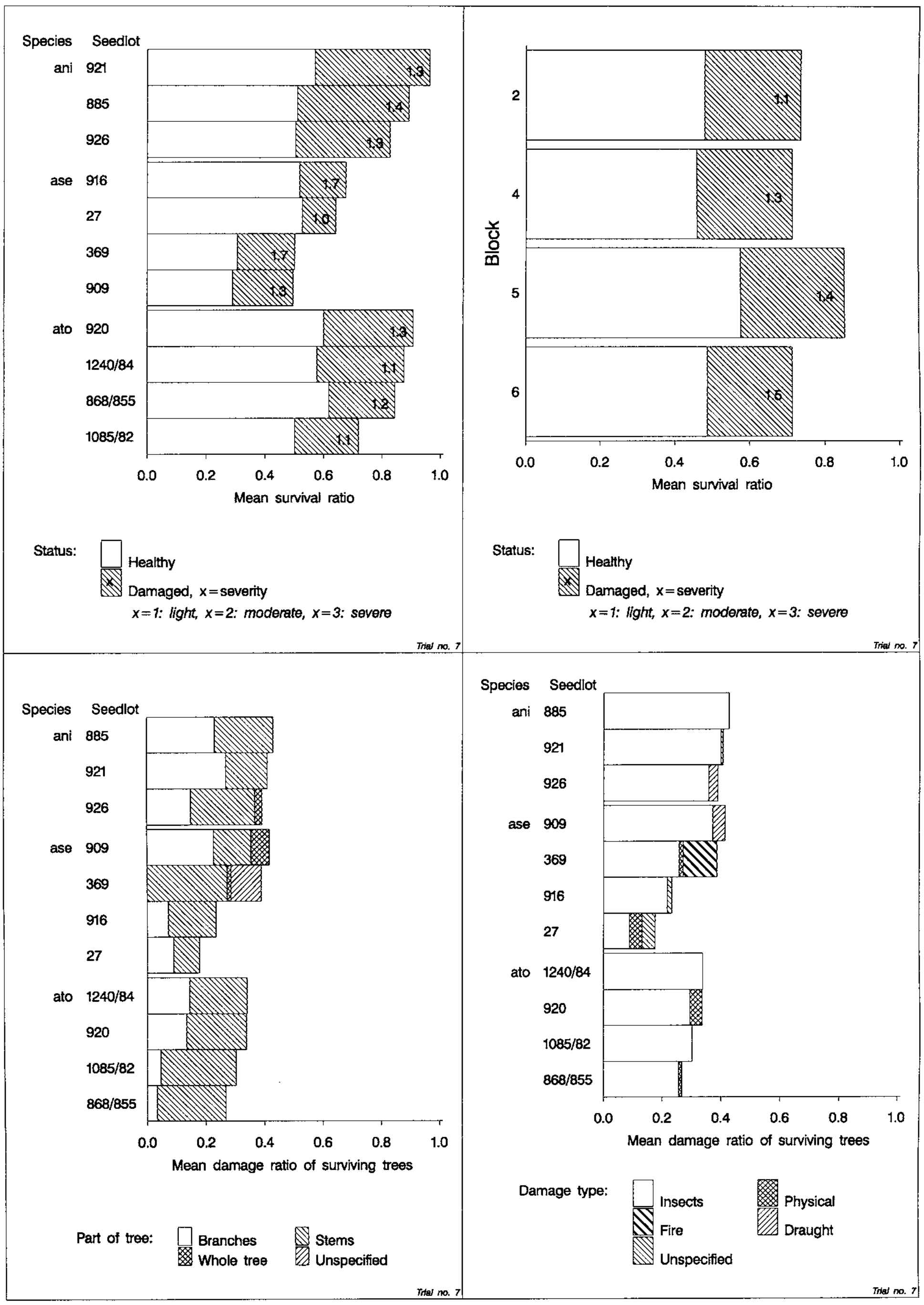
Block	Plot	Plotx	Ploty	Species	Provenance	Survival Proportion	Height	Crown area	Number of stems	Basal area, mean tree	Total basal area	Dry weight, mean tree	Total dry weight
							m	m^2	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	tons ha^{-1}
5	12	4	2	asey	Burkina17	1.00	2.63	11.75	2.44	38.09	2.38	0.00	0.00
6	1	8	4	aniada	Burkina04	0.81	1.69	3.20	2.08	11.02	0.56	1.92	0.97
6	2	7	3	aniada	Burkina05	0.88	1.64	4.15	2.46	14.47	0.73	2.50	1.37
6	3	8	1	anito	Burkina06	1.00	1.87	4.32	1.44	13.36	0.84	2.64	1.65
6	5	9	4	atora	Burkina19	0.93	1.26	3.43	2.45	9.89	0.42	1.63	0.95
6	6	7	2	atora	Burkina02	1.00	1.65	5.66	2.69	20.67	1.05	4.45	2.78
6	7	9	2	atora	Sudan18	0.90	1.58	3.81	3.20	14.76	0.86	3.60	2.11
6	8	8	2	ato	Rajasthan06	0.92	1.49	3.20	2.23	11.09	0.56	2.25	1.32
6	9	9	3	asey	Burkina14	0.38	1.98	5.99	2.67	17.17	0.40	0.00	0.00
6	10	8	3	asey	Burkina16	0.44	1.57	4.84	3.14	14.76	0.40	0.00	0.00
6	11	9	1	asey	Burkina15	0.25	1.90	7.43	2.50	24.29	0.38	0.00	0.00
6	12	7	1	asey	Burkina17	0.86	2.73	9.97	2.43	30.43	1.66	0.00	0.00
6	12	7	4	asey	Burkina17	0.13	1.70	3.70	2.00	11.04	0.09	0.00	0.00

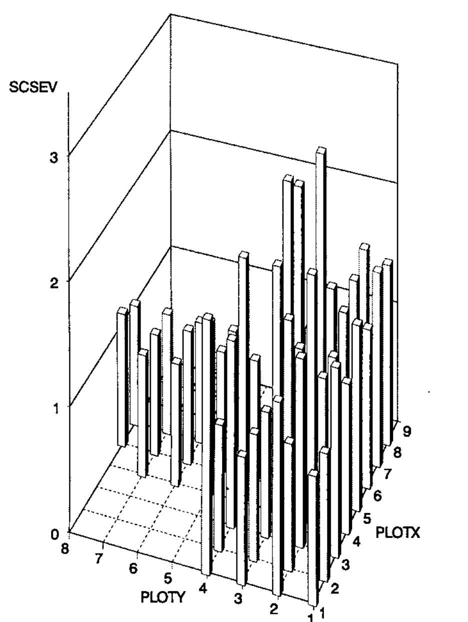
Annex 5. Graphical presentation of the health data

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.

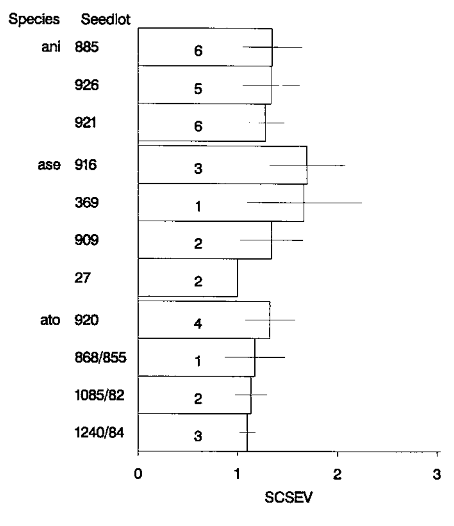
Please note that the seedlot codes correspond to the numbers given in Annex 2.





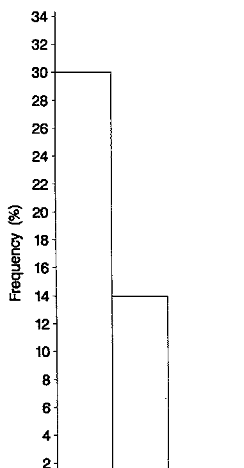
SCSEV = Health status code, severity of attack
Scatter of plot mean values

Trial no. 7



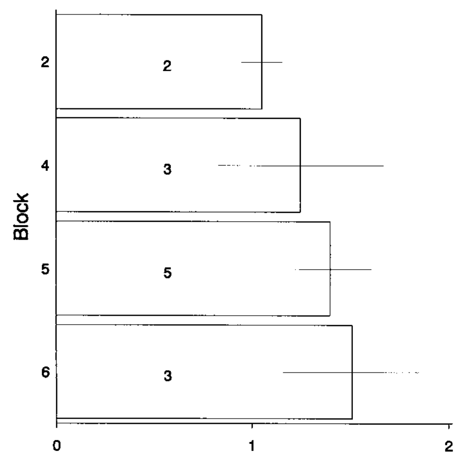
Mean SCSEV of seedlot with error bar line (+/− standard deviation of the mean) and the average number of assessed (living) trees per plot for each seedlot.

Trial no. 7



Frequency distribution of plot mean values

Trial no. 7



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. 7