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

Trial No. 11 in the Arid Zone Series

by

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Diagram showing average basal area for the provenances in the trial at Gonsé, Burkina Faso. See Figure 12.

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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.

The report represents 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 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 Kiemdrébéogo Karim, Kaboré Ousmane, Sawadogo Abel, Kyelem Ibrahim, Kibora P. Daniel, all from INERA/IRBET, Lambert Ouedraogo from Centre National de Semences Forestières, Agnete Thomsen of FAO, and Lars Graudal from DFSC.

The authors wish to acknowledge the help of the personnel at IRBET with the establishment, maintenance and assessment of the trials, and thank the personnel of DFSC for their help with the data management and preliminary analyses. Drafts of the manuscript were commented on by Dr. agro. Axel Martin Jensen and by Marcus Robbins, consultant to FAO.

Abstract

This report describes the results from the analysis of a trial including 16 provenances of *Acacia nilotica* and 5 provenances of *A. tortilis,* established in 1989 with a spacing of 4 x 4 metres at Gonsé, Burkina Faso. The assessment took place after four years in 1993, and included a number of vegetative and growth characters. The provenances of *A. nilotica* represented a selection from Burkina Faso, Senegal, Sudan and India, whereas the provenances of *A. tortilis* were from Burkina Faso and Sudan.

Differences between the provenances were highly significant. For *A. nilotica*, the provenances from Burkina Faso and Senegal had by far the best performance, and the growth of provenances from India was very poor. The provenances from Burkina Faso and Senegal were also clearly separated from the rest of the provenances in the multivariate analysis, but whether this is due to differences between varieties or due to the geographical origin is not clear. The best provenances had a growth rate corresponding to 1.1 t ha^{-1} y^{-1}. Growth in *A. tortilis* was somewhat slower, and in the univariate analyses no difference could be found between the provenances. In the multivariate analysis, however, it appeared that the provenance from Burkina Faso was different from the provenances from Sudan.

Resumé en français

Ce rapport décrit les résultats issus d'un essai de provenances de deux espèces *Acacia nilotica* et *Acacia tortilis*. L'essai a été mis en place en 1989 à Gonsé 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 4 ans après la mise en place. Un certain nombre de paramètres de croissance a été mesuré. Les 16 provenances de *A. nilotica* sont originaires du Burkina Faso, du Sénégal, du Soudan et d'Inde. Les 5 provenances de *A. tortilis* viennent du Burkina Faso et du Soudan.

L'analyse révèle hautes différences significatives entre les provenances. Chez *A. nilotica*, les provenances du Burkina Faso et Sénégal étaient largement les plus performantes. La croissance des provenances d'Inde était très faible. Dans l'analyse multivariable, les provenances du Burkina Faso et Sénégal se séparent du reste des provenances, mais on ne peut pas conclure si cela est dû aux différences entre variétés ou dû à l'origine géographique. Les meilleures provenances avaient une croissance correspondant à 1.1 t ha^{-1} y^{-1}.

La croissance de *A. tortilis* était plus lente, et les analyses univariables n'ont pas révélé des différences significatives. Cependant l'analyse multivariable montrait que la provenance du Burkina Faso étaient différente de celle du Soudan.

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1. Introduction

This report describes the results from trial no. 11 in a large series of provenance trials within the 'International Series of Trials of Arid and Semi-Arid Zone Arboreal Species'. The main goals of the series were to contribute to the knowledge on the genetic variation of woody species, their adaptability and productivity and to give recommendations for the use of the species. The species included in this series of trials are mainly of the genera *Acacia* and *Prosopis*. A more detailed introduction to the series is given by DFSC (in prep.).

The present trial includes 16 provenances of the *Acacia nilotica* and 5 provenances of *A. tortilis (*see Fagg and Greaves (1990a and b) for annotated bibliographies of *A. nilotica* and *A. tortilis*).

A. nilotica is a very variable species with a natural distribution covering large tracts of tropical and subtropical Africa and Asia, and 9 subspecies or varieties are recognised (Brenan 1983, Ross 1979). The provenances in this trial were selected from Burkina Faso, Senegal and Sudan in Africa (five provenances), and from India (eleven provenances).

The two African subspecies included in this trial, *adansonii* (which is also commonly called *adstrigens*) and *tomentosa* differ in their ecological requirements even though they both prefer moist conditions. The 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 and Barnes 1990).

According to the collection sheets, the provenances from India represent at least three different varieties: subsp. *indica* var. *cupressiformis*, subsp. *indica* var. *jaquemontii*, and subsp. *indica* var. *vediana*. In the view of Brenan (1983), this nomenclature is not justified. He states that the subsp. *indica* is a separate subspecies, and that subsp. *indica* var. *cupressiformis* is rightfully the subsp. *cupressiformis*. Furthermore, subsp. *indica* var. *vediana* is considered a synonym of subsp. *subalata*, which is native to East-Africa. The occurrence of subsp. *subalata* in India could be due to crossing between two other subspecies, subsp. *indica* and subsp. *hemispherica*. Finally, subsp. *indica* var. *jaquemontii* is considered a separate species, *A. jaquemontii*. Thus there is some confusion with regard to the taxonomy, and the material should be verified before drawing conclusions regarding varieties of this group of provenances. In this report we shall for simplicity use the terminology applied by the seed collectors.

A. tortilis is widespread in the Sahel, East Africa and Arabia (von Maydell 1986, Ross 1979, Fagg and Barnes 1990). Several subspecies are recognised, but in the current trial only the subspecies *raddiana* is included. It should be noted that in the French literature, the subspecies is often referred to as a separate species, *A. raddiana* (Fagg and Barnes 1990).

2. Materials and methods

2.1 Site and establishment of the trial

The trial is located at Gonsé (12°22′N, 01°19′W) in Burkina Faso at an altitude of 300 m. The mean annual temperature is 28.1, and the annual rainfall is 679 mm with a dry period of eight months. Further information is given in the assessment report (DFSC 1994) and summarised in annex 1. The trial was established in July 1989.

2.2 Species and provenances

The trial includes 16 provenances of the *Acacia nilotica* and 5 provenances of *A. tortilis* (Table 1). Two provenances, one of each of the species, are from Burkina Faso and may serve as local controls. For *A. nilotica* an array of provenances from Africa and Asia are represented, whereas the provenances of *A. tortilis* are from Sudan only (apart from the provenance from Burkina Faso). The provenances of *A. nilotica* include the subspecies *adansonii*, subsp. *indica* var. *cupressiformis*, subsp. *indica* var. *jaquemontii*, subsp. *indica* var. *vediana* and subsp. *tomentosa*. The provenances of *A. tortilis* are all of the subspecies *raddiana*. The provenances are given identification numbers relating to their geographical origin (name of province or country followed by a number), and the original seedlot numbers are provided in annex 2.

2.3 The experimental design

The trial is a single tree plot design with 36 blocks/replications, meaning that within each block a provenance is represented by one tree. The trees were planted with a spacing of 4×4 m. The layout of the trial is shown in annex 3, and further details are given in DFSC (1994).

2.4 Assessment of the trial

In March 1993 IRBET, FAO, CNSF 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 and crown diameter. Furthermore a number of health characters were evaluated, including a damage score on a scale from zero to three. The raw data are documented in DFSC (1994), whereas a data set based on super-blocks (see below) is given in annex 4. A detailed account of the assessment methods is given by DFSC (Graudal *et al.* 2003).

Table 1. Provenances of *Acacia* tested in trial no. 11 at Gonsé, Burkina Faso. See introduction for note on the taxonomy. Data supplied by seed collecting institutions, except for [1]rainfall data (before 1970) from Pigeonnière and Jomni (1998).

Provenance	Species	Seed collection site	Country of origin	Latitude	Longitude	Altitude (m)	Rainfall (mm)	No. of mother trees
Andra Pradesh01	*A. nilotica* subsp. *indica jaquemontii*	Nizamabad (Adilabad)	India	18° 40' N	78° 06' E	381	1086	
Burkina07	*A. nilotica* var. *adansoni*	Debel	Burkina Faso					
Haryana1	*A. nilotica* subsp. *indica* var. *cupressiformis*	Nornaul Singhana Road, Bhiwani, Hissar	India	28° 03' N	76° 07' E	250	714	
Maharashtra1	*A. nilotica* subsp. *indica* var. *jaquemontii*	Pune	India	18° 32' N	73° 51' E	559	715	25
Maharashtra2	*A. nilotica* subsp. *indica* var. *vediana*	Pune	India	18° 32' N	73° 51' E	559	715	25
Maharashtra3	*A. nilotica* subsp. *indica* var. *jaquemontii*	Akola	India	20° 42' N	77° 02' E	282	877	
Maharashtra6	*A. nilotica* subsp. *indica* var. *vediana*	Akola	India	20° 42' N	77° 02' E	282	877	
Maharashtra7	*A. nilotica* subsp. *indica* var. *cupressiformis*	Paratwara	India	20° 56' N	77° 47' E	370	974	
Punjab1	*A. nilotica* subsp. *indica* var. *cupressiformis*	Bikaner Canal Road, Ferozepure	India	30° 15' N	74° 10' E	200	537	
Rajasthan01	*A. nilotica* subsp. *indica* var. *vediana*	Pali (Desuri), Rajasthan	India	24° -- N	73° 35' E	382	400	6
Senegal15	*A. nilotica* subsp. *adansonii*	Gabgal, Louga	Senegal	15° 20' N	15° 30' W			32
Sudan06	*A. nilotica* subsp. *tomentosa*	Hariri Forest (Singa)	Sudan	13° 05' N	33° 56' E	430	588	25
Sudan07	*A. nilotica* subsp. *tomentosa*	Khartoum Forest	Sudan	15° 36 N	32° 33 E	330	165	25
Sudan10	*A. nilotica* subsp. *tomentosa*	Ed Duim, White Nile	Sudan	14° 30 N	32° 10 E		270	
Tamil Nadu1	*A. nilotica* subsp. *indica* var. *jaquemontii*	Vellayur Attur, Salem	India	11° 39 N	78° 10 E	278	965	25
Uttar Pradesh1	*A. nilotica* subsp. *indica* var. *jaquemontii*	Bawain Forest Block, Etawah (Mainpuri),	India	26° 45 N	79° 00 E	157	762	26
Burkina19	*A. tortilis* subsp. *raddiana*	Markoye	Burkina Faso		.		450[1]	
Sudan18	*A. tortilis* subsp. *raddiana*	Elbashiri Oasis, Northern Kordofan	Sudan	13° 48 N	30° 12 E	400	300	25
Sudan19	*A. tortilis* subsp. *raddiana*	El Geteina, Ed Duim	Sudan	14° -- N	32° 05 E	500	300	24
Sudan22	*A. tortilis* subsp. *raddiana*	Ed Duim, White Nile	Sudan	14° 30 N	32° 10 E		270	
Sudan23	*A. tortilis* subsp. *raddiana*	Esh Sheik Essidig, Ed Duim	Sudan	15° 30 N	32° 15 E	400	300	29

3. Statistical analyses

3.1 Variables

In the report the following 9 variables are analysed:

- Survival
- Vertical height
- Crown area
- Number of stems at 0.3 m
- Average basal area at 0.3 m
- Total basal area at 0.3 m
- Average dry weight
- Total dry weight
- Damage score

Since the trial is a single tree plot, some special problems arise. Survival has a binomial character (either 'dead' or 'alive') and in order to make an analysis of variance it is necessary to summarise survival for a larger number of trees. Analysing area-based measures is difficult since there is only one tree on each plot in the block. Consequently, to analyse survival, damage score and total production (of basal area and biomass) we constructed five 'super-blocks', each consisting of 7 or 8 of the small blocks. For these super-blocks the average survival was calculated for each provenance as the proportion of surviving trees to the number of trees originally planted. The average damage score was calculated as the mean of the surviving trees within a super-block. The area related measures, total basal area and total dry weight, were calculated as the sum of the variables for each super-block and provenance and then related to the growth space of the trees, expressing the variables on an area basis. Due to competition, trees from different provenances may experience different growth space, but here it is assumed that all trees have the same growth space (4×4 m^2). All other variables were analysed using the single tree data set.

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 omission of these data will produce biased results and lead to an over-estimation of the provenances in question, the values for crown area, basal area and dry weight for these observations have been set to zero. There is no reasonable way to estimate the number of stems of such trees, and no default value has been set for this variable. In any case, the estimates of the variables will be slightly biased.

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

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

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

$$TreeDW = e^{(2.471 \times \ln(basalarea) - 2.068)}$$

3.2 Statistical model and estimates

The variables were analysed by a two-step procedure. The first step was to test species differences according to a model with the main effects of species, provenances nested within species, and blocks (or super-blocks). The second step was to analyse provenance differences within the species, which was done by application of a model including only provenances and blocks.

Thus in the test of differences between species the following model was used:

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

where X_{ijk} is the value of the trait in question (e.g. height) in plot ijk, μ is the grand mean, $species_i$ is the fixed effect of species number i, $provenance(species)_{ij}$ is the fixed effect of provenance number j nested within species i, block $_k$ is the random effect of block k in the trial, and ε_{jk} is the residual of plot jk which is assumed to follow a normal distribution $N(0, \sigma_e^2)$. The test was performed using the Satterthwaite method for calculation of the degrees of freedom (SAS 1988b). It should be noted that in the analysis of survival, total basal area and total dry weight the block effect was substituted by super-blocks.

The second stage, the analysis of provenance differences, was performed separately for the two species according to 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 fixed effect of provenance number j, block$_k$ is the random effect of block (or super-block) k in the trial, and ε_{jk} is the residual of plot jk which is assumed to follow a normal distribution $N(0, \sigma_e^2)$.

Standard graphical methods and calculated standard statistics were applied to test model assumptions of independence, normality and variance homogeneity (Snedecor and Cochran

1980, Draper and Smith 1981, Ræbild *et al.* 2002). Where appropriate, transformations or weighting of data and exclusion of outliers were performed to fulfil basic model assumptions (*ibid.*; Afifi and Clark 1996). Weighting of data with the inverse of the variance for the seedlots was used to obtain normality of the residuals where the seedlots appeared to have different variances. Where large provenances tended to have larger variances than small provenances, a logarithmic transformation or (in the case of crown area) a square root transformation was used to stabilise variance.

The P-values from the tests of provenance differences were corrected for the effect of multiple comparisons by the sequential tablewide Bonferroni method (Holm 1979). The tests were ranked according to their P values. The test corresponding to the smallest P value (P_1) was considered significant on a 'table-wide' significance level of α if $P_1<\alpha/n$, where n is the number of tests. The second smallest P value (P_2) was declared significant if $P_2<\alpha/(n-1)$, and so on (c.f. Kjaer and Siegismund 1996). In this case the number of tests was set to nine, thus equalling the number of variables analysed. The significance levels are indicated by (*) (10%), * (5%), ** (1%), *** (1 ‰) and n.s. (not significant).

Based on the models, two sets of estimates are presented: The least square means (LS-means) and the Best Linear Unbiased Predictors (BLUPs) (White and Hodge 1989). In brief, the LS-means give the best estimates of the performance of the chosen provenances at the trial site, whereas the BLUPs give the best indication of the range of variation within the species. It should be noted that in the calculation of BLUPs it is assumed that the provenances represent a random selection, which may be a critical assumption in this case.

A multivariate analysis providing canonical variates, and Wilk's lambda and Pillai's trace statistics, complemented the univariate analyses (Chatfield and Collins 1980, Afifi and Clark 1996, Skovgård and Brockdorf 1998).

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

4. Results

4.1 Survival

Survival is regarded as one of the key variables when analysing tree provenance trials, since it indicates the adaptability of the provenance to the environment at the trial site. It should be noted that the survival reflects only the conditions experienced during the first years of 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

Survival was analysed on data calculated from the super-blocks. As there seemed to be variance heterogeneity amongst the provenances, a weight statement was applied. This applied to both the analysis of species differences and the test of provenance differences within *A. nilotica*, but not to the test of provenance differences within *A. tortilis*, which was performed without weights.

Results

There was a large variation in the survival, ranging from below 10 to 100 % (Fig. 1). The *A. tortilis* provenances had a relatively high survival and were not significantly different from each other (Table 2). The provenances of *A. nilotica* were much more variable. There was an overall significant effect of the species, meaning that with the given selection of provenances, *A. tortilis* had a higher survival than *A. nilotica*. On the one hand, two provenances of *A. nilotica* (Burkina07 and Senegal15) had a survival of 100 % (which is higher than any of the *A. tortilis* provenances), but on the other hand all the other provenances had survivals of 50 % or less. It is noteworthy that in the large selection of provenances from India, only Maharashtra7 had a survival approaching 50 %. The three provenances from Sudan had intermediate survival, and it could seem that provenances from Africa in general have a better survival at the site than do provenances from India.

It follows that the predicted values are large by choosing the best surviving provenances of *A. nilotica*. Burkina07 and Senegal5 had predicted values of almost 70 % better than the average (Fig. 2). Since the provenances of *A. tortilis* were not significantly different, it was not possible to calculate BLUP-estimates for this species, and no graph is presented.

Table 2. Results from analysis of variance of provenance differences of survival in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 19.3	494	7.17	0.01	(*)
Provenance (species)	19; 80	138	140	<0.0001	
Super-block	4; 80	3.05	3.1	0.02	
Error	80	0.98			
A. nilotica					
Provenance	15; 60	230	244	<0.0001	***
Super-block	4; 60	0.82	0.87	0.49	
Error	60	0.94			
A. tortilis					
Provenance	4; 16	0.010	0.94	0.47	n.s.
Super-block	4; 16	0.034	3.13	0.04	
Error	16	0.011			

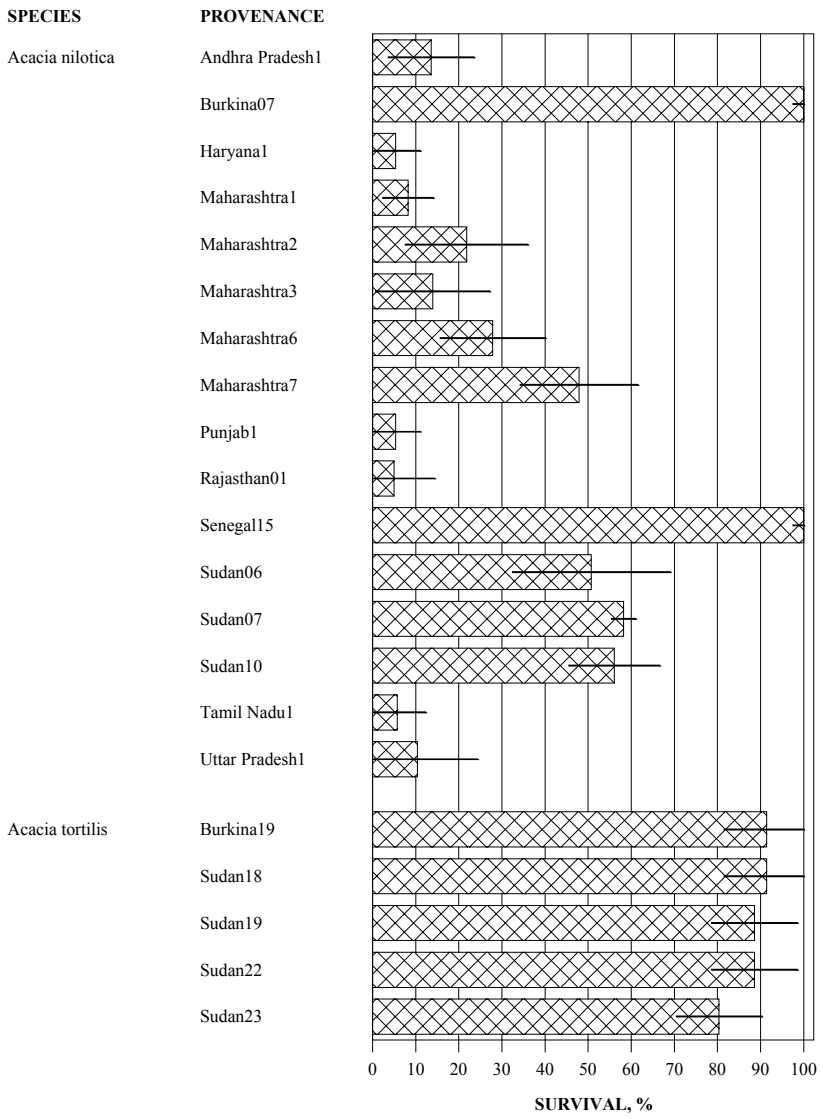

Figure 1. Survival in percent for the provenances in the *Acacia* provenance trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values presented are least square means with 95 % confidence limits. The data were weighted with the reciprocal of the variance for each provenance, and the confidence intervals are therefore of uneven length.

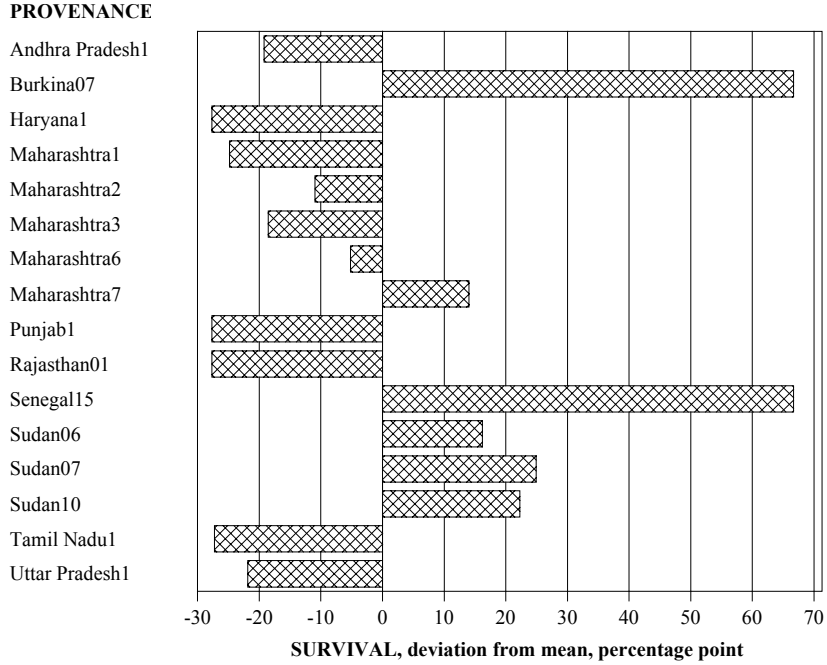

Figure 2. Best linear unbiased predictors (BLUPs) for survival in the A. nilotica provenances in the trial at Gonsé, Burkina Faso (Trial no. 12 in the arid zone series). Values are presented as deviations from the mean value in percentage point.

4.2 Height

Height is usually considered an important variable in the evaluation of species and provenances, though 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 of the plants, this interpretation need not always be true, however.

Statistical analysis

A number of analyses were performed on the height data to compare the effect of a model including single tree data with a model run on super-block data. In short the model with super-block data gave the smallest confidence intervals, but due to small imbalances in the trial the estimates were different from the estimates coming from the single tree model. Since the estimates from the single tree model are assumed to be correct, this model is used for presentation. Due to heterogeneity of variance it was necessary to use weighted models for the analysis of species differences and for analysis of provenance differences in *A. nilotica*.

Results

The average vertical height varied from almost zero for some provenances to about 2.2 m for the best provenances (Fig. 3). The analysis of species differences did not support the hypothesis of general differences in height between the two species (Table 3).

In *A. nilotica* the provenance effect was highly significant (Table 3). The best provenances were clearly the provenances Burkina07 and Senegal15, having predicted values of more than 100% better than the average and average heights of more than 2 m (Figs. 3 and 4), but Maharashtra7 also seemed to be quite fast-growing. In comparison the other *A. nilotica* provenances had heights of about 1 m or less. This included provenances from India as well as from Sudan.

Again the provenances of *A. tortilis* showed much less variation than the provenances of *A. nilotica*. Even so, the provenance effect was at the border of significance for *A. tortilis*, indicating that the provenances may be different (Table 3). The significance disappeared when accounting for multiple comparisons. Burkina19 and Sudan18 were the highest provenances, giving predicted gains of 6 to 8 % of the average value (Fig. 5). The average heights for *A. tortilis* were 1.0 – 1.2 m.

Table 3. Results from analysis of variance of provenance differences of height in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 19.9	2.5	0.15	0.70	n.s.
Provenance (species)	19; 294	23.3	21.7	<0.0001	
Super-block	4; 294	4.3	4.0	<0.0001	
Error	294				
A. nilotica					
Provenance	15; 140	26.5	22.3	<0.0001	***
Super-block	4; 140	3.6	3.1	<0.0001	
Error	140	1.2			
A. tortilis					
Provenance	4; 119	0.42	2.4	0.05	n.s.
Super-block	4; 119	0.21	1.2	0.20	
Error	119	0.17			

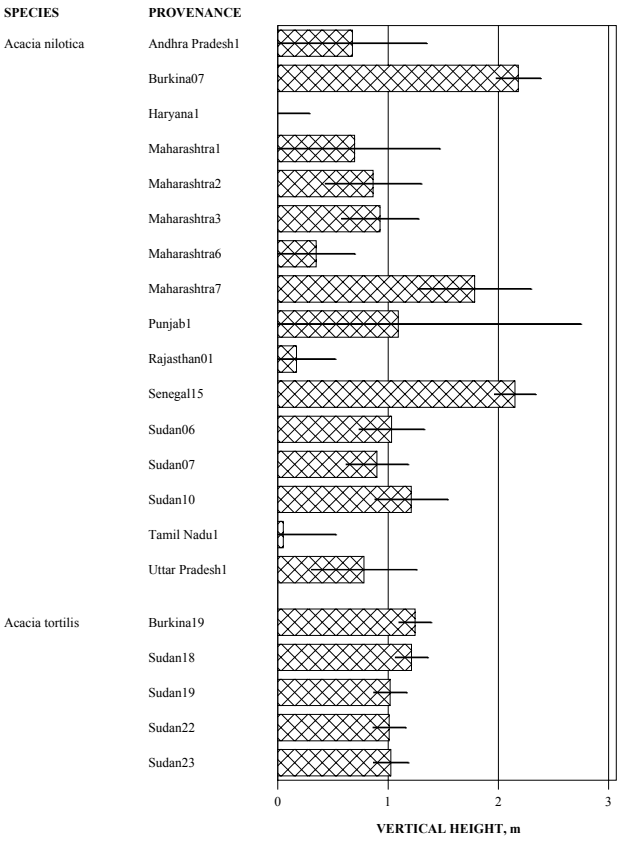

Figure 3. Vertical height for the provenances in the *Acacia* provenance trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values presented are least square means with 95 % confidence limits. The data were weighted with the reciprocal of the variance for each provenance, and the confidence intervals are therefore of uneven length.

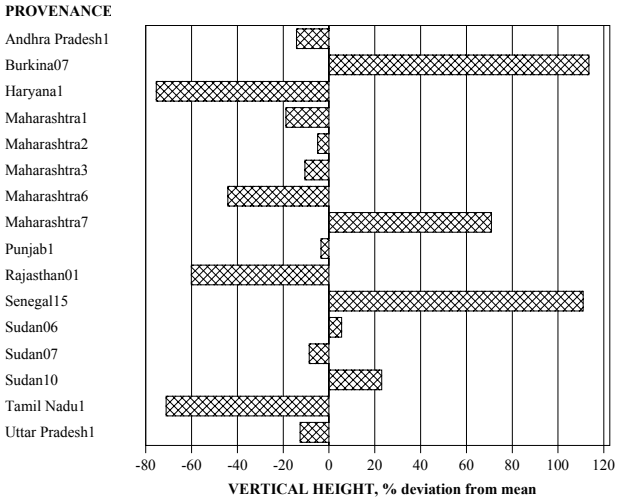

Figure 4. Best linear unbiased predictors (BLUPs) for height in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

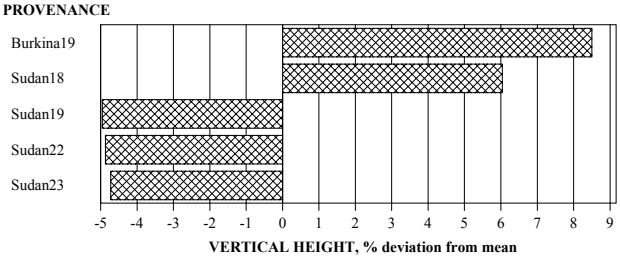

Figure 5. Best linear unbiased predictors (BLUPs) for height in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

4.3 Crown area

The crown area variable indicates the ability of the trees to cover the ground. The character is of importance in shading for agricultural crops, in evaluating the production of fodder and in protection of the soil against erosion.

Statistical analysis

Crown area was analysed on the single tree data set. There was clear variance heterogeneity, and a square root transformation was used. Even after transformation the variance heterogeneity persisted, and a weight statement was used to fulfil the model assumptions. This was the case in the analysis of all data and in the analysis of provenance differences within *A. nilotica*. In the analysis of *A. tortilis*, the square root transformation was sufficient to account for the variance heterogeneity, and no weight statement was used.

Results

The crown areas were modest for most of the provenances (Fig. 6), being close to or below 1 m^2 $tree^{-1}$. The highest provenances had average values up to 6 m^2 $tree^{-1}$, which compares to the 16 m^2 growth space available for each tree. Thus the canopy was still far from closing above the ground. Due to the transformation, the values presented in Fig. 6 are biased towards the low end and should be contemplated as a measure of the relative differences between the provenances and not as absolute values. For example, Senegal15 has an average value of 6.1 m^2 $tree^{-1}$ when calculated on the untransformed value, whereas the back-transformed least square mean is only 5.2 m^2 $tree^{-1}$.

There was no significant difference between the two species (Table 4). On the other hand, the provenances of *A. nilotica* were very variable, and the differences were highly significant. Senegal15, Burkina07 and Maharashtra7 had the largest crown areas, all with large positive expected deviations from the mean value (Fig. 7). The differences between the *A. tortilis* provenances were close to being significant, but this disappeared when accounting for multiple comparisons. In any case, the provenances with the largest predicted deviations from the mean value were Burkina19 and Sudan12 (Fig. 8).

Table 4. Results from analysis of variance of provenance differences of crown area in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 19.2	12.9	0.52	0.48	n.s.
Provenance (species)	19; 294	26.9	24.6	<0.0001	
Block	35; 294	3.2	2.9	<0.0001	
Error	294	1.1			
A. nilotica					
Provenance	15; 140	28.5	24.0	<0.0001	***
Block	35; 140	3.2	3.8	<0.0001	
Error	140	1.2			
A. tortilis					
Provenance	4; 119	1.1	2.2	0.08	n.s.
Block	35; 119	0.6	1.1	0.32	
Error	119	0.5			

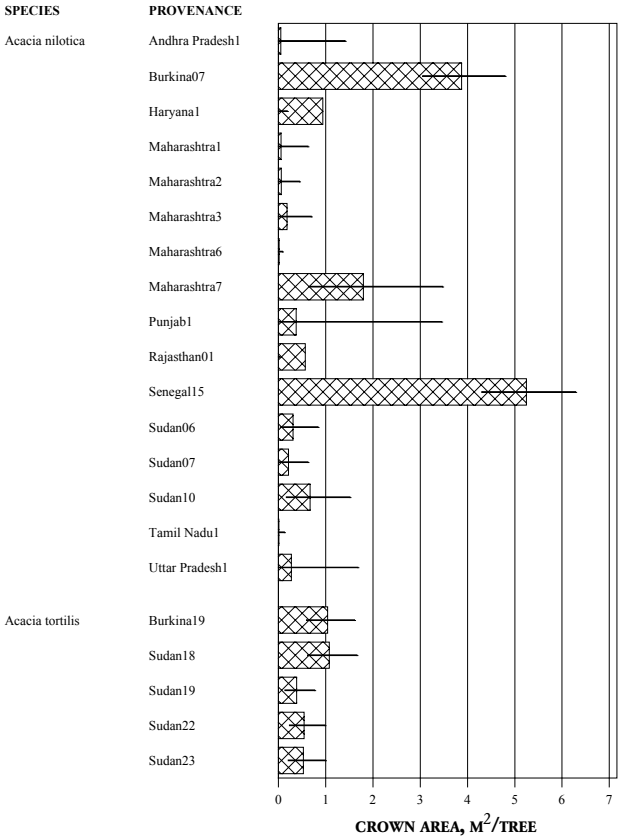

Figure 6. Crown area for the provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Before analysis, the crown area was transformed with the square root, and the values presented are the back-transformed least square means with 95 % confidence limits. Due to the transformation, the confidence intervals are of uneven length.

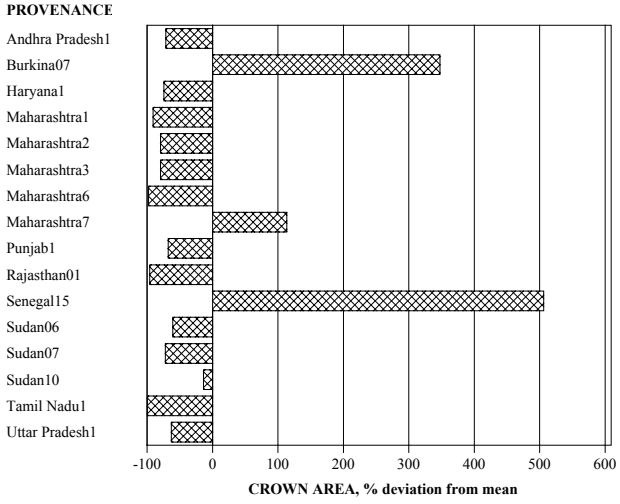

Figure 7. Best linear unbiased predictors (BLUPs) for height in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

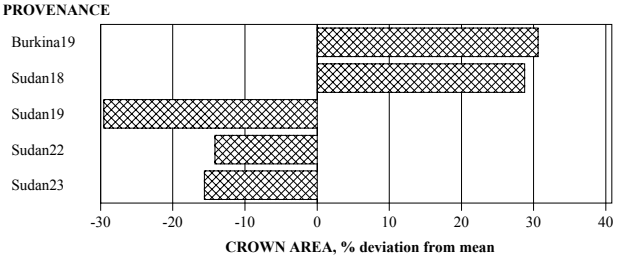

Figure 8. Best linear unbiased predictors (BLUPs) for height in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

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 bushy, whereas trees with only one stem have a more tree-like growth.

Statistical analysis

The analysis of number of stems was performed on the single tree data set. In the analysis of species differences and in the analysis of provenance differences within *A. nilotica*, there were signs of variance heterogeneity, and the data were weighted to ensure a proper distribution of the residuals. After weighting some unexplained outliers occurred, but an analysis without these outliers demonstrated that the results were solid. Therefore the outliers were included in the presented results, acknowledging that their presence may influence the length of the confidence intervals. In the analysis of provenance differences within *A. tortilis* there was no variance heterogeneity, and the analysis was not weighted.

It should be noted that trees below 1 m (in total 115 trees) 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. This also has the effect that there are no estimates for some of the provenances.

Results

The average number of stems varied between one and three (Fig. 9). According to the figure, Maharashtra1 has an average value below 1, but this is an artefact due to the correcting effect of the blocks. The effect of species was significant, meaning that *A. tortilis* could have a larger number of stems than the provenances of *A. nilotica* (Table 5). Note that the significance disappears when accounting for multiple comparisons, which indicate that this conclusion should be interpreted with caution.

There were highly significant differences between the provenances of *A. nilotica*. Within the restriction that the conclusions are only valid for trees above 1 m, Burkina07 and Senegal15 both had large positive deviations from the mean value, indicating that they have more stems than the rest of the provenances (Fig. 10).

The differences between the provenances of *A. tortilis* were smaller and were not significant. The largest numbers of stems were seen in the provenances Sudan22 and Sudan23 (Fig. 11).

Table 5. Results from analysis of variance of provenance differences of number of stems in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 15.6	18.2	5.2	0.04	n.s.
Provenance (species)	13; 183	4.4	3.9	<0.0001	
Block	35; 183	1.7	1.5	0.05	
Error	183	1.13			
A. nilotica					
Provenance	9; 81	6.5	5.0	<0.0001	***
Block	35; 81	2.3	1.8	0.02	
Error	81	1.3			
A. tortilis					
Provenance	4; 67	2.2	1.5	0.22	n.s.
Block	35; 67	1.7	1.1	0.35	
Error	67	1.5			

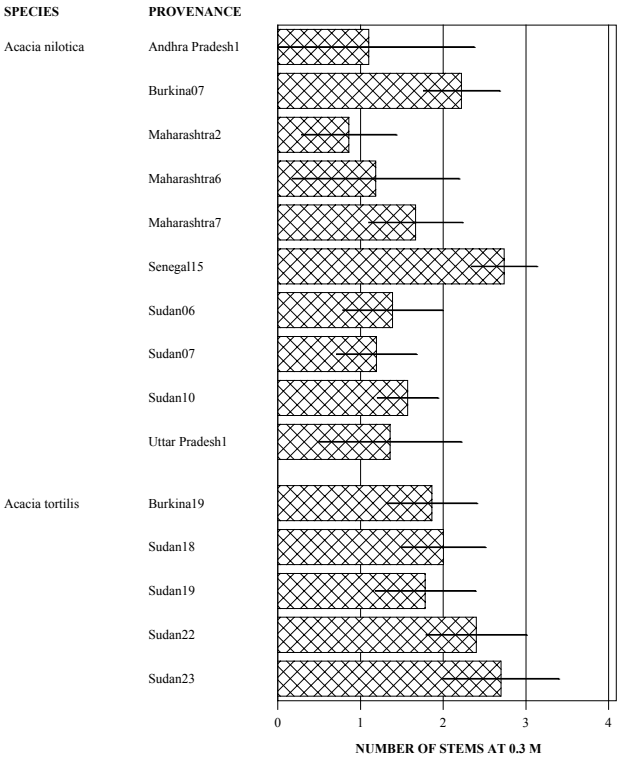

Figure 9. Number of stems for the provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analysis the number of stems was weighted, and the confidence intervals are therefore of unequal lengths. Some provenances are missing because all trees were below 1 m height (see text).

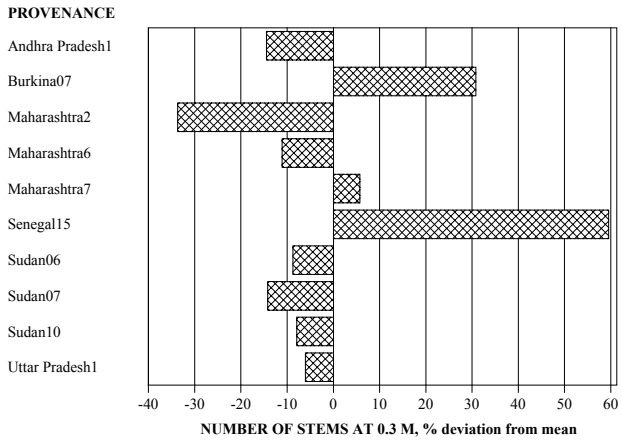

Figure 10. Best linear unbiased predictors (BLUPs) for number of stems in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent. Some provenances are missing because all trees were below 1 m height (see text).

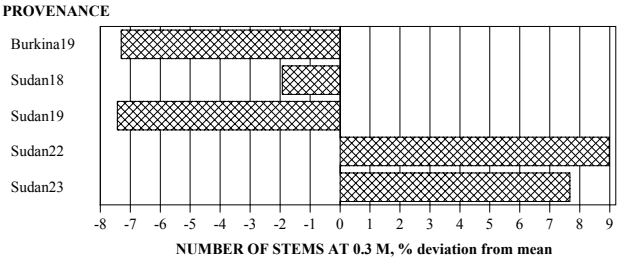

Figure 11. Best linear unbiased predictors (BLUPs) for number of stems in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

4.5 Average basal area

The basal area is often used as a measure of the productivity of stands, since it is correlated with the production of wood. The average basal area 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

Average basal area was analysed on the single tree data set. The analyses of species differences and of provenance differences within *A. nilotica* followed the same pattern. When the analyses were performed on the original data set, there was variance heterogeneity, and a transformation with the natural logarithm was not sufficient to account for this. Therefore the logarithm-transformed data were weighted. In the analysis of *A. tortilis*, a logarithmic transformation was enough to ensure variance homogeneity.

Results

The average basal area varied between 0.1 and 30 cm^2 $tree^{-1}$. Due to the back-transformation, the estimates presented in Fig. 12 are biased towards the low end, but the differences between the provenances are illustrated correctly. As an example, the raw mean for Senegal15 was 29 cm^2 $tree^{-1}$, but the least square mean presented in Fig. 12 is only 19 cm^2 $tree^{-1}$.

The species were not significantly different, but there were significant differences between the provenances of *A. nilotica* (Table 6). Senegal15, Burkina07 and Maharashtra7 were clearly the best with predicted values of up to several hundred percent of the mean value (Fig. 13). The provenances of *A. tortilis* were not signficantly different, but still the predicted values of the best provenances (Burkina19 and Sudan12) were around 20 % of the mean value (Fig. 14).

Table 6. Results from analysis of variance of provenance differences of average basal area in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 19.2	14.2	0.43	0.52	n.s.
Provenance (species)	19; 294	36.9	33.7	<0.0001	
Block	35; 294	4.4	4.1	<0.0001	
Error	294	1.1			
A. nilotica					
Provenance	15; 140	38.2	32.4	<0.0001	***
Block	35; 140	3.9	3.3	<0.0001	
Error	140	1.2			
A. tortilis					
Provenance	4; 119	2.0	2.0	0.10	n.s.
Block	35; 119	1.6	1.6	0.04	
Error	119	1.0			

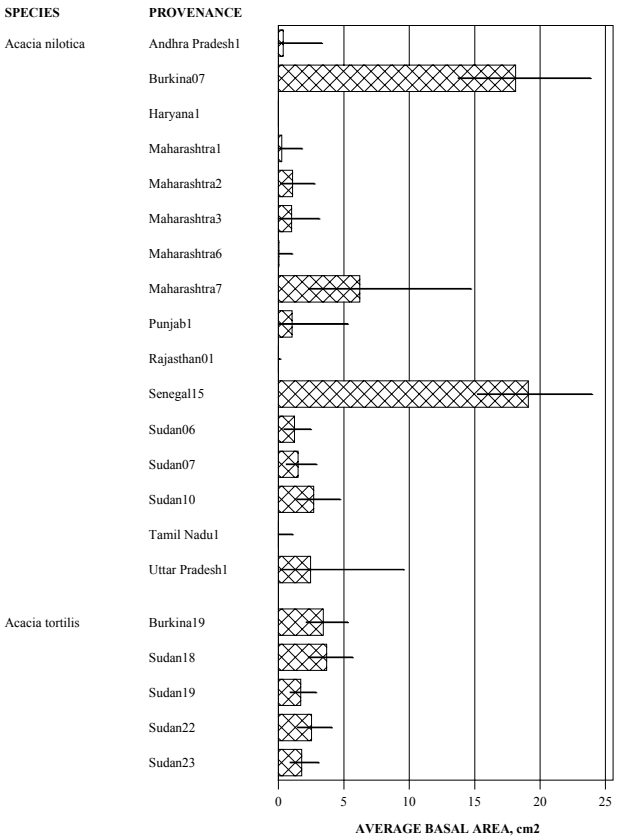

Figure 12. The average basal area for the provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Before analysis, the average basal area was transformed with the natural logarithm. Values presented are back-transformed least square means with 95 % confidence limits. Due to the transformation upper and lower confidence intervals are of unequal length.

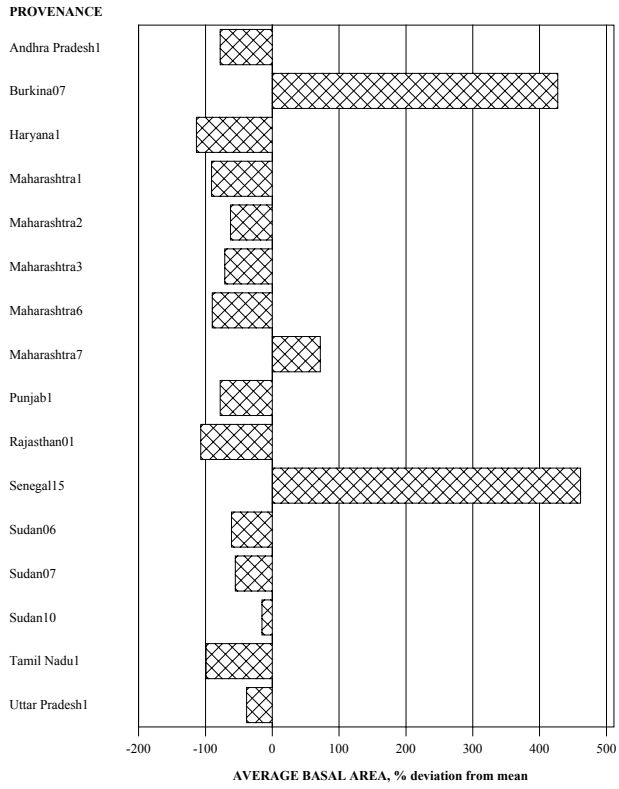

Figure 13. Best linear unbiased predictors (BLUPs) for average basal area in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

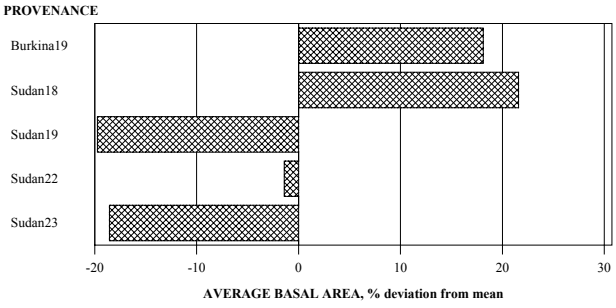

Figure 14. Best linear unbiased predictors (BLUPs) for average basal area in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

4.6 Total basal area

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

Statistical analysis

The analysis of these data is based on the data set with super-blocks. There was clear variance heterogeneity in the data, and weight statements were used to solve the problems in all three analyses.

Results

Again there was a large variation in the data, the total basal areas ranging from just above zero to close to 2 m^2 ha^{-1} (Fig. 15). There was no significant difference between the two species, but the variation between the provenances of *A. nilotica* was highly significant (Table 7). The three best provenances were Senegal15, Burkina07and Maharashtra7, which all had predicted values far above the average (Fig. 16). In *A. tortilis* there were no significant differences between the species, but the predicted values were 12 and 18 % better than the average for the two best provenances, Burkina19 and Sudan12, respectively (Fig. 17).

Table 7. Results from analysis of variance of provenance differences of total basal area in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 24.8	0.004	0.001	0.97	n.s.
Provenance (species)	19; 80	10.3	14.6	<0.0001	
Super-block	4; 80	2.5	3.5	0.01	
Error	80	0.7			
A. nilotica					
Provenance	15; 60	12.3	21.2	<0.0001	***
Super-block	4; 60	1.6	2.8	0.04	
Error	60	0.6			
A. tortilis					
Provenance	4; 16	2.2	1.9	0.16	n.s.
Super-block	4; 16	2.1	1.8	0.18	
Error	16	1.2			

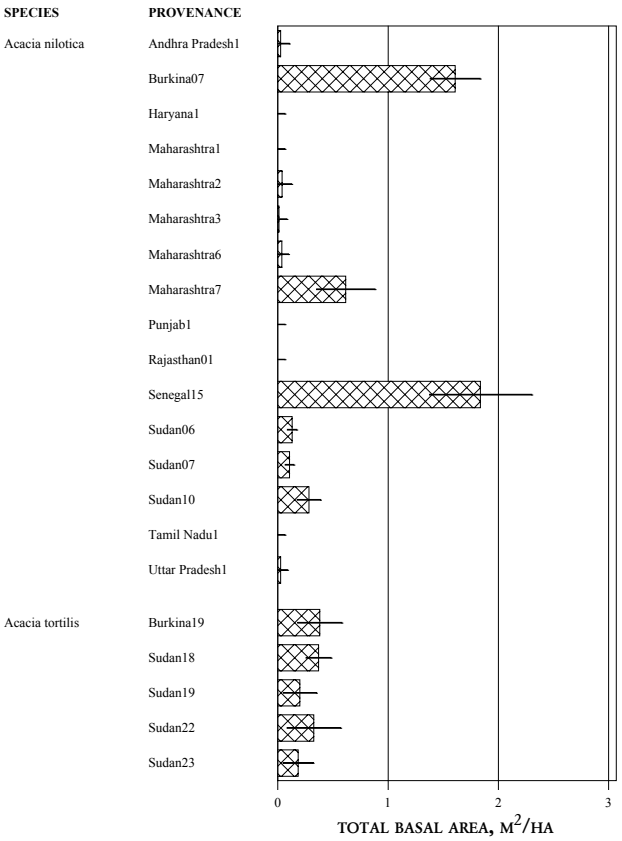

Figure 15. Total basal area for the provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analysis the total basal was weighted, and the confidence limits are therefore of unequal length.

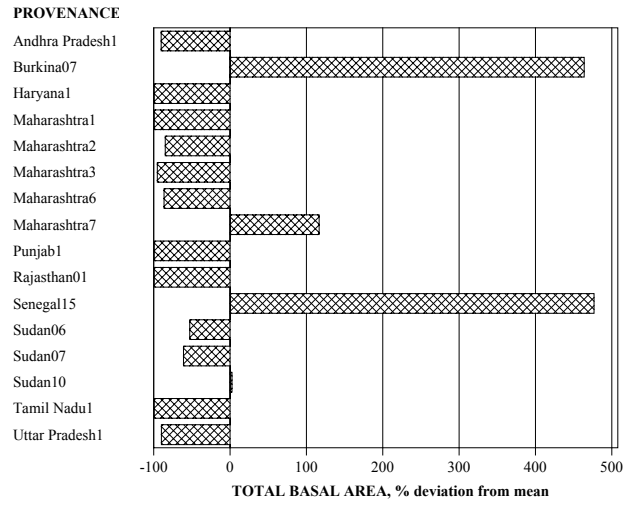

Figure 16. Best linear unbiased predictors (BLUPs) for total basal area in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

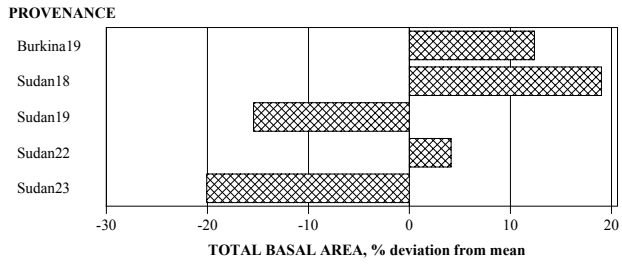

Figure 17. Best linear unbiased predictors (BLUPs) for total basal area in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

4.7 Average dry weight

The average dry weight is comparable to the average basal area 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, 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 average dry weight is thus the best estimate for the production of biomass at the site.

Statistical analysis

The analyses were performed on the single tree data set. There was clear variance heterogeneity, and in all three models a logarithmic transformation was applied. Since diameter had not been measured on trees with heights below 1 m, the value for dry weight for these trees were set to zero. More than 100 trees were treated this way, and this resulted in skew distributions in the analyses. For the analysis of provenance differences in *A. nilotica*, a weight statement improved the distribution of residuals, but in the other two analyses there were no such improvements. Therefore the results from these tests should be treated with caution. Nevertheless, the impression from visual inspections of the data is that the conclusions are correct.

Results

The range for average dry weight was from 0 to just above 7 kg tree^{-1}. Due to the back-transformation the values presented in Fig. 18 are biased, but the graph illustrates the differences between provenances correctly. As an example of the bias, Senegal15 had a raw mean value of 7.3 kg tree^{-1}, but a back-transformed least square mean of only 3.7 kg tree^{-1}.

The effect of species was not significant, but in A. nilotica there were highly significant differences between the provenances (Table 8). The provenances of *A. tortilis* were not significantly different from each other. Overall the largest provenances were Senegal15 and Burkina07, having predicted values of several hundred percent above the average for *A. nilotica* (Fig. 19). The largest provenance of *A. tortilis* was Sudan12 with a predicted value of 23 % above the average for the species (Fig. 20).

Table 8. Results from analysis of variance of provenance differences of average dry weight in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 19.8	16.8	1.1	0.30	n.s.
Provenance (species)	19; 294	18.3	12.7	<0.0001	
Block	35; 294	4.9	3.4	<0.0001	
Error	294	1.4			
A. nilotica					
Provenance	15; 140	37.5	31.6	<0.0001	***
Block	35; 140	3.9	3.3	<0.0001	
Error	140	1.2			
A. tortilis					
Provenance	4; 119	2.7	1.7	0.16	n.s.
Block	35; 119	2.7	1.6	0.03	
Error	119	1.6			

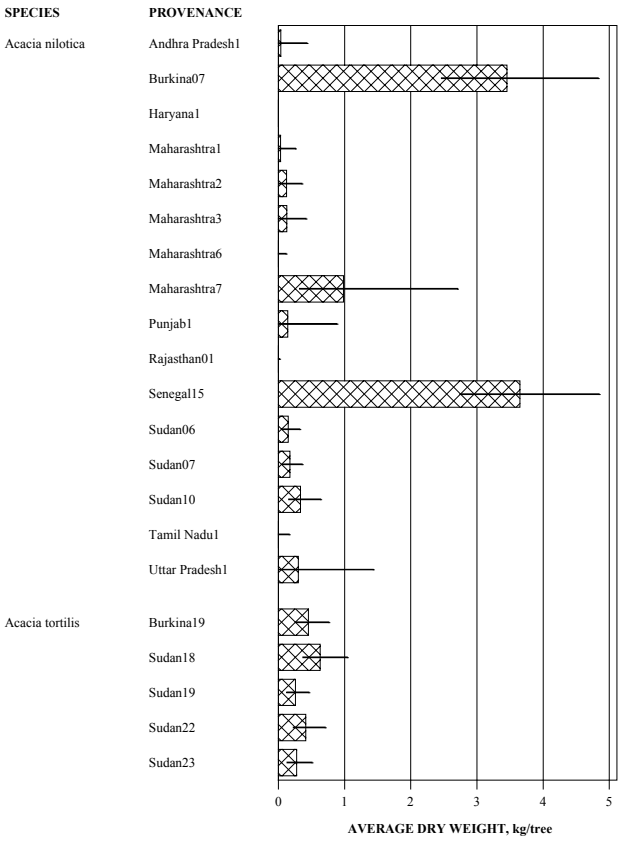

Figure 18. Average dry weight for the provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Before analysis the data were transformed with the natural logarithm, and the values presented are back-transformed least square means with 95 % confidence limits. Due to the transformation the upper and lower confidence intervals are of unequal lengths. Note that the transformation has serious consequences for the size of the averages (see text).

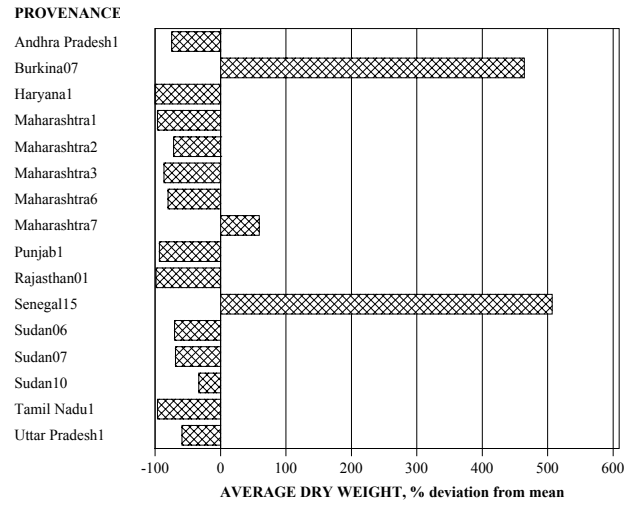

Figure 19. Best linear unbiased predictors (BLUPs) for total basal area in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

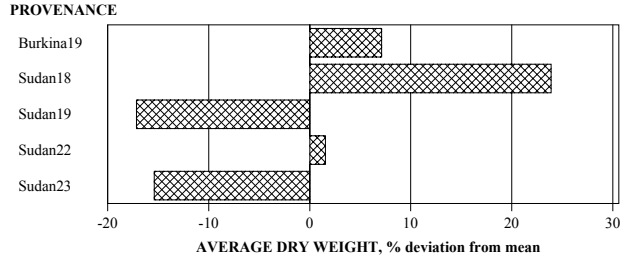

Figure 20. Best linear unbiased predictors (BLUPs) for total basal area in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

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 analyses of total dry weight were performed on the super-block data. In all three analyses a weight statement was used to account for variance heterogeneity. However, the SAS® programme did not accept calculation of BLUP estimates for *A. nilotica*, and to get these estimates a model without weights was applied.

Results

The highest production of dry weight in the trial was 4.6 t ha^{-1}, corresponding to a growth rate of 1.1 t ha^{-1} y^{-1}. On the other hand most of the provenances had obtained dry weights of below 1 t ha^{-1} with some provenances not even reaching 0.1 t ha^{-1} (Fig. 21). By far the largest production was seen in the provenances Senegal15 and Burkina07 of *A. nilotica*, which had predicted values of 400 to 500 % above the average (Fig. 22). There was no significant difference between the species, but there were highly significant differences between the provenances of *A. nilotica* (Table 9). The differences between the provenances of *A. tortilis* were not significant, but the estimated gain by choosing Sudan12 instead of a random selection of the other provenances nevertheless amounted to 18 % (Fig. 23).

Table 9. Results from analysis of variance of provenance differences of total dry weight in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 32.5	0.2	0.1	0.72	n.s.
Provenance (species)	19; 80	5.0	8.1	<0.0001	
Super-block	4; 80	1.4	2.2	0.07	
Error	80	0.6			
A. nilotica					
Provenance	15; 60	5.9	13.0	<0.0001	***
Super-block	4; 60	0.7	1.6	0.18	
Error	60	0.5			
A. tortilis					
Provenance	4; 16	1.5	1.3	0.32	n.s.
Super-block	4; 16	1.8	1.5	0.24	
Error	16	1.2			

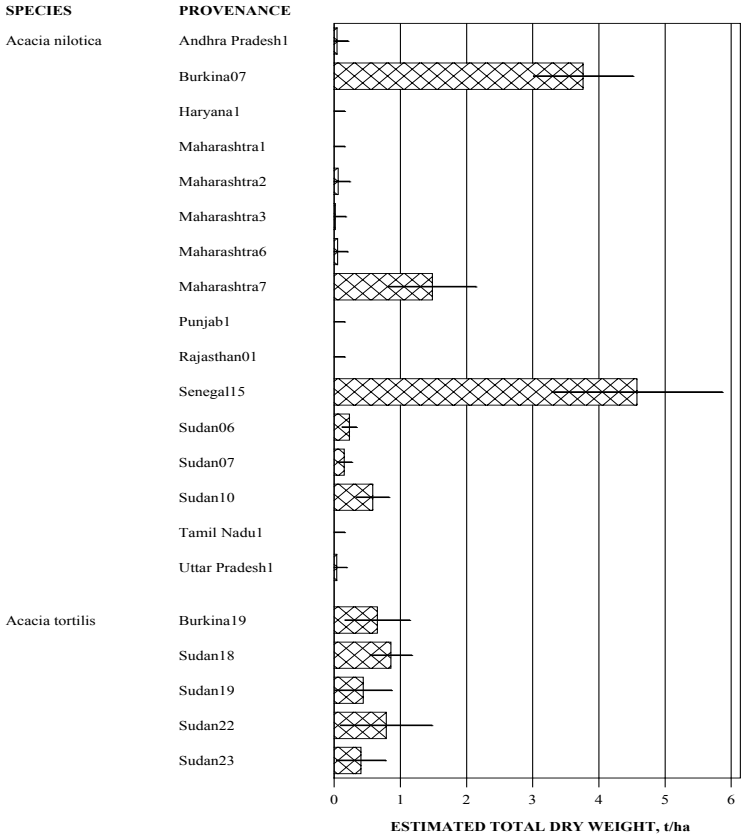

Figure 21. Total dry weight for the provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analysis the total dry weight was weighted, and the confidence intervals are therefore of unequal lengths.

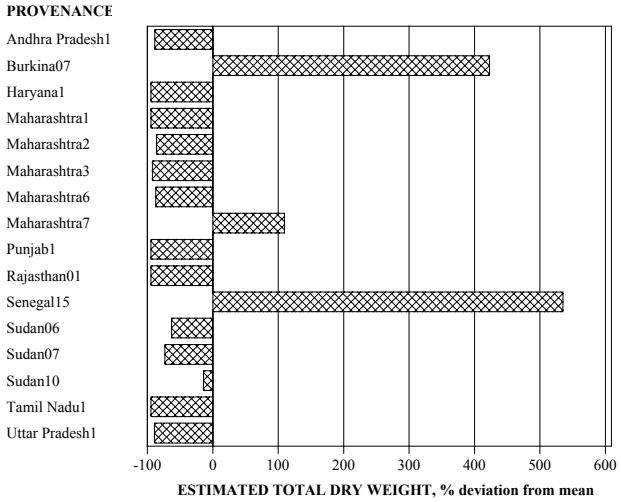

Figure 22. Best linear unbiased predictors (BLUPs) for total dry weight in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

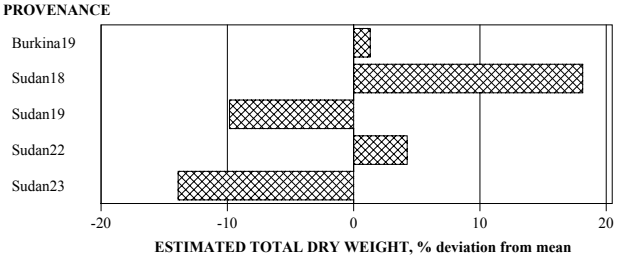

Figure 23. Best linear unbiased predictors (BLUPs) for total dry weight in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in percent.

4.9 Damage

A large proportion of the trees in this trial was damaged by drought stress, and an analysis of the damage score was made. This variable was only recorded on surviving trees, which means that dead trees do not appear in this analysis. Therefore the picture is complete only in combination with the analysis of survival.

Statistical analysis

Damage was recorded on a scale from 0 to 3, where 0 represents a healthy tree, 1 a tree with light damage, 2 a tree with moderate damage, and 3 a tree with severe damage. The evaluation of damage is subjective in that the assessor himself decides what is light, moderate or severe damage. Furthermore, it is a problem that the damages may not be equidistant – i.e. the step from no damage to light damage may not be as important as the step from moderate damage to severe damage. There are different ways to account for this, but the current analysis was performed on the mean values of the damage score for the super-blocks in order to keep things simple.

In the analysis of species differences there was variance heterogeneity between the provenances, and a weight statement was used. This applied also to the analysis of provenance differences within *A. nilotica*, but in the analysis of *A. tortilis* there was no variance heterogeneity, and the data were used without weights.

Results

The average damage scores ranged from close to zero (no damage) to three (all trees damaged) (Fig. 24). Please note that in the Figures 24 – 26 the scale is reverse to the usual, meaning that large values (Fig. 24) or positive values (Figs. 25-26) denote that the provenances are highly damaged.

In the analysis of variance, the difference between species was not significant (Table 10), but there were highly significant differences between the provenances of *A. nilotica*. Especially the provenances Burkina07 and Senegal15 had low damage scores, but also provenances such as Maharashtra3, Maharashtra7, Sudan10 and Uttar Pradesh1 had damage scores below the average (Figs. 24 and 25). Most of the other provenances from India had high damage scores.

There were no differences between the provenances of *A. tortilis*, and the predicted deviations from the mean value were only small (Fig. 26).

Table 10. Results from analysis of variance of provenance differences of damage score in trial 11.

Effect	DF (numerator; denominator)	MS	F-value	P-value	Bonferroni sequential tablewide correction
Test of species differences					
Species	1; 18.9	68.5	3.0	0.10	n.s.
Provenance (species)	18; 57	52.7	52.2	<0.0001	
Super-block	4; 57	4.9	4.8	0.002	
Error	57	1.0			
A. nilotica					
Provenance	14; 37	30.9	30.4	<0.0001	***
Super-block	4; 37	1.8	1.8	0.15	
Error	37	1.0			
A. tortilis					
Provenance	4; 16	0.15	1.2	0.35	n.s.
Super-block	4; 16	0.27	2.2	0.11	
Error	16	0.12			

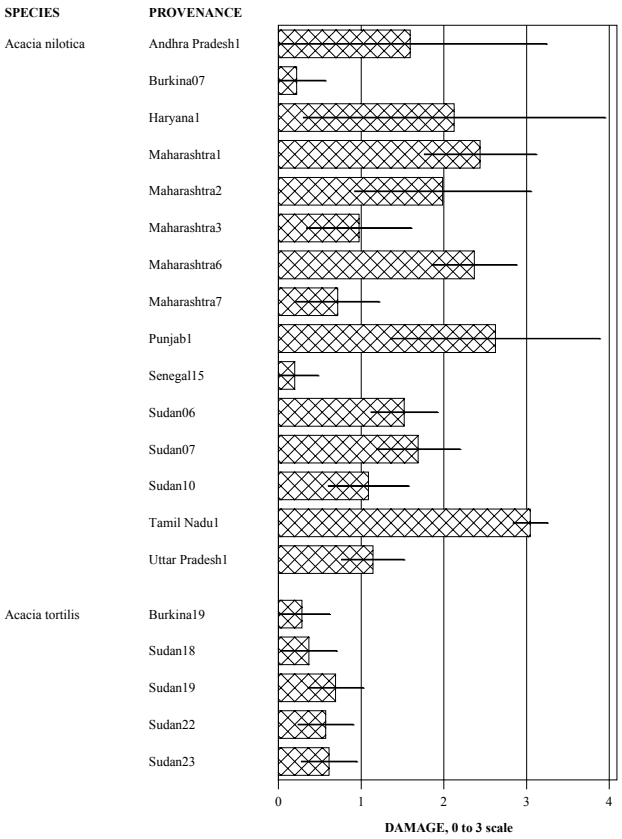

Figure 24. Total damage scores for the provenances in the provenance trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values presented are least square means with 95 % confidence limits. In the analysis the damage scores were weighted, and the confidence intervals are therefore of unequal lengths.

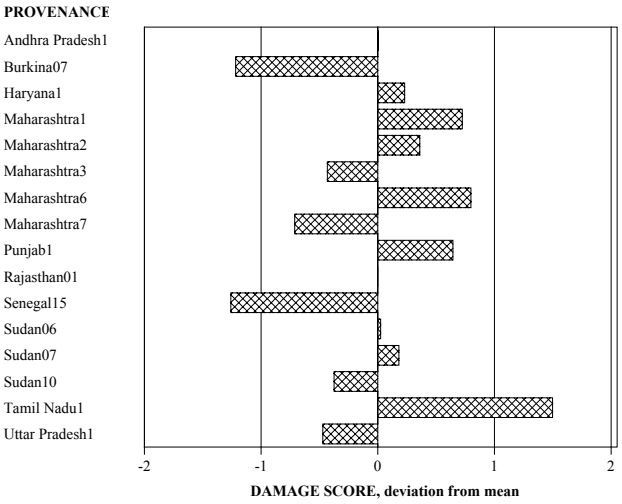

Figure 25. Best linear unbiased predictors (BLUPs) for damage score in the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in units of the damage score scale.

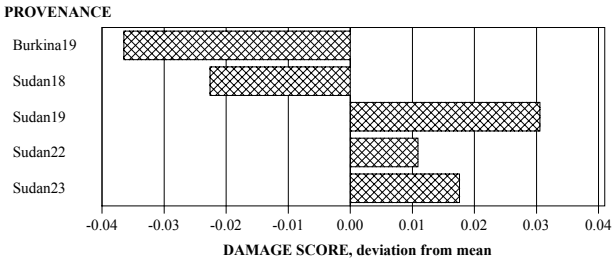

Figure 26. Best linear unbiased predictors (BLUPs) for damage score in the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). Values are presented as deviations from the mean value in units of the damage score scale.

4.10 Multivariate analysis

The multivariate analyses included all the variables analysed in the univariate analyses, except for the number of stems, which was excluded because a large proportion of the trees had not been assessed in this character. The analyses were performed on mean values (calculated as means of sub-blocks) because some variables (e.g. survival) were not available for the single tree data. Since there is no easy way to account for variance heterogeneity in the multivariate analysis, those variables that were transformed in the univariate analyses were also transformed in the multivariate analysis. Therefore crown area was transformed with the square root, and basal area of the mean tree and dry weight of the mean tree were transformed with the natural logarithm. The analyses were performed separately for the two species.

A. nilotica

In the analysis the first two canonical variates were significant, accounting for a total of 91% of the variation (Table 11). Differences between the provenances were highly significant (P-value for Wilk's lambda <0.0001 and P-value for Pillai's trace =0.0009).

The plot of scores for the two first canonical variates is given in Fig. 27. 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.

The provenances appear to cluster in two groups, one containing Burkina07 and Senegal15, and one containing the rest. This would also be expected from the univariate analyses where Burkina07 and Senegal15 always had much larger values than the other provenances. These two provenances are the only representatives of *A. nilotica* subsp. *adansonii*, but are also the only provenances from West Africa.

The three provenances from Sudan (all *A. nilotica* subsp. *tomentosa*) seemed to clump in the one end of the large cluster, but apart from this it was difficult to see other patterns related to geographical origin or variety. Apparently there were significant differences between the provenances from India, but considering the poor growth of these provenances, the differences may not be as pronounced as they would be when growing on a site more apt for these provenances. Since the two West African provenances may have dominated the analysis, another analysis was performed without these. However, the results were basically the same, giving no better resolution of provenance or variety differences, and are therefore not presented.

A. tortilis

In this analysis only the first canonical variate was significant, accounting for 86 % of the variation (Table 11). While none of the univariate analyses provided convincing evidence that the provenances were significantly different (at least not when accounting for multiple comparisons), the multivariate analysis was able to do so. The provenance effect was significant or highly significant, depending on the test (P-value for Wilk's lambda 0.0005, P-value for Pillai's trace=0.03). The canonical variate analysis demonstrated that this was due to the provenance from Burkina Faso, which separated clearly from the provenances from Sudan (Fig. 28). The plot of canonical variates also indicated that there could be differences between the provenances from Sudan. However, when a multivariate analysis was run separately on these provenances, no significance was found (P-value for Wilk's lambda = 0.46, P-value for Pillai's trace=0.42).

Table 11. Results from the canonical variate analyses for *A. nilotica* and *A. tortilis* in trial 11. Only the two first canonical variates are presented.

	A. nilotica		*A. tortilis*	
Canonical variate no.	**1**	**2**	**1**	**2**
Proportion of variation accounted for	0.79	0.12	0.86	0.11
Significance, P-value	<0.0001	0.02	0.0005	0.22
Raw canonical coefficients				
Survival	6.6	6.5	-2.5	24.7
Height	0.78	-0.06	4.6	11.6
Crown area	-1.0	0.78	-5.3	-3.3
Average basal area	2.6	10.0	-35.2	2.9
Total basal area	11.0	-16.2	-3.5	-34.1
Average dry weight	-1.8	-7.2	23.7	3.1
Total dry weight	-3.0	4.6	4.9	4.8
Damage score	0.31	0.19	0.18	-0.10
Standardised canonical coefficients				
Survival	2.0	2.0	-0.3	3.0
Height	0.5	-0.04	1.1	2.7
Crown area	-1.0	0.7	-1.3	-0.8
Average basal area	3.3	12.8	-20.2	1.7
Total basal area	7.6	-11.2	-0.7	-6.8
Average dry weight	-2.9	-11.7	17.7	2.3
Total dry weight	-5.3	8.1	2.5	2.5
Damage score	0.3	0.2	0.07	-0.04
Canonical directions				
Survival	2.6	1.7	-0.08	0.4
Height	4.8	1.8	-0.34	0.8
Crown area	6.0	7.9	-0.36	0.2
Average basal area	9.2	8.3	-0.51	1.8
Total basal area	5.8	-2.3	-0.21	0.7
Average dry weight	11.5	9.7	-0.12	2.4
Total dry weight	14.0	-6.3	-0.10	1.6
Damage score	-6.4	-5.8	0.49	-1.0

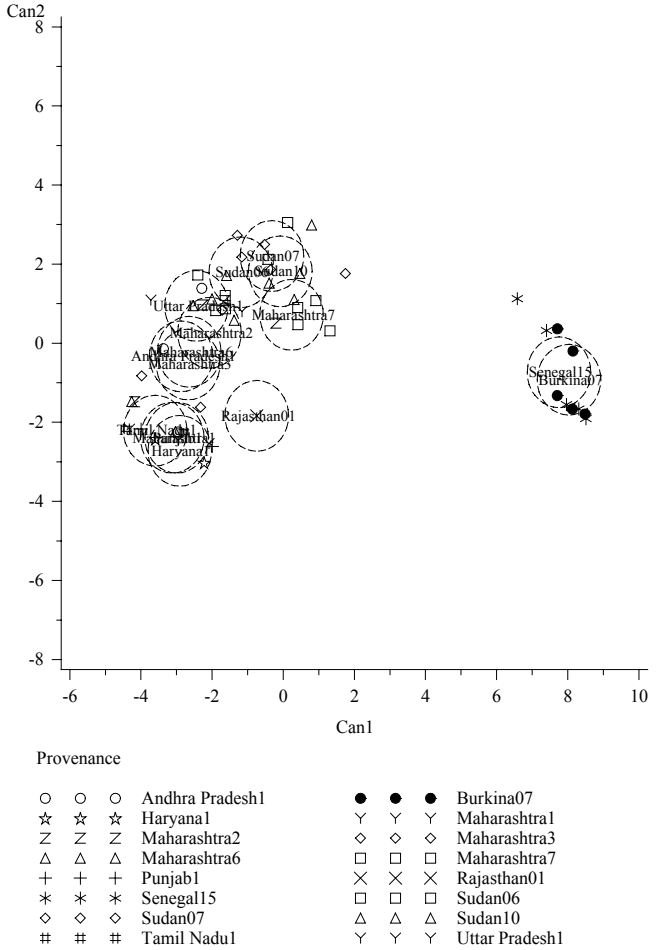

Figure 27. Score plot of the first and the second canonical variate from the canonical variate analysis for the *A. nilotica* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). The variables survival, height, crown area, average basal area, total basal area, average dry weight, total dry weight and damage score were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

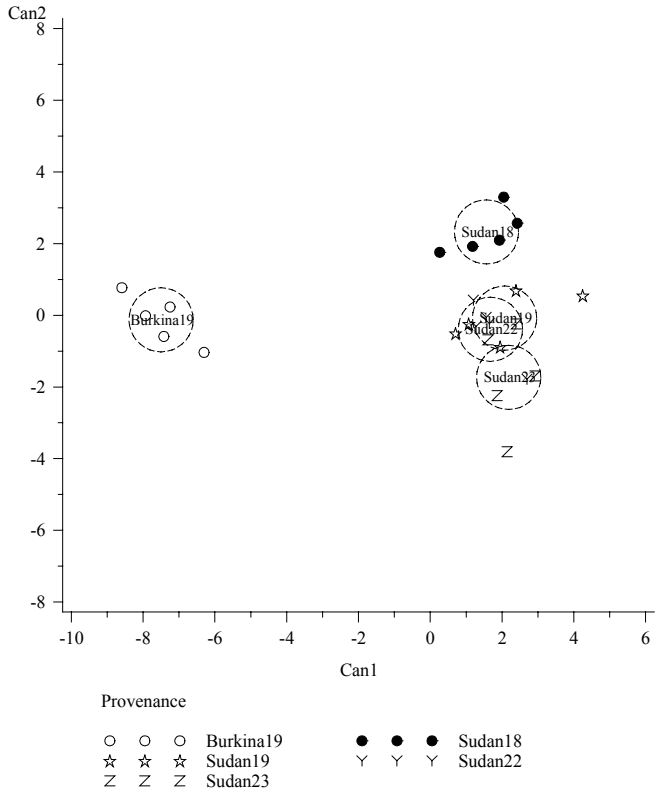

Figure 28. Score plot of the first and the second canonical variate from the canonical variate analysis for the *A. tortilis* provenances in the trial at Gonsé, Burkina Faso (Trial no. 11 in the arid zone series). The variables survival, height, crown area, average basal area, total basal area, average dry weight, total dry weight and damage score were included. Each provenance is marked at the mean value and surrounded by a 95 % confidence region.

5. Discussion and conclusions

Productivity

One year before the establishment of this trial, another trial including provenances of *A. nilotica* and *A. tortilis* was established at Gonsé, and may serve well as a base for comparison (Trial no. 10 in the arid zone series). The provenances in the trial were mainly from Burkina Faso. While the height growth in the two trials was comparable, the productivity levels of the best provenances were lower in the current trial than in trial no. 10. In this trial, the fastest growing provenance of *A. nilotica* had an average annual increment of 1.1 t ha^{-1}, while in trial 10 the best provenance produced 1.6 t ha^{-1} annually. This trend was even more pronounced for *A. tortilis*, which in this trial had total growth rates of 0.2 t ha^{-1} y^{-1} or less, compared to 1.4 t ha^{-1} y^{-1} in trial no. 10. The different productivities between the two trials could be due to differences in the environment, but considering the proximity of the trials it seems more likely that they represent differences in genetic material.

Provenance differences in *A. nilotica*

In the trial a large array of provenances from northern and western India were tested, but none of them seems to be suitable for the conditions at Gonsé. Only one provenance, Maharashtra7, was a little better than the rest, but still the total dry weight was less than half of the provenances Burkina07 and Senegal15. The reason for the poor performance of the Indian provenances is unknown, but it appears that many of them originate from areas with a slightly higher precipitation than that at Gonsé (Table 1). The rather obvious conclusion is that provenances from these areas are not recommended for plantations in areas with similar conditions as Gonsé. Within the group of Indian provenances, there were no obvious differences between the different varieties included (cf. discussion on taxonomy in the introduction).

The provenances from Sudan had a better survival than the Indian provenances, but still Burkina07 and Senegal15 were doing much better, also with respect to dry weight production. However, the provenances originate from a rather small area within Sudan, and it would be premature to conclude that *A. nilotica* from Sudan cannot grow satisfactory at Gonsé.

Even though Burkina07 and Senegal15 were the best provenances, the higher production levels in trial no. 10 (see above) indicate that some provenances may have an even better growth at Gonsé.

Provenance differences in *A. tortilis*

Although the univariate tests did not show any convincing differences, the multivariate test demonstrated that the provenance Burkina19 was significantly different from the provenances from Sudan. Even though Burkina19 is from the extreme north of Burkina Faso, it still origins in a climate with 100-200 mm more annual rainfall than the provenances from Sudan.

It is important to notice that all provenances from Sudan in this trial (included those of *A. nilotica*) originate from the Sahelian vegetation zone and must be expected to be adapted to dryer conditions than is found at Gonsé, which lies in the Sudanian zone (White 1981). Most likely an important factor for the productivity of the trees is that there is a match to the rainfall patterns at the site.

Giving provenance recommendations on the basis of this trial is difficult, recalling that the production of dry weight is much higher in the nearby trial 10. However, it would be interesting to investigate in more detail whether there are any north-south gradients in the adaptation of provenances to the site, as well as to include more local provenances.

6. References

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

Brenan, J.P.M. 1983. Manual on taxonomy of *Acacia* species. Food and Agriculture Organisation of the United Nations, Rome, 47 pp.

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

CNSF 1999. Data from the climate station in Gonsé, Burkina Faso. Unpublished.

DFSC 1994. Preliminary assessment report – Trial no. 11. *Acacia nilotica* provenance trial, Gonsé, Burkina Faso. Danida Forest Seed Centre.

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.

Falconer, D. S. and T.F.C. Mackay. 1996. Introduction to quantitative genetics. 4th edition, Longman, UK, 464 pp.

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

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, R.D. Wolfinger. 1996. SAS® System for mixed models. SAS Institute Inc., Cary, NC, 633 pp.

Pigeonnière, A.L. and S. Jomni (eds.). 1998. Les Atlas Jeune Afrique: Burkina Faso. Les Editions J.A., Paris, 62 pp.

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. Statistical analysis of data from provenance trials. DFSC Guidelines and Technical Notes 63. Danida Forest Seed Centre, Humlebæk, 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.

White, F. 1981. Vegetation map of Africa. Unesco, Paris (3 maps).

White, T.L. and G.R. Hodge. 1989. Predicting breeding values with applications in forest tree improvement. Kluwer Academic Publishers, Dordrecht, 367 pp.

Annex 1. Description of the trial site

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

Annex 2. Seedlot numbers

Species codes: aniada=*A. nilotica* subsp. *adansonii*, aniincu=*A. nilotica* subsp. *indica* var. *cupressiformis*, aniinja=*A. nilotica* subsp. *indica* var. *jaquemontii*, *A. nilotica* subsp. *indica* var. *vediana*, anito=*A. nilotica* subsp. *tomentosa*, atora=*A. tortilis* subsp. *raddiana*. Data supplied by seed collecting institutions, except for [1]rainfall data (before 1970) from Pigeonnière and Jomni (1998). The plot numbers refer to the seedlots in the map of the trial, see annex 3.

Seedlot numbers				**Provenance information**							
Provenance identification	**DFSC**	**Country of origin**	**Plot**	**Species code**	**Origin**	**Country**	**Latitude**	**Longitude**	**Altitude (m)**	**Rainfall (mm)**	**No. of mother trees**
Andra Pradesh1	1072/82		11	aniinja	Nizamabad (Adilabad)	India	18 40 N	78 06 E	381	1086	
Burkina07		957 CNSF)	5	aniada	Debel	Burkina Faso					
Haryana1	1441/84		8	aniincu	Nornaul Singhana Road, Bhiwani, Hissar	India	28 03 N	76 07 E	250	714	
Maharashtra1	1070/82		10	aniinja	Pune	India	18 32 N	73 51 E	559	715	25
Maharashtra2	1071/82		14	aniinve	Pune	India	18 32 N	73 51 E	559	715	25
Maharashtra3	1075/82		12	aniinja	Akola	India	20 42 N	77 02 E	282	877	
Maharashtra6	1084/82		15	aniinve	Akola	India	20 42 N	77 02 E	282	877	
Maharashtra7	1222/83		6	aniincu	Paratwara	India	20 56 N	77 47 E	370	974	
Punjab1	1432/84		7	aniincu	Bikaner Canal Road, Ferozepure	India	30 15 N	74 10 E	200	537	
Rajasthan01	1217/83		16	aniinve	Pali (Desuri), Rajasthan	India	24 -- N	73 35 E	382	400	6
Senegal15	1202/83	83/766	4	aniada	Gabgal, Louga	Senegal	15 20 N	15 30 W			32
Sudan06	1053/82	5/1982	21	anito	Hariri Forest (Singa)	Sudan	13 05 N	33 56 E	430	588	25
Sudan07	1054/82	6/1982	1	anito	Khartoum Forest	Sudan	15 36 N	32 33 E	330	165	25
Sudan10	1552/85		2	anito	Ed Duim, White Nile	Sudan	14 30 N	32 10 E		270	
Tamil Nadu1	1078/82		13	aniinja	Vellayur Attur, Salem	India	11 39 N	78 10 E	278	965	25
Uttar Pradesh1	1069/82		9	aniinja	Bawain Forest Block, Etawah (Mainpuri),	India	26 45 N	79 00 E	157	762	26
Burkina19		920 (CNSF)	3	atora	Markoye	Burkina Faso		.		450[1]	
Sudan18	1240/84	6/1983	17	atora	Elbashiri Oasis, Northern Kordofan	Sudan	13 48 N	30 12 E	400	300	25
Sudan19	1335/84	5/1984	18	atora	El Geteina, Ed Duim	Sudan	14 -- N	32 05 E	500	300	24
Sudan22	1550/85	1/1985	19	atora	Ed Duim, White Nile	Sudan	14 30 N	32 10 E		270	
Sudan23	1642/86	3	20	atora	Esh Sheik Essidig, Ed Duim	Sudan	15 30 N	32 15 E	400	300	29

Annex 3. Layout of the trial

Layout of super-blocks (bold lines), blocks (thin lines) and position of individual trees in the field. The super-blocks are numbered 1-5 from the bottom.

The numbers correspond to the seedlots given in Annex 2.

N

Block Y	Tree y	Block No.								Block No.								Tree y	Block Y
	45	17	4	21	9	20	3	16	**15**	**30**	16	5	19	3	15	13	14	**36**	13	15	18	42	
15	44	10	7	12	14	8	18	6			21	6	2	12	18	8	4		9	21	8	41	
	43	1	2	15	11	13	19	5			1	17	9	10	11	7	20		4	17	5	40	
	42	5	20	11	9	21	1	17	**14**	**29**	7	18	3	19	9	5	16		12	1	11	39	14
14	41	6	16	10	18	12	3	15			4	8	15	10	21	2	14		6	16	7	38	
	40	13	4	7	3	2	14	19			12	13	6	20	17	11	1		3	14	2	37	
	39	6	12	10	18	7	21	9	**13**	**28**	19	5	3	7	20	10	16		19	10	20	36	
13	38	20	5	11	4	16	17	13			21	9	15	4	14	8	18	**35**	2	12	18	35	
	37	3	1	14	8	15	19	2			17	2	12	6	11	1	13		1	5	17	34	
	36	9	6	20	18	1	11	10	**12**	**27**	5	14	1	19	15	18	8		6	13	19	33	
12	35	5	14	17	4	3	19	15			9	12	13	4	6	11	17		14	20	3	32	12
	34	12	7	8	16	2	13	21			7	21	2	3	16	20	10		7	4	8	31	
	33	16	8	12	15	20	4	6	**11**	**26**	1	16	6	21	19	4	8		21	11	15	30	
11	32	9	14	19	5	17	11	7			17	5	13	11	12	18	3		10	16	9	29	
	31	18	13	2	10	3	21	1			14	10	15	9	20	2	7	**34**	11	6	15	28	
	30	11	6	19	12	1	8	16	**10**	**25**	19	5	7	13	8	11	9		16	3	7	27	
10	29	9	10	17	3	18	15	2			4	18	20	6	17	16	12		14	8	18	26	
	28	13	5	14	4	21	7	20			1	15	21	2	14	10	3		5	21	20	25	10
	27	5	16	8	11	7	20	17	**9**	**24**	16	6	21	19	1	4	8		10	13	19	24	
9	26	6	15	13	19	9	14	4			17	5	13	11	12	18	3		9	12	1	23	
	25	1	18	2	10	12	3	21			14	10	15	9	20	2	7		2	17	4	22	
	24	11	6	19	12	8	1	16	**8**	**23**	19	5	7	13	8	11	9	**33**	2	17	11	21	
8	23	9	10	17	3	18	15	2			4	18	20	6	17	16	12		5	13	3	20	
	22	13	5	14	4	21	7	20			1	15	21	2	14	10	3		8	1	6	19	
	21	5	16	8	11	7	20	17	**7**	**22**	6	18	3	17	21	9	15		7	14	18	18	7
7	20	6	15	13	19	9	14	21			5	19	10	16	4	1	20		16	19	20	17	
	19	4	1	18	2	10	12	3			14	7	8	11	2	13	12		4	10	21	16	
	18	12	6	4	2	13	18	19	**6**	**21**	16	5	6	17	4	19	9		15	9	12	15	
6	17	8	1	3	5	7	11	21			11	15	1	10	2	12	13	**32**	10	20	4	14	
	16	9	17	15	10	14	20	16			20	7	8	14	3	18	21		7	15	12	13	
	15	2	16	5	18	21	1	17	**5**	**20**	11	10	3	17	13	2	14		8	19	3	12	
5	14	8	12	19	20	6	15	3			7	20	4	19	8	12	21		21	1	6	11	5
	13	7	11	4	10	9	13	14			15	6	16	9	5	1	18		18	13	2	10	
	12	9	12	21	3	16	11	18	**4**	**19**	5	20	11	9	21	1	17		17	11	5	9	
4	11	6	7	15	4	5	20	10			6	16	10	18	12	8	15		14	16	9	8	
	10	1	8	2	13	17	14	19			13	4	7	3	2	14	19	**31**	4	13	17	7	
	9	1	12	3	16	6	10	8	**3**	**18**	14	5	8	17	18	6	19		11	10	1	6	
3	8	20	2	18	5	17	13	21			13	4	9	7	15	3	20		9	19	5	5	
	7	13	7	19	11	14	4	9			21	12	2	1	16	11	10		18	6	16	4	3
	6	17	16	3	19	6	8	4	**2**	**17**	3	14	16	4	15	10	17		12	14	7	3	
2	5	21	7	1	2	9	20	5			19	11	20	9	2	21	6		3	2	21	2	
	4	11	18	14	13	12	15	10			1	12	18	13	5	8	7		15	20	8	1	
	3	7	20	2	13	5	21	15	**1**	**16**	10	6	11	7	9	4	1		1	2	3	Tree x	
1	2	1	17	9	12	4	18	16			12	19	1	20	17	18	3						
	1	3	6	11	19	10	14	18			2	5	16	21	14	8	1						
		1	2	3	4	5	6	7			1	2	3	4	5	6	7	**Tree x**					

1 2 3 Block X

Annex 4. Super-block data set

Damage score was measured on a scale from 0 (no damage) to 3 (severe damage)
Species codes: aniada=*A. nilotica* subsp. *adansonii*, aniincu=*A. nilotica* subsp. *indica* var. *cupressiformis*, aniinja=*A. nilotica* subsp. *indica* var. *jaquemontii*, *A. nilotica* subsp. *indica* var. *vediana*, anito=*A. nilotica* subsp. *tomentosa*, atora=*A. tortilis* subsp. *raddiana*.

Super-block	Provenance	Species	Survival	Height	Crown area	Number of stems	Basal area, mean tree	Total basal area	Dry weight mean tree	Total dry weight	Damage score
			Proportion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	tons ha^{-1}	
1	Burkina07	aniada	1.00	2.20	3.63	3.14	21.8	1.36	4.46	2.79	0.00
1	Senegal15	aniada	1.00	2.69	8.28	2.57	45.8	2.86	12.51	7.82	0.00
1	Haryana1	aniincu	0.00					0.00		0.00	
1	Maharashtra7	aniincu	0.57	2.00	3.78	1.33	20.1	0.72	4.44	1.59	1.00
1	Punjab1	aniincu	0.00					0.00		0.00	
1	Andhra Pradesh1	aniinja	0.00					0.00		0.00	
1	Maharashtra1	aniinja	0.14	0.30			0.0	0.00	0.00	0.00	3.00
1	Maharashtra3	aniinja	0.00					0.00		0.00	
1	Tamil Nadu1	aniinja	0.14	0.20			0.0	0.00	0.00	0.00	3.00
1	Uttar Pradesh1	aniinja	0.14	1.10	1.04	1.00	9.6	0.09	1.50	0.13	1.00
1	Maharashtra2	aniinve	0.00					0.00		0.00	
1	Maharashtra6	aniinve	0.43	0.77	0.95	1.00	2.8	0.07	0.41	0.11	1.67
1	Rajasthan01	aniinve	0.00					0.00		0.00	
1	Sudan06	anito	0.57	0.85	1.04	3.00	2.8	0.10	0.45	0.16	1.50
1	Sudan07	anito	0.57	0.70	0.77	1.67	3.9	0.14	0.52	0.18	2.25
1	Sudan10	anito	0.57	1.70	7.31	1.75	14.2	0.51	2.82	1.01	0.75
1	Burkina19	atora	0.86	1.65	4.51	2.50	14.1	0.75	2.88	1.54	0.33
1	Sudan18	atora	0.86	1.17	1.20	2.00	4.4	0.24	0.88	0.47	0.67
1	Sudan19	atora	1.00	0.73	1.89	1.75	2.3	0.14	0.43	0.27	1.00
1	Sudan22	atora	0.71	0.96	2.05	2.67	5.3	0.24	1.26	0.56	0.40
1	Sudan23	atora	0.71	1.04	1.59	3.33	6.1	0.27	1.38	0.62	0.20
2	Burkina07	aniada	1.00	2.19	4.32	2.14	28.8	1.80	6.45	4.03	0.14
2	Senegal15	aniada	1.00	2.20	7.24	4.29	35.4	2.21	8.65	5.40	0.43
2	Haryana1	aniincu	0.00					0.00		0.00	
2	Maharashtra7	aniincu	0.57	2.33	7.35	2.33	33.8	1.21	8.99	3.21	0.50
2	Punjab1	aniincu	0.00					0.00		0.00	
2	Andhra Pradesh1	aniinja	0.00					0.00		0.00	
2	Maharashtra1	aniinja	0.00					0.00		0.00	
2	Maharashtra3	aniinja	0.29	0.45			0.0	0.00	0.00	0.00	1.50
2	Tamil Nadu1	aniinja	0.00					0.00		0.00	
2	Uttar Pradesh1	aniinja	0.00					0.00		0.00	
2	Maharashtra2	aniinve	0.14	0.80			0.0	0.00	0.00	0.00	3.00
2	Maharashtra6	aniinve	0.14	0.70			0.0	0.00	0.00	0.00	3.00
2	Rajasthan01	aniinve	0.00					0.00		0.00	
2	Sudan06	anito	0.29	1.40	2.69	2.00	14.1	0.25	2.79	0.50	2.50
2	Sudan07	anito	0.57	1.00	2.41	2.00	5.3	0.19	0.86	0.31	2.00
2	Sudan10	anito	0.57	1.23	5.52	2.00	14.8	0.53	3.77	1.35	1.50
2	Burkina19	atora	0.86	1.10	2.44	1.75	6.2	0.33	0.99	0.53	0.83

Super-block	Provenance	Species	Survival	Height	Crown area	Number of stems	Basal area mean tree	Total basal area	Dry weight mean tree	Total dry weight	Damage score
			Propor-tion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	tons ha^{-1}	
2	Sudan18	atora	0.71	1.36	2.31	2.20	10.6	0.47	2.54	1.13	0.60
2	Sudan19	atora	0.86	0.88	1.22	1.67	2.5	0.13	0.49	0.26	0.83
2	Sudan22	atora	0.71	1.52	2.77	3.40	18.4	0.82	4.94	2.20	0.40
2	Sudan23	atora	0.71	0.96	1.02	1.75	2.1	0.10	0.35	0.15	1.20
3	Burkina07	aniada	1.00	2.20	6.42	2.00	30.2	1.89	7.33	4.58	0.43
3	Senegal15	aniada	1.00	1.97	5.58	2.29	25.7	1.60	5.75	3.60	0.43
3	Haryana1	aniincu	0.14	0.50			0.0	0.00	0.00	0.00	3.00
3	Maharashtra7	aniincu	0.57	1.48	6.49	2.00	22.5	0.80	5.56	1.99	0.75
3	Punjab1	aniincu	0.14	1.20	0.38	1.00	0.0	0.00	0.00	0.00	2.00
3	Andhra Pradesh1	aniinja	0.29	0.95	0.38	1.00	0.5	0.01	0.04	0.01	0.00
3	Maharashtra1	aniinja	0.00					0.00		0.00	
3	Maharashtra3	aniinja	0.00					0.00		0.00	
3	Tamil Nadu1	aniinja	0.00					0.00		0.00	
3	Uttar Pradesh1	aniinja	0.00					0.00		0.00	
3	Maharashtra2	aniinve	0.14	1.30	0.28	1.00	4.2	0.04	0.51	0.05	3.00
3	Maharashtra6	aniinve	0.43	0.67	1.54	2.00	2.8	0.07	0.41	0.11	2.67
3	Rajasthan01	aniinve	0.00					0.00		0.00	
3	Sudan06	anito	0.71	1.20	4.15	1.00	4.0	0.18	0.72	0.32	1.60
3	Sudan07	anito	0.57	0.93	0.94	1.00	1.4	0.05	0.15	0.05	0.75
3	Sudan10	anito	0.57	1.43	1.52	1.50	7.6	0.27	1.27	0.45	0.25
3	Burkina19	atora	1.00	1.30	2.22	2.00	7.2	0.45	1.12	0.70	0.00
3	Sudan18	atora	1.00	1.24	2.05	2.50	8.4	0.52	2.01	1.25	0.29
3	Sudan19	atora	0.71	1.52	2.51	2.75	11.3	0.51	2.86	1.28	1.20
3	Sudan22	atora	1.00	0.86	1.89	1.75	4.0	0.25	0.84	0.52	1.14
3	Sudan23	atora	0.71	1.02	2.03	3.00	4.0	0.18	0.85	0.38	0.80
4	Burkina07	aniada	1.00	2.14	6.13	2.29	30.7	1.92	8.58	5.36	0.25
4	Senegal15	aniada	1.00	2.00	6.49	2.86	27.4	1.71	7.43	4.65	0.13
4	Haryana1	aniincu	0.13	0.70			0.0	0.00	0.00	0.00	1.00
4	Maharashtra7	aniincu	0.25	1.10	2.99	1.00	2.9	0.04	0.38	0.06	1.00
4	Punjab1	aniincu	0.13	0.20			0.0	0.00	0.00	0.00	3.00
4	Andhra Pradesh1	aniinja	0.25	1.35	8.30	1.00	7.6	0.12	1.35	0.21	1.50
4	Maharashtra1	aniinja	0.13	1.00	0.16		0.0	0.00	0.00	0.00	2.00
4	Maharashtra3	aniinja	0.13	1.70	1.89	1.00	7.3	0.06	1.05	0.08	0.00
4	Tamil Nadu1	aniinja	0.00					0.00		0.00	
4	Uttar Pradesh1	aniinja	0.38	0.87	2.14	2.00	2.0	0.05	0.26	0.06	1.00
4	Maharashtra2	aniinve	0.38	1.37	2.26	1.00	5.7	0.13	0.97	0.23	1.00
4	Maharashtra6	aniinve	0.25	0.95	1.33	1.00	2.0	0.03	0.24	0.04	1.50
4	Rajasthan01	aniinve	0.25	0.75			0.0	0.00	0.00	0.00	3.00
4	Sudan06	anito	0.25	1.70	4.71	1.00	5.5	0.09	0.90	0.14	1.00
4	Sudan07	anito	0.63	1.26	1.44	1.00	3.3	0.13	0.49	0.19	1.20
4	Sudan10	anito	0.38	1.20	0.62	1.00	2.5	0.06	0.27	0.06	1.33

Super-block	Provenance	Species	Survival	Height	Crown area	Number of stems	Basal area mean tree	Total basal area	Dry weight mean tree	Total dry weight	Damage score
			Proportion	m	m^2 $tree^{-1}$	no. $tree^{-1}$	cm^2 $tree^{-1}$	m^2 ha^{-1}	kg $tree^{-1}$	tons ha^{-1}	
4	Burkina19	atora	1.00	1.00	1.67	1.60	2.9	0.18	0.40	0.25	0.25
4	Sudan18	atora	1.00	1.24	2.56	1.86	6.9	0.43	1.72	1.08	0.00
4	Sudan19	atora	1.00	1.01	1.23	1.00	1.4	0.09	0.21	0.13	0.25
4	Sudan22	atora	1.00	0.91	1.34	2.50	2.9	0.18	0.55	0.35	0.63
4	Sudan23	atora	0.88	1.17	2.78	2.75	5.5	0.30	1.37	0.75	0.00
5	Burkina07	aniada	1.00	2.19	3.49	1.57	17.2	1.07	3.26	2.04	0.29
5	Senegal15	aniada	1.00	1.91	3.57	1.71	12.8	0.80	2.27	1.42	0.00
5	Haryana1	ani-incu	0.00					0.00		0.00	
5	Maharashtra7	ani-incu	0.43	2.23	2.93	1.67	11.5	0.31	2.10	0.56	0.33
5	Punjab1	ani-incu	0.00					0.00		0.00	
5	Andhra Pradesh1	aniinja	0.14	0.40			0.0	0.00	0.00	0.00	3.00
5	Maharashtra1	aniinja	0.14	0.80			0.0	0.00	0.00	0.00	2.00
5	Maharashtra3	aniinja	0.29	0.60			0.0	0.00	0.00	0.00	1.50
5	Tamil Nadu1	aniinja	0.14	0.60			0.0	0.00	0.00	0.00	3.00
5	Uttar Pradesh1	aniinja	0.00					0.00		0.00	
5	Maharashtra2	aniinve	0.43	0.67	0.64	1.00	1.0	0.03	0.12	0.03	1.00
5	Maharashtra6	aniinve	0.14	0.30			0.0	0.00	0.00	0.00	3.00
5	Rajasthan01	aniinve	0.00					0.00		0.00	
5	Sudan06	anito	0.71	0.74	0.95	1.00	0.6	0.03	0.06	0.03	1.00
5	Sudan07	anito	0.57	0.65	0.50	2.00	0.7	0.03	0.08	0.03	2.25
5	Sudan10	anito	0.71	0.94	0.60	1.00	0.9	0.04	0.09	0.04	1.60
5	Burkina19	atora	0.86	1.28	1.61	1.40	3.4	0.18	0.43	0.23	0.00
5	Sudan18	atora	1.00	1.06	1.66	1.75	2.9	0.18	0.55	0.34	0.29
5	Sudan19	atora	0.86	1.05	1.31	2.00	2.5	0.13	0.45	0.24	0.17
5	Sudan22	atora	1.00	0.97	2.04	2.50	2.4	0.15	0.47	0.29	0.29
5	Sudan23	atora	1.00	0.86	1.49	2.00	1.1	0.07	0.20	0.12	0.86