INCO-DC: International Cooperation With Developing Countries (1998 – 2002)

Contract number: ICA4-CT-2002-10017

Third Annual Report: 1/12/2004 – 30/11/2005

Title: Utilisation of wastewater for fuel and fodder production and environmental and social benefits in semi-arid, peri-urban zones of sub-Saharan Africa.

Project homepage: www.bioman.ceh.ac.uk/ubenefit.htm

Key words: peri-urban, wastewater recycling, irrigation, fodder, fuelwood, microsymbionts

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Utilisation of wastewater for fuel and fodder production and environmental and social benefits in semi-arid, peri-urban zones of sub-Saharan Africa.

Third Annual Report: 1/12/2004 – 30/11/2005

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Compiled by J. Wilson

Summary Report

Since the beginning of the contract, the results achieved are as follows:

Work package 1 Water treatment and irrigation
Sites for waste water treatment plants and irrigation systems were identified and the systems have been constructed in Burkina Faso, Mali and Niger. Progress was slower than planned for a variety of reasons, including delays to obtaining permits for construction, delays associated with importation and shipping of components and delays in purchase of expensive items due to cashflow problems. Now that construction is complete, staff have been trained in how to use and maintain the systems and they are fully functioning in each country. Soil and water analyses have been conducted and the irrigation sites were characterised in advance of tree planting.

WP2 Tree growth and management
Nb. There are strong linkages with WP4
Tree species with potential for use in irrigated conditions in each country were identified and experimental designs for these trials were produced. Some common species are going to be used in all three countries. Nursery screening trials were conducted and plants were then outplanted to the irrigation sites. Due to the delays in Wp1, trials are running behind schedule. However, as expected, trees are growing quickly under the irrigated conditions. In Mali, 5 months after planting, *Leucaena leucocephala* was 2.5 m tall, with a diameter of 12 mm. The indigenous species, *Khaya senegalensis* was the smallest, but nonetheless was performing well with a height of approximately 1 m and diameter of 9 mm.

WP3 Tree water use and soil water status
Staff in Mali and Niger have both received training in the use of sapflow, soil water and associated measuring equipment. In Mali, considerable variation between tree species in soil water use has been noted, together with differential effects according to the inoculation history of the plants. Data are still being analysed, but *Acacia angustissima* appears to have particularly high water use when it has been inoculated. This is supported by observations in the nursery that plants of this species require 4 waterings a day to prevent wilting, compared with 2 waterings for other species. Observations of differential effects of symbiont inoculation on tree water use are unexpected and require further study. Species such as *Khaya senegalensis* and *Gliricidia sepium* appear to be more conservative in their use of water. Optimal use of irrigated systems requires species which can grow well with the supplied water, but which do not waste it.

WP4 Microsymbionts and N fixation
Working in controlled glasshouse conditions, using sterised soil media, the UK partner has identified considerable variation in effectiveness of different mycorrhizal strains on different tree species. After the intial screening phase, selected tree species were taken on to the second phase of the study in which plant response to simulated irrigation water is being measured. Uninoculated plants are growing very poorly irrespective of whether they are receiving the simulated irrigation water or not. The response of inoculated plants to irrigation varies with inoculant and tree species.

However nursery and field studies in Mali, Niger and Burkina Faso are giving much less clear results. These differences may be linked to the use of unsterile soil for tests in these countries and the consequent colonisation of roots by wild-type mycorrhizal fungi and rhizobia. Further investigation, including critical evaluation of root infection rates and soil inoculum potential is required. Results by partner 3 indicate that inoculant rhizobia are showing poor persistence in the field in Mali. This supports previous observations by partner 6 on nodules from Niger. Further studies are needed to confirm these observations and understand the causes of them.

WP 5 Economics and quality of produce
Questionnaires have been developed by the partner in Niger, in collaboration with other partners. Niger and Burkina Faso have now completed their surveys, which have generated a considerable amount of useful information about fuelwood and fodder supplies. For Ouagadougou, it is estimated that 225,004 tons of fuelwood and 6708 tons of charcoal per year are transported to the city. The average price of firewood was approximately 21 F CFA per kg, and charcoal was 60 – 110 F CFA per kg. Sellers can achieve a substantial income from sales.
The large quantities of fuel imported into Ouagadougou highlight the pressure on fuel resources. This is further indicated by the observations in Niger, where wood cutters cut an average of 27 steres per month, and each village can have 40 – 80 woodcutters.

WP6 Soil and plant nutrition
Nutrient contents of irrigation water and soil nutrient status are being monitored at each site. Some analyses have been conducted and more are in progress.

WP7 Planting stock quality
Studies have been conducted in Burkina Faso and Mali.

Using various parameters of planting stock quality (shoot: root ratio, sturdiness quotient, Dickson's Quality Index), considerable variations in quality have been identified, between species, production methods and between partners testing the same species. The plants which have been assessed have now been planted out to the field sites where their subsequent performance will be assessed relative to these assessments of quality. These data will inform nursery managers of the optimal plant characteristics for planting in irrigated sites.

WP8 Pest monitoring and management
So far, monitoring has been conducted by partner 3 in Mali, who has examined nematode populations in the nursery and at the field site after planting. Results indicate that there is no correlation between nursery observations on roots of different species and subsequent field observations.

Scientific Annual Report

Following delays reported last year in the setting up of the water treatment and irrigation facilties, a considerable amount of progress has been made in 2005. However, in recognition of the delays to planting which arose from the problems of installing these facilties, a 12- month project extension has been agreed.

Progress since the start of the project is as follows:

Work package 1 Water treatment and irrigation

All the treatment facilties (in Niger, Mali and Burkina Faso) have been installed and are up and running. The SCP subcontractor revisited all sites in late 2005 and provided advice and training (to project and non-project staff) on all aspects to ensure correct and sustainable operation of the facilities and their maintenance. Information has been disseminated to local stakeholders. The completion of these facilites has enabled progress to be made on many other work-packages which were dependent upon the field facilities. With the permission of the EU project manager, partner 2 has been also receiving training under an international programme on sustainable sanitation.

Deliverables 1.1, 1.2, 1.3 achieved. 1.4 is on target
On-going: Monitoring of human health aspects and quality of treated water will be an ongoing process in each country

Work package 2 Tree growth and management

Following selection of the tree species and design of the trials in previous years, trials are now in progress at the irrigation sites in Mali and Niger, examining the growth of various tree species with and without mycorrhizal and rhizobial inoculation. The trees are growing well. In Mali, 5 months after planting, the best performing species was *Leucaena leucocephala* (2.5 m tall, with a diameter of 12 mm). Several other species were also performing very well. Although the performance of indigenous *Khaya senegalensis* (1.0 m tall, 9 mm diameter) was not as good as the exotic species, it nevertheless performed very well under the irrigated conditions compared with its normal growth rate. Although trees have also been planted in Niger, their growth data has not yet been analysed.

Deliverables: 2.1 trials established, assessments ongoing,
Incomplete/ not started: 2.2 – 2.5 work on these deliverables will commence when the trees have reached the appropriate size

Work package 3 Tree water use and soil water status

Following training in Niger in 2004, sapflow and associated equipment were shipped from Niger to Mali in 2005, and scientists of IER provided with training by CEH staff. Scientists in both countries are now confident in use of the techniques, and data on tree water use and soil water have been collected. This year, in Mali, substantial differences between species, and effects of inoculation treatment have been observed. The effect of inoculation is unexpected and requires further replication. Plant nutrient status, which can affect stomatal control, may be a factor which requires further investigation. Differences in leaf morphology (finely divided leaves vs. entire leaves)

are also likely to have substantial effects due to effects on leaf temperature and boundary layers.
Despite irrigation, the soil shows considerable drying in the top 30 cm, where root activity of young trees is likely to be most intense. Between 30 and 40 cm, there is a transition to a more more water-retentive clayey soil, which is reflected by much higher levels of soil water.

Deliverables: 3.1 work in progress, 3.3 training complete in Niger and Mali, not yet done in Burkina (planned for 2006)
Not started 3.2 – data is now accumulating and work will commence in 2006

Work package 4 Microsymbionts and N fixation

Studies by partner 1 in glasshouse conditions have highlighted the variation in effectiveness (growth promotion) of different mycorrhizal strains with different tree species. In 2005, with additional nutrients from simulated 'irrigation water', inoculated plants grow much better than those which are not inoculated, indicating the importance of symbionts in facilitating nutrient uptake even when nutrients were supplied in solution. However nursery and field studies in Mali, Niger and Burkina Faso are giving much less clear results. These differences may be linked to the use of unsterile soil for tests in these countries and the consequent colonisation of roots by wild-type mycorrhizal fungi and rhizobia. Further investigation, including critical evaluation of root infection rates and soil inoculum potential is required. Results by partner 3 indicate that inoculant rhizobia are showing poor persistence in the field, which requires further examination.

Deliverables: 4.1 in progress, 4.2 – 4.8 in progress. NB it was agreed last year, that field measurements of N-fixation, (deliverable 4.6, would not be done)

Work package 5 Economics and quality of produce

Niger and Burkina Faso have completed their surveys, which have generated a considerable amount of useful information about fuelwood and fodder supplies. For Ouagadougou, it is estimated that 225,004 tons of fuelwood and 6708 tons of charcoal per year are transported to the city. The average price of firewood was approximately 21 F CFA per kg, and charcoal was 60 – 110 F CFA per kg. Sellers can achieve a substantial income from sales.
The large quantities of fuel imported into Ouagadougou highlight the pressure on fuel resources. This is further indicated by the observations in Niger, where wood cutters cut an average of 27 steres per month, and each village can have 40 – 80 woodcutters.

Deliverables: 5.1 complete for Niger and Burkina, not for Mali, 5.2 a video has been produced in Mali, 5.3 in progress
Not started: deliverables 5.4 – 5.8 depend upon progress of the irrigation trials.

Work package 6 Soil and plant nutrition

Analyses are in progress and will be repeated as required.

Deliverables: 6.1, 6.2 ongoing
Not started: 6.3 – 6.5 progress depends on tree growth in the irrigated plots.

Work package 7 Planting stock quality

Using various parameters of planting stock quality, considerable variations in quality have been identified, between species, production methods and between partners testing the same species. The plants which have been assessed have now been planted out to the field sites where their subsequent performance will be assessed relative to these assessments of quality. These data will inform nursery managers of the optimal plant characteristics for planting in irrigated sites.

Deliverables: 7.1 completed
Ongoing: 7.2 progress depends on tree growth on the irrigated plots

Work package 8 Pest monitoring and management

Nursery and field observations have been conducted in Mali. So far, no significant pest problems have been observed.

Deliverables: 8.1 in progress
Ongoing: 8.2, 8.3 will be conducted as field trials progress

Technical problems

All water treatment plants are now up and running. The visit by SCP was very useful in highlighting the importance of continual maintenance and in discussion of day- to– day management. Repairs in Burkina Faso were necessary as the treatment tanks were leaking.

Plans for next year

The project has been extended by one year, to 2007. In 2006, there will be a considerable emphasis on planting and evaluation of field trials, and linking this with the socioeconomic studies. Studies of symbionts will continue, especially to understand the links between soil inoculum potential and plant performance, and to analyse the effectivenss and persistence of inoculants. Sap flow studies will commence in Burkina Faso. Seedling quality will be correlated with subsequent performance in the field. Pest monitoring activities will increase. Chemical analyses will continue. Water use data will be worked up with assessments of total leaf area to develop a model of water use and irrigation.

Management Annual Report

Organisation of the collaboration
Management of the collaboration is through annual coordination meetings and also by regular email communication with all participants, and scientific visits and exchanges between partners.

The annual coordination meeting was held in Burkina Faso (Figure 1) (minutes and programme attached – see Annex 1), and all partners were represented.

Figure 1 Group photo of the participants at the third progress meeting visiting a water treatment plant in Burkina Faso.

All work packages were extensively discussed and problems aired. Due to the delays and problems with setting up the water treatment plants, it was agreed that a project extension of 12 months would be requested. This has now been granted.

Francoise Bouroulet of the subcontractor SCP visited Niger, Mali and Burkina Faso to evaluate the set up of the water treatment plants in each country, and provide training to project staff and other interested groups.

Exchanges

Mr Fallaye KANTE registered for Ph. D degree at ISFRA in Mali, spent 6 months in the laboratory of IRD in Sénégal. Results obtained are contained in the report of the University of Mali.

Management problems

Cash-flow problems have put pressure on the project in a number of ways, as cash for repair and replacement of essential equipment has not always been readily available and funding for staff salaries and even visits to field sites and maintenance of security has been extremely tight for some partners. At IER Mali, one of the project staff, responsible for the fieldwork has left due to the difficulties of paying salaries on time. On two occasions in 2005, CEH advanced money to IER. CEH administration was concerned about doing this, because of the risk which it exposes them to, but were persuaded on this occasion.

Partner 1 Centre for Ecology and Hydrology, UK

K Ingleby, RC Munro, and J Wilson

Summary of Progress

- A simulated irrigation experiment has shown significant effects of inoculation on plant growth, and differences in the effects of different mycorrhizal inoculants. Uninoculated plants were not responsive to addition of nutrients.
- Training in the installation and use of equipment to measure sapflow, meteorological conditions, leaf area and soil water was provided to IER in Mali

Work package 3: Tree Water–use and soil water status

CEH staff (Julia Wilson and Bob Munro) spent 2 weeks training IER staff in Mali during April – May 2005. They provided hands-on training, with information sheets on setup and use of sapflow and meterological equipment, including use of data loggers and data processing, together with use of soil moisture equipment and use of scanners and software for leaf area determination. Equipment had previously been in use in Niger and some small repairs were required. Some changes have been made to the methods used for measuring leaf area to take advantage of free windows software which is now available (previous software was expensive and required knowledge of DOS). Most repairs were conducted in Mali, but some cables required new connectors and these were returned to the UK for fitting. Further details are provided in partner 2's report.

Workpackage 4: Glasshouse experiment at CEH: summary of progress

The irrigation experiment which was set up in the glasshouse in October 2004 using trees of *Senna siamea*, *Khaya senegalensis* and *Leucaena leucocephala* inoculated with *Glomus mosseae*, *Glomus etunicatum* or an uninoculated control, has continued. Irrigation treatments, supplying additional nutrients, were applied from January 2005 onwards using a modified Ingestad's nutrient solution containing increased levels of N (132 mg/l – x 2 normal) Zn (1.46 mg/l – x100 normal) and Cu (0.157 mg/l – x 10 normal). In addition to the normal supply of water, initially, each tree received 250 ml/week of nutrient solution or water, increased to 500 ml/week in March 2005 as the trees increased in size.

Monthly non-destructive measurements (stem diameter) were continued during the year and showed that inoculated trees of all 3 species continued to grow better than the uninoculated trees (Figure 2- Figure 4). None of the uninoculated trees showed any response to nutrient addition, whereas responses of the inoculated trees differed according to the tree species and fungal inoculant. *S. siamea* trees inoculated with both fungi showed improved growth with nutrient addition (Figure 2), while only *K. senegalensis* trees inoculated with *G. mosseae* responded to nutrient addition (Figure 3). Growth of *L. leucocephala* showed little response to nutrients with either inoculant (Figure 4).

These results also suggest that *S. siamea* and *K. senegalensis* show greater mycorrhizal dependency than *L. leucocephala*, as uninoculated trees of *L. leucocephala* continued to grow better than uninoculated trees of *S. siamea* and *K. senegalensis*. Inoculated *S. siamea* and *K. senegalensis* trees also showed a greater growth response to irrigation than those of *L. leucocephala*, which could indicate that their mycorrhizas were more effective in the uptake of nutrients from the irrigation water, or that the N-fixing *L. leucocephala* was less responsive to increased levels of N in the soil.

Figure 2 Growth of inoculated and uninoculated *Senna siamea* with either water or water containing additional nutrients ('irrigation'), with and without mycorrhizal inocula.

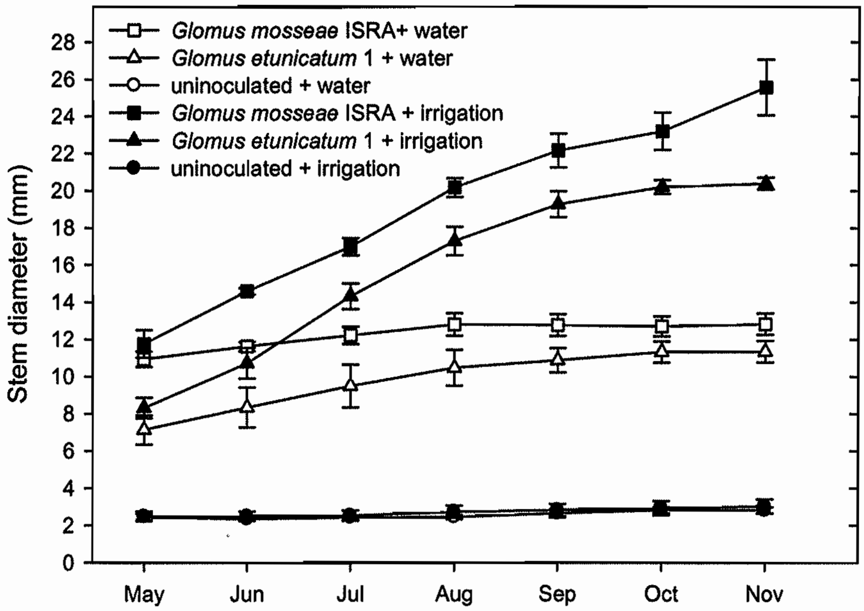


Figure 3 Growth of inoculated and uninoculated *Khaya senegalensis* with either water or water containing additional nutrients ('irrigation'), with and without mycorrhizal inocula.

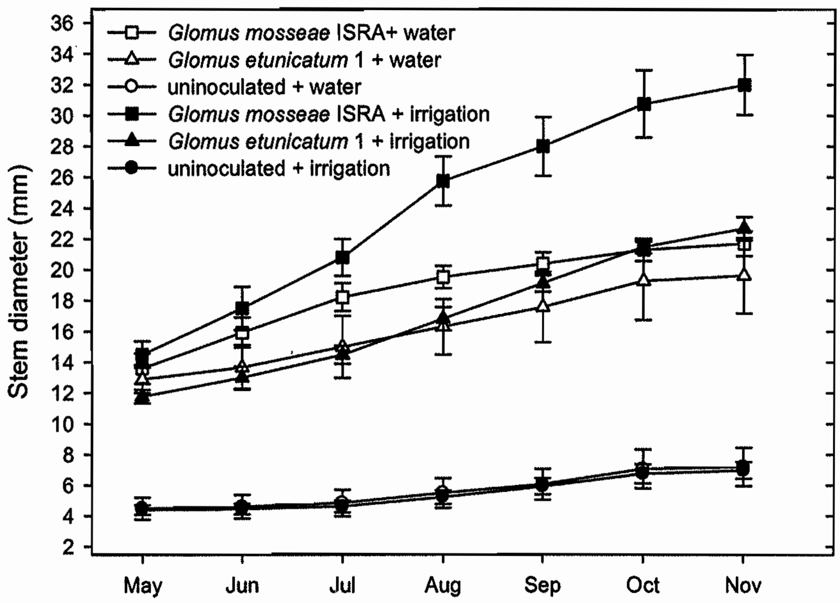
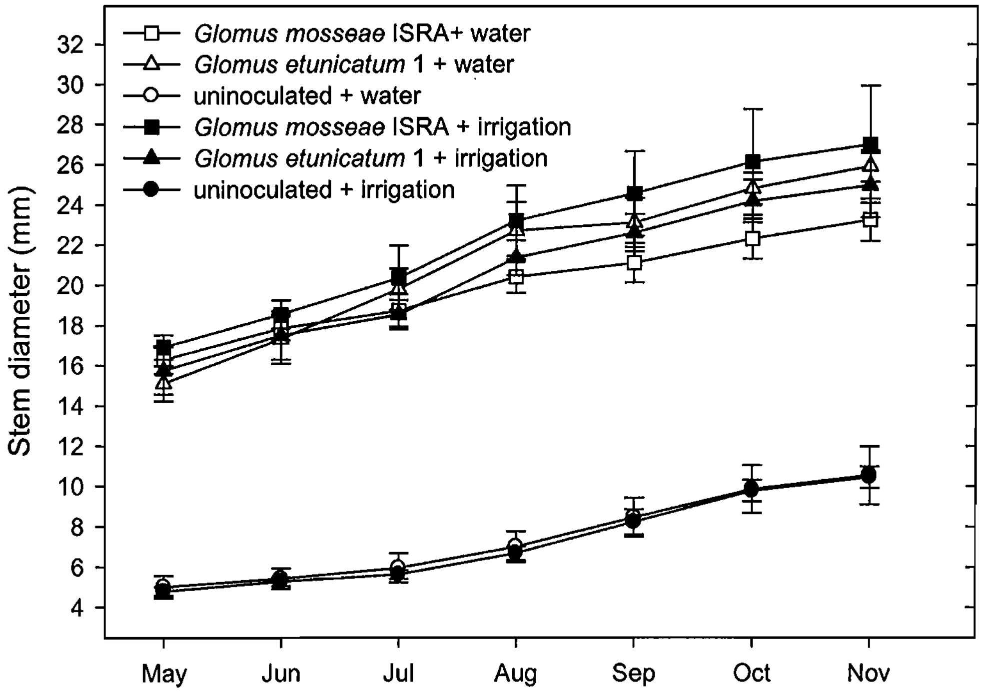
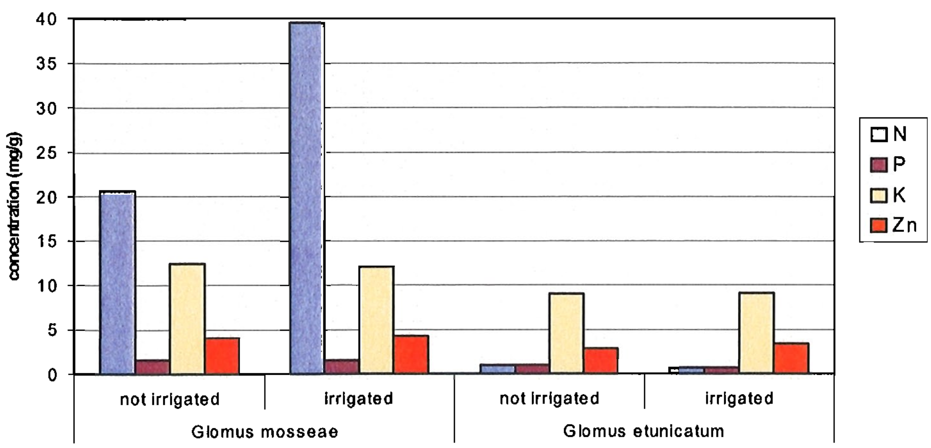


Figure 4 Growth of inoculated and uninoculated *Leucaena leucocephala* with either water or water containing additional nutrients ('irrigation'), with and without mycorrhizal inocula.



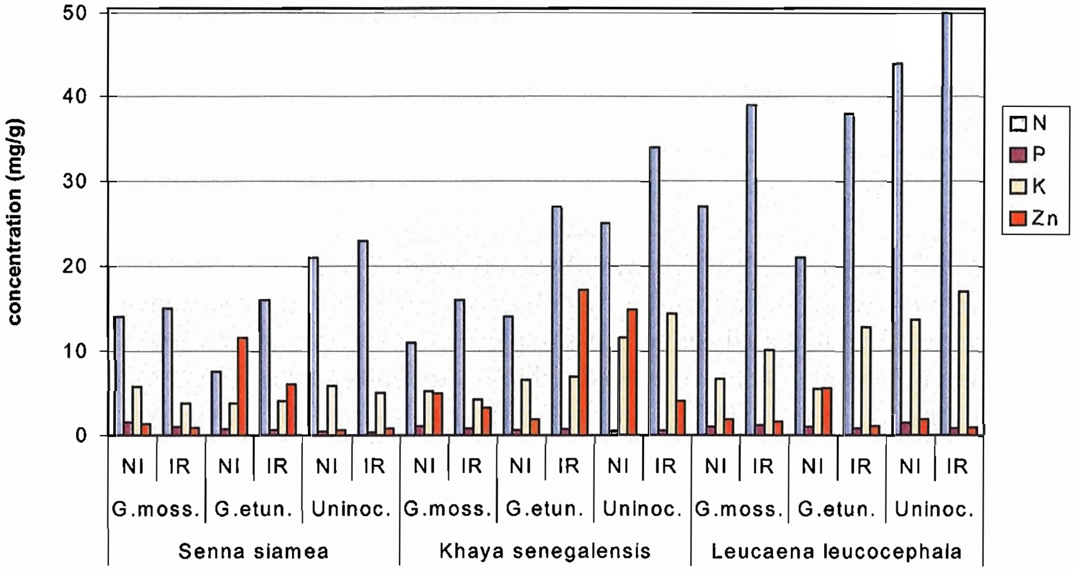
In April 2005, extensive leaf fall was observed on all *S. siamea* trees inoculated with *G. etunicatum*, whereas no leaf fall was observed for *S. siamea* trees inoculated with *G. mosseae*. Chemical analysis of leaf samples taken at that time showed that most N was found in irrigated trees inoculated with *G. mosseae* ($P<0.001$) and that overall concentrations of N ($P = 0.011$), P ($P = 0.005$) and K ($P = 0.015$) were greater in the trees inoculated with *G. mosseae* than in those inoculated with *G. etunicatum* (Figure 5). No differences were observed in Zn concentration. These results may indicate that N deficiency and the relative inability of *G. etunicatum* inoculated trees to supply sufficient N to these large, fast-growing trees was primarily responsible for the leaf fall.

Figure 5 Leaf nutrient content in *Senna siamea*, April 2005, inoculated with *Glomus mosseae* or *Glomus etunicatum*, with and without additional nutrients supplied in irrigation water



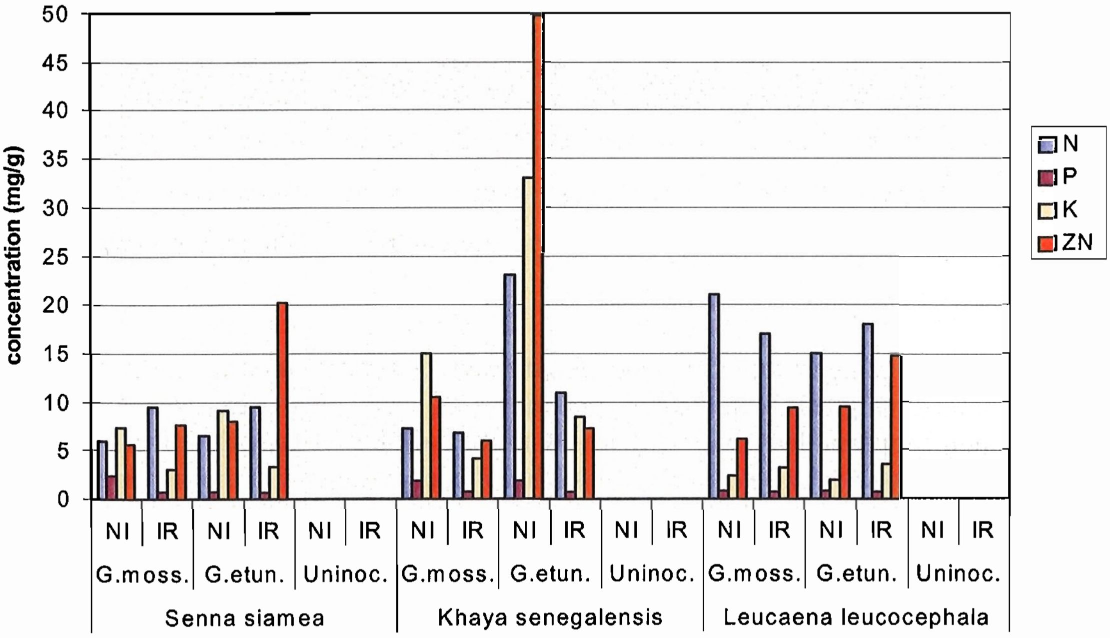
Results of chemical analyses carried out on plant and soil samples taken in October 2005 are shown in Figure 6 - Figure 8. Concentrations of P and K found in leaves of inoculated *S. siamea* were very similar to those found in April 2005, but levels of N were now much higher in leaves of trees inoculated with *G. etunicatum*.
There was a significant main effect of tree species on N content, with *L. leucocephala* trees containing more N than other species. For K, significant tree*fungus and tree*water interactions were detected such that uninoculated *L. leucocephala* and irrigated *K. senegalensis* contained more K than other treatments. Most P was found in leaves of *L. leucocephala* and *G. mosseae* inoculated trees, although a significant tree*fungus interaction was detected. No differences between treatments were found in Zn concentration.

Figure 6 Nutrient content of leaves of *Senna siamea, Khaya senegalensis* and *Leucaena leucocephala* in October 2005. Plants were inoculated or not with mycorrhizal fungi and received addition nutrients (IR) or no nutrients (NI).



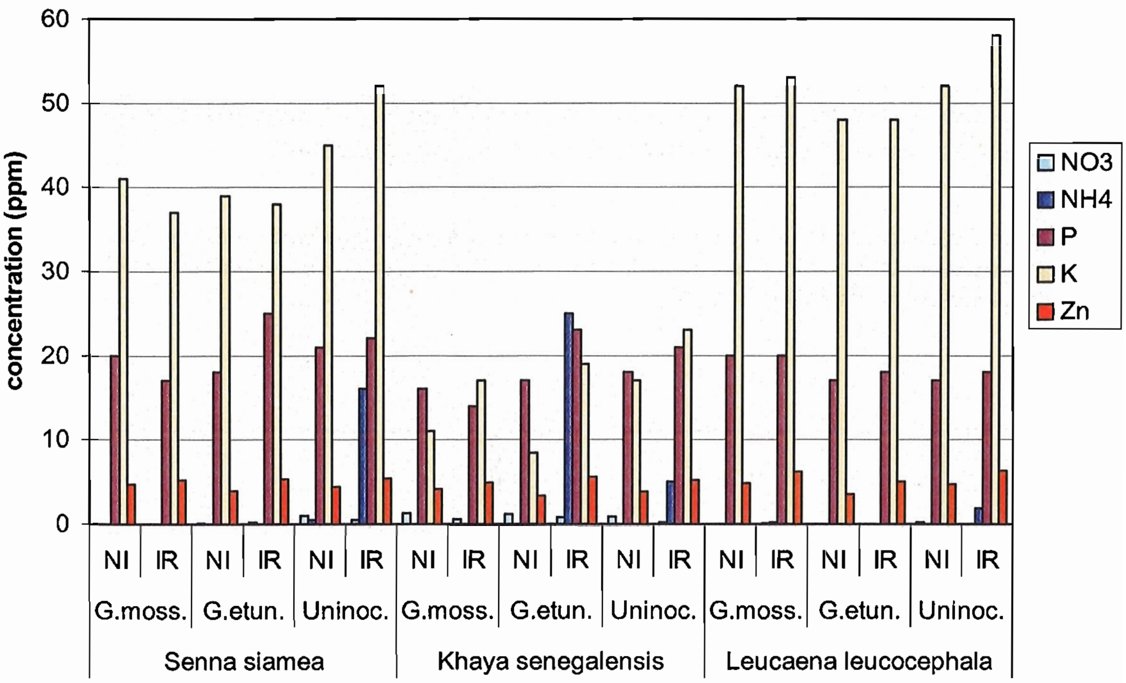
Root nutrient concentrations were only examined in inoculated trees as insufficient root material was recovered from the uninoculated control trees for chemical analysis (Figure 7). Concentrations of N were greatest in roots of *L. leucocephala*, and higher in *K. senegalensis* than *S. siamea*, although significant tree*fungus and tree*water interactions were detected. Concentrations of K were greatest in roots of *K. senegalensis*, and higher in *S. siamea* than *L. leucocephala*, although a significant tree*water interaction was detected. Concentrations of P were least in roots of irrigated trees. No differences were found in Zn concentration.

Figure 7 Nutrient content of roots of *Senna siamea, Khaya senegalensis* and *Leucaena leucocephala* plants which were inoculated or not with mycorrhizal fungi and receiving additional nutrients (IR) or not (NI)



Chemical analysis of the soils showed that concentration of NH_4 was greatest in soil from *K. senegalensis,* and higher in soil from *S. siamea* than *L. leucocephala* (Figure 8). Higher concentrations of NH_4 were found in soil from irrigated trees, although significant tree*fungus and tree*water interactions were detected. Concentration of K was greatest in soil of *L. leucocephala*, and higher in *S. siamea* than *K. senegalensis*. Concentrations of K were also higher in soil from uninoculated trees and irrigated trees. Concentrations of Zn were higher in irrigated soil.

Figure 8 Nutrients in soil associated with *Senna siamea, Khaya senegalensis* and *Leucaena leucocephala* with and without mycorrhizal inoculants and with (IR) and without (NI) additional nutrients



These results suggest that *L. leucocephala* trees accumulate more N in their leaves and roots leaving less N in the soil. In contrast, *K. senegalensis* trees accumulate more K in their roots and leaves leaving less K in the soil. Better growth of trees inoculated with *G. mosseae* may be reflected by higher P concentrations in the leaves and roots of *S. siamea* and *K. senegalensis*, the two trees which have responded best to mycorrhizal inoculation.

Progress against activities defined in the technical annex

- Glasshouse experiment to test effects of waste-water irrigation on effective inoculants is in progress and has yielded useful results
- Isolates of AM fungi are being maintained
- Training in field techniques has been provided to Mali

Forward look

- WP3 provide further training in tree water use and develop irrigation model
- WP4 complete glasshouse inoculant study, consider measurements of stomatal conductance to cross-refer with sapflow results from Mali and write up data for publication.

Partner 2: Institut d'Economie Rurale, Bamako, Mali

Work package 1: Water treatment and Irrigation

An experimental site (4 ha) was chosen near Siribala village, 30 km from Niono, at 14° 04′ N, 6°03′ W and at an altitude of 274.3 m. The drainage canal to be used for irrigation is called the drain of Minimana. Experimental plots (1 ha), have been delimited and surrounded with wire netting.

Using the conceptual irrigation plan produced by SCP, the Mali team has installed the irrigation system in the field. This irrigation system which involved works such as site management (earthworks, house, guard room, dam building, fencing the experimental site) and buying and installing equipments (water pump engine and irrigation materials) is now perfectly functioning.

Francoise Bouroulet from SCP provided training in Mali on waste water treatment and valorisation from 26 - 28 November 2005. Daouda Sidibé, Kalifa Traoré and Broulaye Koné of IER participated in this, together with some additional participants from the University of Bamako. The topics of the training were:

- Re-use of waste water;
- Management of sanitary quality of waste water;
- Management of waste water in terms of quantity;
- Managerial aspects of waste water;
- Examples of waste water projects.

Many documents either in hard copy or CD ROM concerning waste water management were given to the participants.

Before the training, a two-day field visit was made to the experimental site at Siribala. Francoise made useful remarks, especially concerning the depth of irrigation canal and the management of artificial basin. Many exchanges were made between researchers. One of the most important aspects discussed with Francoise concerned taking care of irrigation infrastructures (irrigation canals, dykes, artificial basin…) and equipment (water pump, PVC tubes, and flood gates)(Plate 1).

Plate 1 Primary irrigation canal at the experimental site of Minimana. Maintenance works are permanently needed for all the irrigation canals.

Work package: 2 Tree growth and Management

2. Field experiments:
During the meeting in Bamako in 2003, it was agreed that all the participating countries will do the same experiments in different countries. It was also agreed that two of the tree species would be same in all countries. These experiments were set up following the experimental design described in Annex 1 of the 2003-2004 annual report. Progress has been as follows.

2.1. Experiment 1.
Objective: To compare the growth of tree species in different countries under irrigated field conditions in Burkina Faso, Niger and Mali.
Nursery works were done in the experimental field at Minimana. Seeds of the following tree species were sown in plastic pots on 10/12/2004: *Gliricidia sepium*, *Leucaena leucocephala*, *Acacia angustissima* and *Khaya senegalensis*. The choice of tree species per country for the field experiments was defined at the meeting held in Bamako in 2003.
All the data concerning the nursery phase of this experiment are available but will not be presented in this report.

Materials and Methods
There are two factors: tree species and inoculation treatment. Two levels of inoculation treatment were double inoculation with mycorrhizas and rhizobia (R+M) and the control treatment without inoculation. The inoculation was done at the nursery phase. In the field, there were 5 blocks, each containing one plot of each species x inoculation treatment. Each plot contains 16 trees arranged 4 x 4. Only the central 4 trees will be measured. There will be 1 m between trees within a row, and 2 metres between the rows.

Data Collection
Field planting started on 26/05/2005. The first measurements of biophysical parameters started one month after planting. Parameters to be measured monthly are tree height, root collar diameter, diameter at 1.30 m and the number of branches.

Data Analysis: Data were analysed using MINITAB statistical software (Release 13 for Windows).

Results and discussion
Growth of all 4 species is presented in Table 1, one month after planting in the field. The survival rate was 100%, indicating that all the seedlings have overcome the post transplant shock. There were species x inoculation effects on height growth. Otherwise, main effects of inoculation and tree species were found on all parameters, and inoculation had a positive effect on tree growth.

Gliricidia sepium has the highest diameter followed by *Khaya senegalensis* and *Leucaena leucocephala*. *Acacia angustissima* has the lowest diameter. In terms of height growth *Leucaena leucocephala* is the best followed by *Gliricidia sepium* and *Acacia angustissima*. *Khaya senegalensis* was considerably shorter than the other species. *Acacia angustissima* has more branches than the other species. *Gliricidia sepium* and *Leucaena leucocephala* have the same branching pattern with at least 6 branches per tree. The number of branches of Khaya shows that this species does not grow many branches when it is young.

Table 1 Effects of inoculation on growth of different tree species (means ± SE) one month after planting (26/06/2005)

Species	Diameter (mm)		Height (cm)		Number of branches	
	R+M	C	R+M	C	R+M	C
Acacia angustissima	1.75 ± 0.08	1.64 ± 0.11	51.95 ± 1.77	44.80 ± 2.33	11.75 ± 0.7	9.78 ± 0.7
Gliricidia sepium	3.15 ± 0.11	3.00 ± 0.13	51.40 ± 2.37	48.80 ± 2.14	6.35 ± 0.6	4.00 ± 0.5
Khaya senegalensis	2.75 ± 0.16	2.28 ± 0.12	27.40 ± 0.91	23.10 ± 1.1	0.25 ± 0.1	0.25 ± 0.1
Leucaena leucocephala	2.30 ± 0.09	2.30 ± 0.13	55.00 ± 1.94	58.85 ± 2.56	6.95 ± 0.9	4.40 ± 0.7
p values						
species	0.000		0.000		0.000	
inoculation	0.03		0.05		0.001	
sp inoc*	0.25		0.03		0.19	

R+M = Double inoculation with rhizobium and mycorrhizas; C = Control, no inoculation

Five months after planting in the field there had been considerable growth of the trees (Table 2). Main effects of tree species on growth remained significant, but effects of inoculation had disappeared, apart from a species x inoculation effect on diameter.

Table 2 Effects of inoculation on growth of different tree species (means ± SE) 5 months after planting (26/10/2005)

Species	Diameter (mm)		Height (cm)		Number of branches	
	R+M	C	R+M	C	R+M	C
Acacia angustissima	7.15 ± 0.50	6.59 ± 0.4	167.0 ± 7.25	164.5 ± 8.3	15.0 ± 1.3	13.9 ± 1.12
Gliricidia sepium	12.54 ±0.55	12.62 ± 0.6	185.8 ± 10.2	172.8 ± 10	6.5 0 ± 0.5	5.85 ± 0.46
Khaya senegalensis	9.55 ± 0.40	9.25 ± 0.33	99.75 ± 5.2	108.0 ± 5.4	1.00 ± 0.39	0.35 ± 0.20
Leucaena leucocephala	12.35 ± 0.73	10.72 ± 0.6	249.4 ± 12.5	245.2 ± 9.8	20.5 ± 1.52	17.95 ± 1.6
p values						
species	0.00		0.00		0.00	
inoculation	0.62		0.65		0.09	
sp x inoc	0.02		0.70		0.76	

R+M = Double inoculation with rhizobium and mycorrhizas; C = Control, no inoculation

Gliricidia sepium has the highest diameter followed by *Leucaena leucocephala* and *Khaya senegalensis*. *Acacia angustissima* has the lowest diameter as observed during the first measurement. In terms of height growth *Leucaena leucocephala* (Plate 2) is the best followed by *Gliricidia sepium* and *Acacia angustissima*. *Khaya senegalensis* has the poorest growth in height compared to exotic species. This indigenous species is known to be slow growing and the growth rates observed here (1 m in 5 months) are fast by comparison with local expectations, due to the irrigation. In terms of the number of branches, the ranking of species changed and *Leucaena leucocephala* took over, followed by *Acacia angustissima* and *Gliricidia sepium*. *Khaya senegalensis* had few branches.

Some phenological characteristics such as flowers and fruits of trees are being observed. For instance, *Leucaena* trees have many flowers and fruits only five months after planting (Plate 2).

From Figure 9, it is clear that the height growth rate of *Leucaena leucocephala* is superior to that of *Khaya senegalensis*. *Gliricidia sepium* and *Acacia angustissima* have similar growth patterns. Diameter growth is different (Figure 10), *Gliricidia sepium* is similar to *Leucaena*, and *Khaya senegalensis* outperforms *Acacia angustissima*.

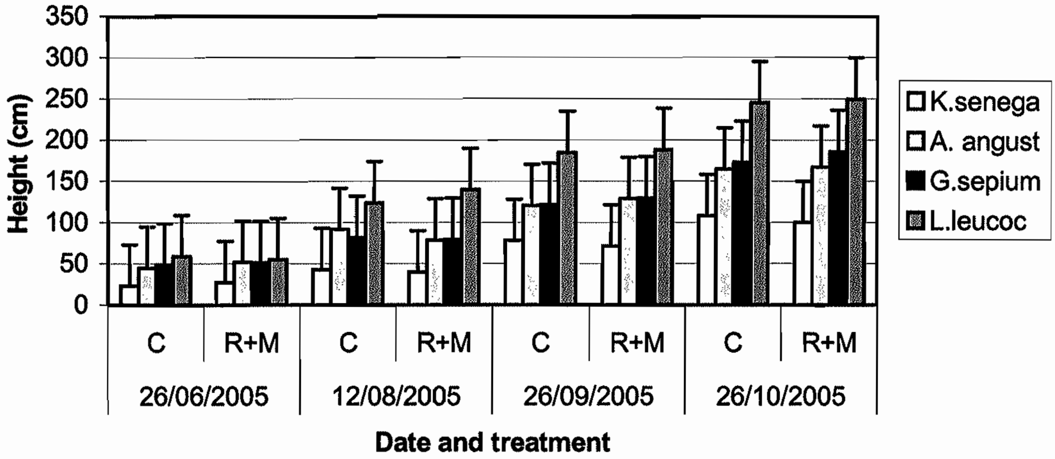


Figure 9 Height growth of the 4 tree species used in the first trial 5 months after plantation (Bars indicate ± SE). In legend: *Acacia angustissima, Gliricidia sepium, Khaya senegalensis* and *Leucaena leucocephala.*

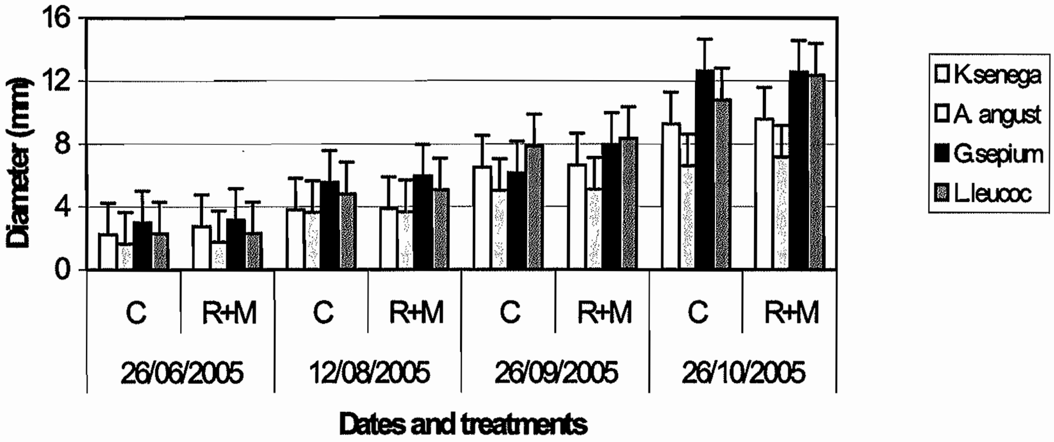


Figure 10 Growth in diameter of the 4 tree species used in the first trial 5 months after planting (Bars indicate ± SE).). In legend: *Acacia angustissima, Gliricidia sepium, Khaya senegalensis* and *Leucaena leucocephala.*

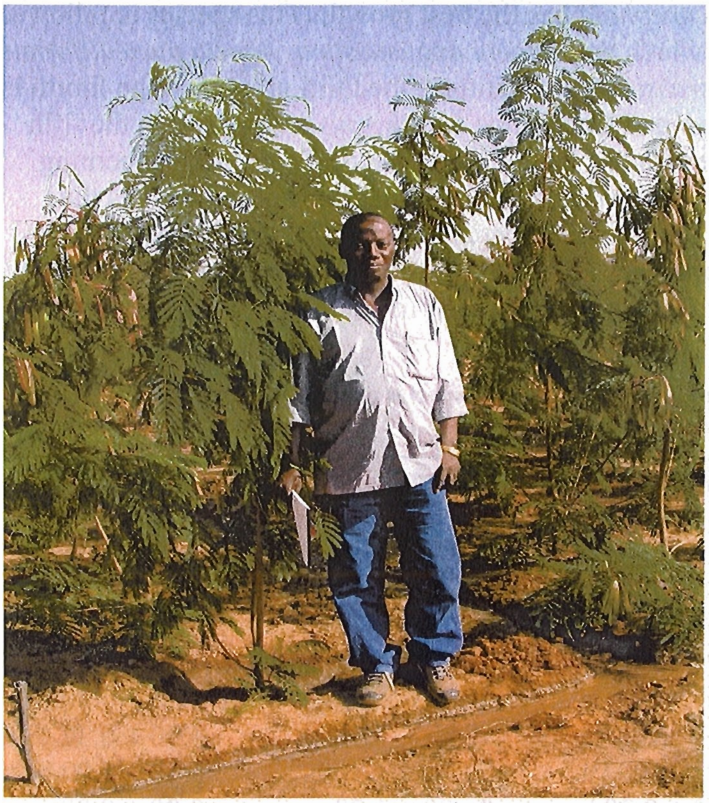


Plate 2 ***Leucaena leucocephala*** **with many seed pods at trial 1 at Minimana**

2.2. Experiment 2

Objective: to screen a wider range of species than were used in experiment 1 and compare their growth rates

Material and methods

Seeds of the ten tree species were sown on 10/12/2004: *Acacia crassicarpa*, *Acacia mangium*, *Acacia auriculiformis*, *Leucaena leucocephala*, *Gliricidia sepium*, *Calliandra calothyrsus, Acacia angustissima*, *Acacia senegal*, *Pterocarpus lucens* and *Khaya senegalensis*. Concerning the seeds of *Acacia seyal*, there was a problem of availability due to strong attack by insects. Field planting started at the end of May (like the first experiment) and finished in early June.

This experiment used a very simple design, with one tree per species per block, randomised within the block. In total we have used 30 blocks, therefore 30 trees of each species were needed. This experiment used the trees that we had already grown in the nursery in Sotuba. Trees from the +M+R treatment with the sizes closest to the mean size for the treatment were used. Once a month, height and root collar diameter were measured.

Results and Discussion

Table 3 shows the growth parameters (means ± SE) of the species used in the second experiment, one month after planting (26/06/2005). In terms of diameter growth, 4 distinct groups can be observed with significant differences between their diameters. The growth of *Gliricidia sepium* is significantly higher than the other species (Group A) which is followed by the group B with species like *Khaya senegalensis* and *Leucaena leucocephala*. The third group is formed by *Acacia crassicarpa*, *Acacia senegal* and *Calliandra calothyrsus*. The last group of species with the smallest diameters are *Acacia angustissima, A. auriculiformis, A. mangium* and *Pterocarpus lucens*. Concerning the growth in height, 6 groups with statistically significant differences between the heights of tree species can be distinguished. At this stage of experimentation, *Leucaena leucocephala* has the best growth. This species is followed by the second group of species which are: *Acacia angustissima*, *Acacia auriculiformis* and *Gliricidia sepium*. *Acacia crassicarpa* constitutes the third group and the fourth is *Acacia mangium*. *Acacia senegal* and *Calliandra calothyrsus* are present in the fifth group. The last species with the smallest height is *Pterocarpus lucens*. Concerning the number of branches, we can observe from table 3, that *Acacia senegal* has the high number followed by *Acacia mangium*, *Acacia auriculiformis* and *Leucaena leucocephala*. The number of branches of *Khaya senegalensis* is the lowest which is in conformity with the data obtained in the first experiment.

Table 3 Morphological parameters (means ± SE) of the species used in the second experiment, one month after planting (26/06/2005)

Tree species	Diameter (mm)	Height (cm)	Number of branches
Acacia angustissima	1.75 ± 0.08 d	55.00 ± 2.19 b	7.60 ± 1.03 b
Acacia auriculiformis	1.55 ± 0.05 d	54.50 ± 2.51 b	10.40 ± 1.42 a
Acacia crassicarpa	2.07 ± 0.14 c	43.20 ± 2.36 c	6.30 ± 0.97 b
Acacia mangium	1.71 ± 0.07d	32.70 ± 1.99 d	6.70 ± 1.04 b
Acacia senegal	2.07 ± 0.15 c	28.10 ± 2.25 de	7.30 ± 0.90 b
Calliandra calothyrsus	2.16 ± 0.13 c	31.80 ± 1.61de	0.90 ± 0.37 c
Gliricidia sepium	3.21 ± 0.07 a	50.00 ± 1.30 b	5.60 ± 1.00 b
Khaya senegalensis	2.70 ± 0.20 b	26.70 ± 1.23 e	0.00 ± 0.00 c
Leucaena leucocephala	2.61 ± 0.04 b	73.60 ± 2.27 a	8.30 ± 1.47 ab
Pterocarpus lucens	1.43 ± 0.09 d	16.10 ± 0.90 f	2.20 ± 0.51c

Values within a column with the same letter are not significantly different from each other at p= 0.05 (Fisher's pair wise comparisons)

Five months after planting (Table 4) differences in species' performance were clear. *Leucaena leucocephala* had performed well, whereas *Pterocarpus* and *Khaya* were both much slower growing than other species.

Table 4 Morphological parameters and variations (means ± SE) of the species used in the second experiment, 5 months after planting (26/06/2005)

Tree species	Diameter (mm)	Height (cm)	Number of branches
Acacia angustissima	8.14 ± 0.41 c	193.5 ± 10.5 b	13.60 ± 2.07 c
Acacia auriculiformis	9.83 ± 0.44 bc	169.5 ± 7.32 b	20.90 ± 1.19 b
Acacia crassicarpa	10.48 ± 1 .07 b	155.5 ± 16.3 bc	14.50 ± 1.92 c
Acacia mangium	13.96 ± 0.83 a	196.2 ± 10.9 b	24.60 ± 2.00 b
Acacia senegal	9.32 ± 0.71 bc	134.6 ± 8.43 c	38.00 ± 3.41 a
Calliandra calothyrsus	9.79 ± 0.5b c	184.00 ± 9.83 b	7.20 ± 0.6 d
Gliricidia sepium	12.50 ± 1.15 ab	174.5 ± 17.00 b	8.40 ± 1.86 d
Khaya senegalensis	6.46 ± 0.82 c	74.50 ± 8.00 d	0.70 ± 0.39 e
Leucaena leucocephala	13.19 ± 0.64 a	249.1 ± 10.7 a	20.30 ± 1.28 b
Pterocarpus lucens	2.28 ± 0.23 d	33.30 ± 2.68 e	4.50 ± 0.68 de

Values within a column with the same letter are not significantly different from each other at p= 0.05 (Fisher's pair wise comparisons)

From Figure 11, it is obvious that the height growth rate of *Leucaena leucocephala* is significantly higher than that of the other species. *Khaya senegalensis* and *Pterocarpus lucens* have the lowest growth rates and *Acacia mangium*, *A. angustissima, Calliandra calothyrsus* and *Gliricidia sepium* are intermediate. In terms of diameter (Figure 12), *Acacia mangium* (Plate 3), *Leucaena leucocephala* and *Gliricidia sepium* have the best growth. These species are followed by *Acacia crassicarpa* and *Acacia auriculiformis* (Plate 4). Although *Acacia* is among the species with good height growth, its diameter growth rate is low. It is well known that local species such as *Pterocarpus lucens Khaya senegalensis* and *Acacia senegal* are slow growing species but from these irrigated experiments this may have to be reconsidered since the two last species have made surprising growth over 5 months.

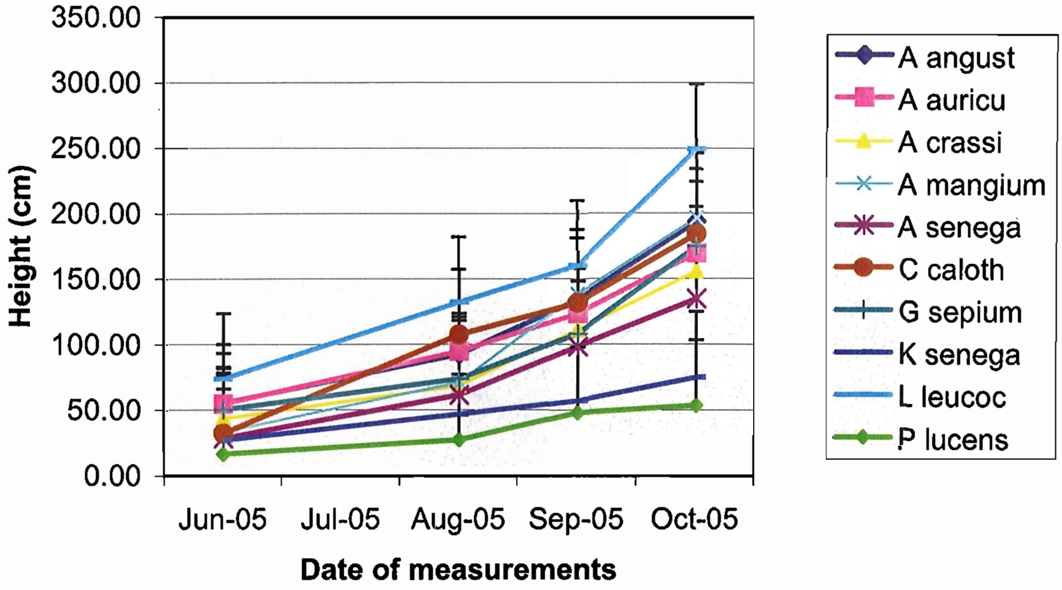


Figure 11 Height growth rate of the 10 tree species used in the second trial, 5 months after planting (Bars indicate ± SE).

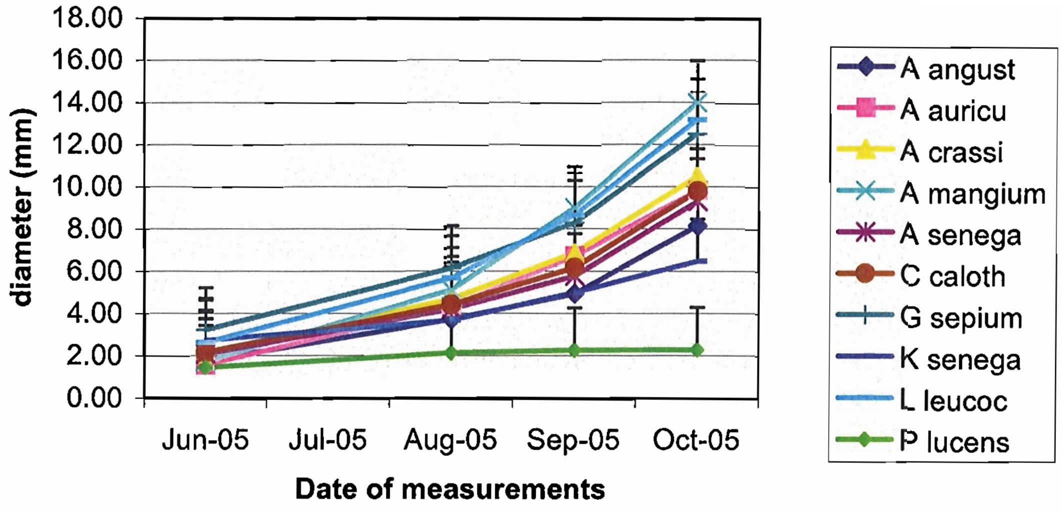


Figure 12 Diameter growth rate of the 10 tree species used in the second trial, 5 months after plantation (Bars indicate + SE).

Plate 3 ***Acacia mangium*** **tree in the second trial 5 months after planting (tertiary irrigation canal leading to planting hole)**

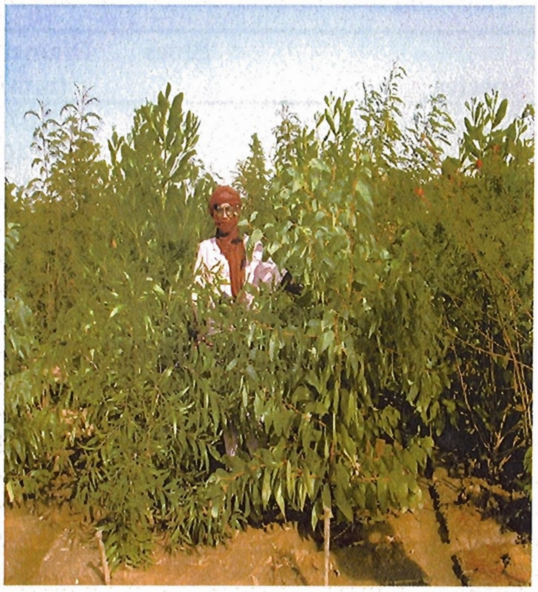
 

Plate 4 ***Acacia senegal*** **at the left,** ***Acacia auriculiformis*** **and** ***Acacia crassicarpa*** **at right in the second trial at the site of Minimana, 5 months after planting**

Work package 3: Tree Water–use and soil water status.
Dr Julia Wilson and Bob Munro from CEH Edinburgh visited Mali for training Malian staff from 16 to 30 April 2005. The aim was to train the African colleagues on the techniques to do sapflow, meteorological and soil moisture (probe) measurements. Before they arrived in Mali, Dr Sanoussi from the University of Abdou Moumouni in Niger shipped the equipment from Niger (where it was used in the previous season) to IER. Researchers from IER who participated in this training are: Daouda Sidibé, Kalifa Traore, Bakary Diassana and Broulaye Koné.
Participants have been trained (Plate 5) in the following techniques:
1. Sapflow equipment installation; placing the dynagages (Plate 8) on tree stems; sending the program to the data logger Dynamax (Plate 7); collecting the data from the data logger to the computer, checking the voltage of the data logger and the batteries, scanning techniques of leaves; installation and uses of FLOW32W and PC208W software.
2. Meteorological equipment installation: fixing up the data logger and the related equipment for ambient temperature, soil temperature, wind speed, rain gauge, the batteries, solar radiation (Plate 6).
3. Moisture meter (how the moisture Meter type HH2 reads and stores measurements taken with soil moisture sensor Profilė Probe). Soil profile probe type PR1 equipment installation in the field: how to use access tubes, augering kit and extraction kit.
Full documentation either in hard copies or CD ROM has been given to participants. After the training in Bamako at the nursery of IER Forestry Research Program, all the equipments were transported to the experimental site of Minimana for installation. Since then many data have been collected. All the results (too many) cannot be presented in this report but it is worthwhile to show some of them.

The following tables will show the different sapflow measurement done in the experimental site of Minimana either in the first or the second experiment.

Table 5 Sapflow measurement done on different trees at the date of 25 / 07 / 05

Species	Blocs	Diameter (mm)	Cable number	Resistance (Ohm)	Gage number	Ksh.
K. senegalensis	III	7.07	2	175.0	5	0.677
G. sepium	III	10.40	4	148.6	5	0.827
A. angustissima	I	6.06	6	208.0	9	0.622
L. leucocephala	I	9.50	8	118.0	9	1.062
K. senegalensis	IV	11.15	10	141.7	10	0.739
G. sepium	IV	11.53	11	128.1	10	0.811
A. angustissima	III	8.99	14	123.1	9	0.808
L. leucocephala	V	6.49	15	211.0	5	0.831

Table 6 Sapflow measurement done on different trees at the date of. 17 /08 / 05

Species	Blocs	Diameter (mm)	Cable number	Gage number	Resistance (Ohm)	Ksh.
A. angustissima	II	06.8	2	5	175	0.433
L. leucocephala	III	11.3	4	10	128.10	0.80
K. senegalensis	III	10.2	6	9	123.10	0.484
G. sepium	IV	12.7	8	13	120.9	1.387
A. angustissima	IV	06.7	10	5	208	0.487
L. leucocephala	V	11.5	13	10	148.6	0.358
G. sepium	III	11.6	14	10	141.7	0.80
K. senegalensis	V	10.1	15	10	135.5	0.80

Table 7 Sapflow measurement done on different trees at the date 27 /09 / 05

Species	Diameter (mm)	Cable number	Gage number	Resistance (Ohm)	Ksh.
G. sepium	16.8	2	16	58.8	1.33
C. calothyrsus	12.9	3	10	141.7	0.80
L. leucocephala	16.3	4	13	127.6	0.80
A. angustissima	06.3	6	5	175.0	0.80
A. crassicarpa	11.4	7	10	148.6	0.86
K. senegalensis	11.8	8	10	145.1	1.09
A. angustissima	11.0	10	10	128.1	0.80
L. leucocephala	18.2	11	16	85.7	0.87
K. senegalensis	12.7	12	10	148.30	1.06
A. angustissima	10.8	13	9	118.0	1.38
L. leucocephala	13.7	14	13	129.4	1.90
G. sepium	14.9	15	13	120.2	1.15

Table 8 Sapflow measurement done on different trees at the date 21 /11 /05

Species	Diameter (mm)	Cable number	Gage number	Resistance (Ohm)	Ksh.
G. sepium	17.20	2	16	86.0	1.08
C. calothyrsus	9.97	3	9	118.0	1.12
K. senegalensis	17.96	4	16	85.7	0.80
L leucocephala	15.41	6	13	120.2	1.20
A angustissima	12.29	7	10	148.3	0.90
A. crassicarpa	12.20	8	10	141.7	0.80
G. sepium	12.95	10	10	145.1	1.36
G. sepium	16.53	11	16	85.3	1.12
K. senegalensis	15.19	13	13	128.2	1.59
L. leucocephala	15.20	14	13	127.6	1.08
A. angustissima	12.09	15	10	128.1	0.90

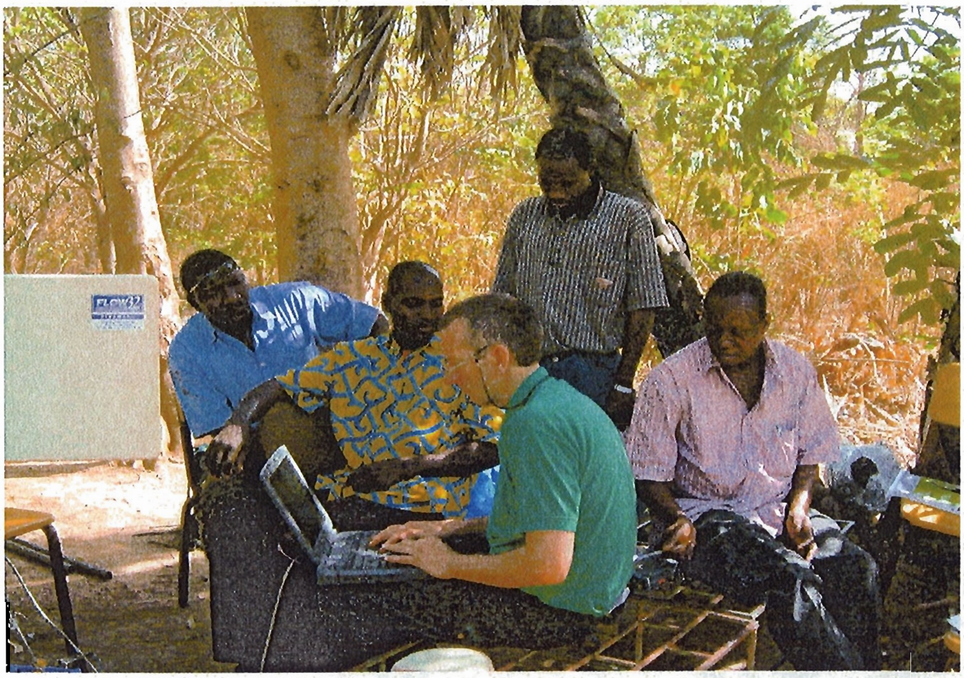


Plate 5 Training on the use of sap flow equipment (members of the UBENEFIT project team in Mali trained by Bob Munro from CEH Edinburgh).

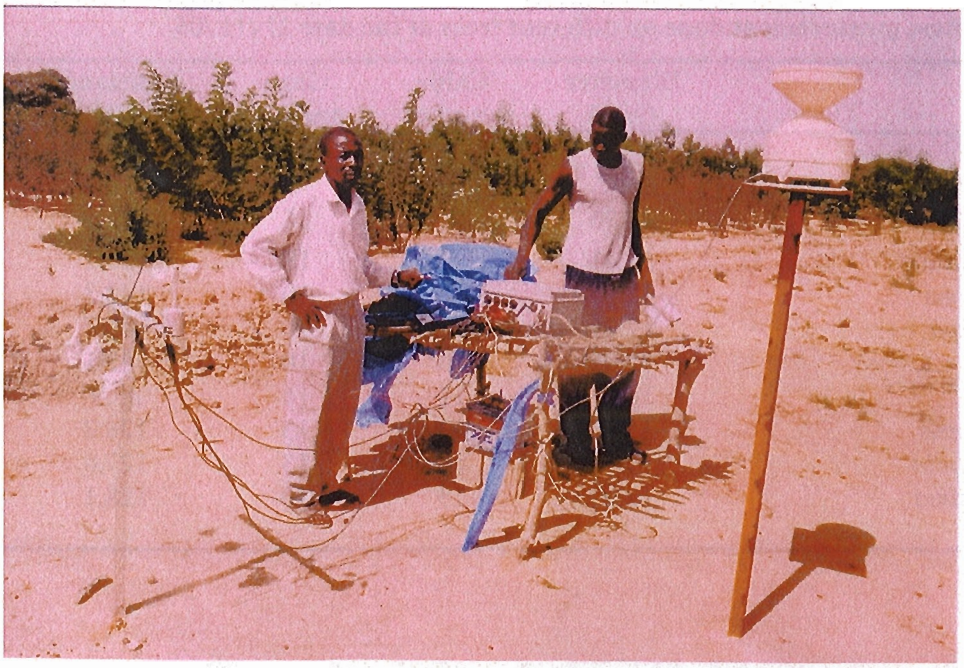


Plate 6: Meteorological station at the Minimana experimental site

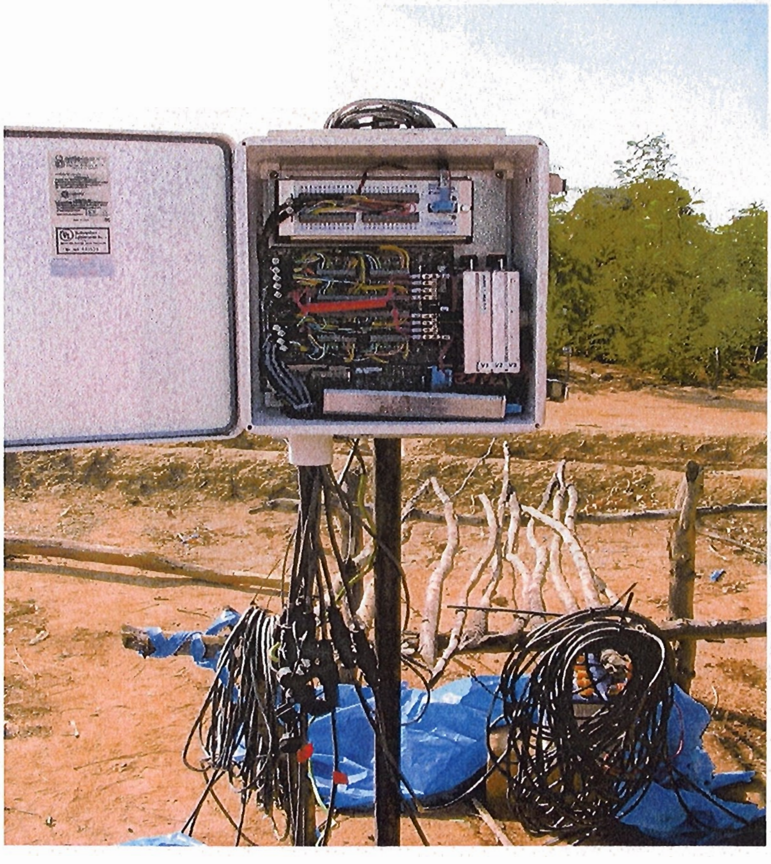


Plate 7 Sap flow equipment Box 2 installed in the experimental site at Minimana: Picture taken by Francoise Bouroulet from SCP during her field visit.

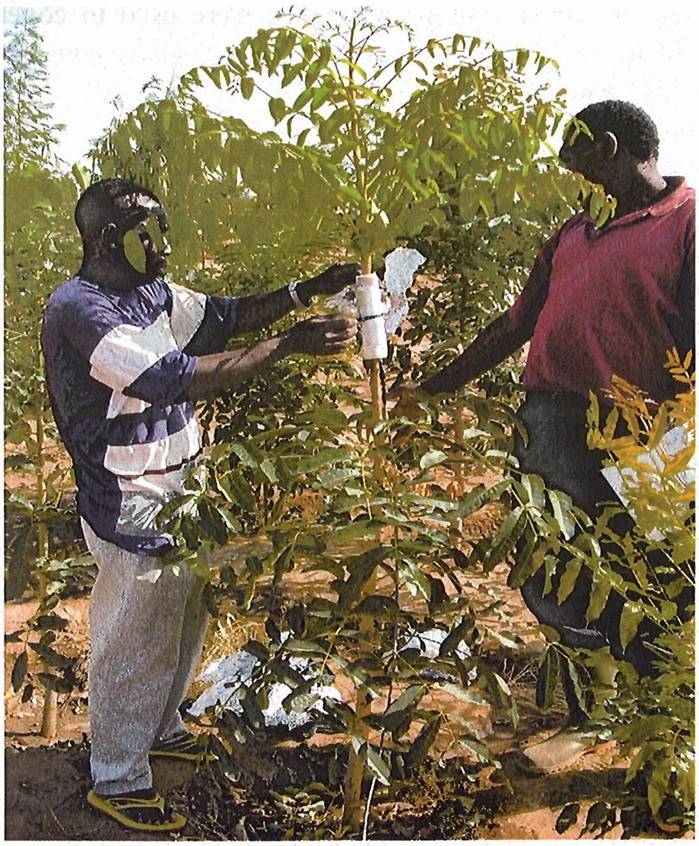


Plate 8 A project team member showing a technician how to put a sapflow gauge on a young *Khaya senegalensis* tree stem

Field measurements of sapflow

The flow of sap was measured on *Leucaena leucocephala*, *Gliricidia sepium*, *Accacia angustissima*, and *Khaya senegalensis* with and without mycorrhizal and rhizobial inoculation during the growing season of 2005 in Seribala. This device has been implemented in two replications. The trees were measured 2 months after planting in the field.

To measure the sapflow, eight (8) gauges (SGB 5, SGB 9 and SGB 10, Dynamax Inc, Houston, TX, USA) were used; these fit stems of diameters reaching from 6.06 mm (*K. senegalensis* and control plant of *A. angustissima*), 9 mm (control plant of *L. leucocephala* and *G. sepium* and R+M plant of *A. angustissima*) to 10 mm (R+M plant of *L. leucocephala* and *G. sepium*). Table 9 shows this information concerning the measurements done in July.

Table 9 Plant diameter height and gauges used according to treatment in July 2005 in Siribala

	Cable N°	Stem diam. (mm)	Height (cm)	Gauge N°	Treat.
Acacia angustissima	6	6.06		5	Control
Gliricidia sepium	4	10.4		9	
Leucaena leucocephala	8	9.50		9	
Khaya senegalensis	2	7.07		5	
Acacia angustissima	14	9.99		9	R + M
Gliricidia sepium	10	11.15		10	
L. leucocephala	11	11.53		10	
Kaya senegalensis	15	6.49		5	

After placing the gauges arround the stems, aluminium sheets were used to cover them in order to minimize the changes of the temperatures in the stems.The constant power of heating for all the gauges was within the range of 2.5 – 4.5 Volts. Each gauge was leading from the logger directly to the heater using a separate cable. Signals of the gauges were logged every 15 s and averaged over 15 mn before recorded.

The sapflow data have been corrected for leaf area and are expressed here as grams per m^2 per hour. To do so, a sample of leaves has been taken on a single main stem, the leaf area was determined using a scanner and software. The weight of leaves has been determined using a weighing machine. After this, all the remaining leaves have been removed and weighed. The relation obtained between the leaf area of the sample and its weight have been used to assess those of the all monitored stem. Figure 13 shows sap flow of uninoculated plants. Data indicate that without inoculation, *Gliricidia sepium* and *Acacia angustissima* (exotic species) and *Khaya senegalensis* (indigenous species) use about ten times less water for their growth compared to *Leucaena leucocephala* (exotic species).

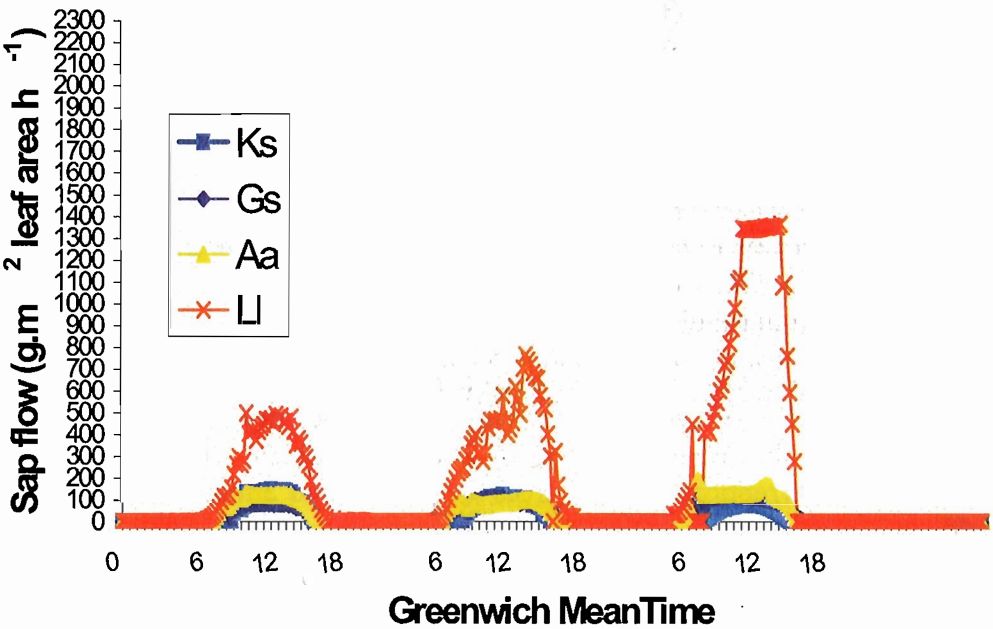


Figure 13 Sapflow of various species in control plots during three successive days in the rainy season of 2005 in Siribala, Mali.

Sapflow of plants inoculated with rhizobium and mycorrhizas shows another pattern. Least sapflow is observed with *Khaya senegalensis* identically followed by *Gliricidia* and *Leucaena,* whereas *Acacia angustissima* used about 20 times more water (Figure 14).

With or without rhizobium and mycorrhizas, the maximum of sap flow is observed at midday. *Khaya senegalensis* is not sensitive to the treatment. Otherwise, if the amount of sapflow is small for *Acacia angustissima* without treatment, it's the greatest with application of rhizobium and mycorrhiza. The opposite trend is observed for *Leucaena leucocephala.*

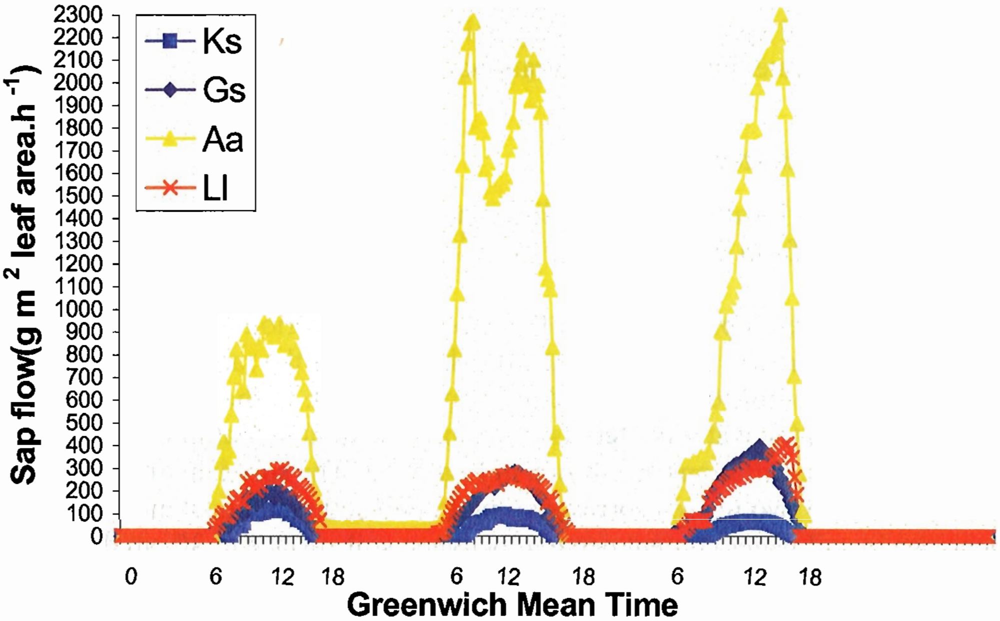


Figure 14 Sapflow of various species treated with rhizobium and mycorrhizas during three successive days in the rainy season of 2005 in Siribala, Mali.

Discussion:

The difference between inoculated and uninoculated plants is surprising and replicate measurements are needed to confirm these effects. As leaf area has been accounted for in the calculations, physiological and anatomical differences must be related to these differences. Both *Acacia* and *Leucaena* have small leaves, which will have small boundary layers (likely to increase transpiration) but at the same time, such small leaves will maintain a temperature closer to ambient than larger leaves of species such as *Khaya* which are likely to be several degrees above ambient. If the inoculation with rhizobium and mycorrhizas has a very little effect on the amount of sapflow of *Khaya senegalensis* and *Gliricidia sepium*, it diminishes considerably the sap flow amount of *Leucaena* and increases those of *Acacia angustissima*. The high transpiration rates of *A. angustissima* are not surprising because since the nursery *Acacia angustissima* needs more water (4 watering per day again 2 for the other species). This fact can be explained by a fast growth and consequently more sap is requested to encounter these great needs. Moreover the small size of leaves and their great number decrease the water use efficiency. Contrary, concerning *Leucaena leucocephala* the decrease of sap flow amount can be explained by the decrease of transpiration in presence of rhizobium and mycorrhizas (which is related to stomatal opening) which improve the water use efficiency. Many authors reported the linear relationship between plant transpiration rate and stomatal conductance and soil moisture content (Inoue et al., 1990; Moran et al., 1994; Pamela et al., 2003) which is relatively high (Figure 15). The amount of *Gliricidia sepium* sap flow (about 200 g m^{-2} leaf area h^{-1}) is comparable to those obtained in Senegal by Deans and Munro (2004) although these trees were older than the one we have in our experiment. The peak of sapflow observed for all the species can be explained by the maximum radiation observed at that period.

Our result is based on main stem analysis of species, therefore it cannot permit to predict the sap flow of the whole tree but it can help in identifying the most adapted species (small sapflow) in arid or semi-arid area. This has been already reported by

Deans and Munro (2004) when studying exotic and indigenous tree species water use in Senegal. The ideal species for planting will be those which are water-use efficient, with a high growth rate, but low transpirational demand.

1-2 Soil Water content

The variations of soil water content at different dates are reported in Table 10. Down the profile it varies from 0.098 to 0.508 m^3m^{-3} with a maximum from 0.4 to 1 m depth.

Changes in soil water depletion during the experimental period were analysed from the profiles of volumetric water content at the begining of the rainy season in July and at the end when the profile is suspected to be more humid. In the deepest layers (from 40 - 100 cm depth) the water content is more than the double that in the upper layers (0 to 40 cm). These variations are shown in Figure 15. The soil dehydration pattern can be divided into two phases corresponding to two soil water content levels. First the decrease in soil water content occured between soil surface to 30 cm depth for all the dates, then the profile became humid in the deeper soil layers (from 40 to 100 cm), especially for the measurements done in September.

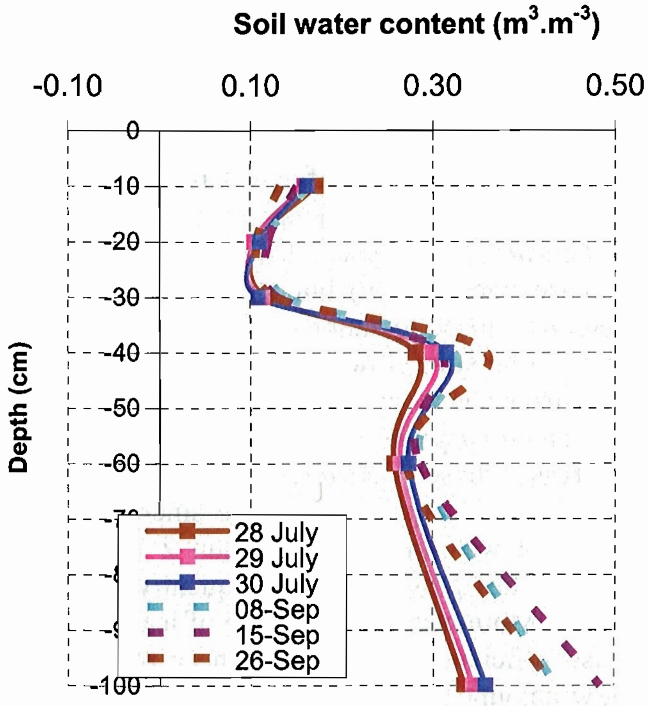


Figure 15 Vertical profiles of soil water content ($m^3.m^{-3}$) on different dates in 2005, at Siribala in the experimental plot. Data are averages of 36 measurements for each depth.

Discussion

The fact that soil water content decreases on the upper soil layers can be due to the presence of plant roots which use water for their growth. The deeper layers were strongly more humid because the plants roots which are young didn't reach this area. The relation between soil water depletion and plant roots activities have been reported by Granier et al. (2000) in France when studying water balance in two beech stands.

Furthermore, previous studies in the area (pedological pit and soil analysis) reported the high clay content of the deeper layers which can partly explain the high water content. These soils are well drained vertically; consequently it improves sensitively water infiltration. This drainage is mainly based on the biological activity which is intense in this area (Sedogo, 1981; N'Diaye, 1987; Pieri, 1989; Bertrand et Gigou, 2000).

Table 10 Means of 36 daily water content measurements in Siribala from July to October 2005.

Months / Depth (cm)	28 july	29 july	30 july	01 Aug	02 Aug	03 Aug	04 Aug	06 Aug	15 Aug	17 Aug	24 Aug	1-sept	8-sept	15-sep	26-sep	14-oct	21-oct	28-oct
10	0,172	0,160	0,163	0,185	0,168	0,167	0,106	0,164	0,163	0,167	0,169	0,177	0,165	0,152	0,133	0,124	0,127	0,112
20	0,107	0,104	0,111	0,105	0,098	0,100	0,075	0,097	0,092	0,093	0,106	0,119	0,118	0,120	0,108	0,096	0,101	0,096
30	0,117	0,114	0,109	0,130	0,132	0,131	0,114	0,137	0,135	0,133	0,135	0,143	0,140	0,130	0,127	0,125	0,126	0,138
40	0,282	0,300	0,316	0,286	0,332	0,325	0,269	0,333	0,350	0,223	0,207	0,221	0,324	0,309	0,359	0,346	0,354	0,363
60	0,258	0,265	0,275	0,275	0,278	0,274	0,250	0,283	0,287	0,278	0,284	0,290	0,288	0,286	0,272	0,255	0,257	0,265
100	0,335	0,345	0,359	0,414	0,401	0,383	0,508	0,454	0,493	0,469	0,422	0,473	0,436	0,484	0,432	0,385	0,394	0,370

Conclusion:

Preliminary results indicate that inoculation has a great effect on the sap flow amount of *Leucaena leucocephala* and *Acacia angustissima* species. The application of rhizobium and mycorrhizas on *Acacia angustissima* increases considerably the need of water through the great amount of sap flow it request for growing. At the opposite, the inoculation decrease the water used (sap flow) for *Leucaena leucocephala*. The species well adapted in semi-arid zone of Siribala are without inoculation *Khaya senegalensis*, *Acacia angustissima*, *Gliricidia sepium* and with inoculation *Khaya senegalensis*, *Leucaena leucocephala* and *Gliricidia sepium*.

Work package 4: Microsymbionts and N-fixation: We have received 1 kg of mixed inoculum from Partner 4 (Burkina Faso). This inoculum has been used in the first and second experiments. Inoculation has been done in the nursery at Minimana.
Fine roots of all the species have been collected and stored in a cool place to await assessment of mycorrhizal infection. Data concerning root length, shoot dry weight and root dry weight are available. Prior to the planting, mycorrhizal spores have been extracted from the soil. Soil has been sampled in the entire experimental plots. The preliminary results of spore extraction are presented in Table 11. Plots were numbered from 1 to 11. Standard errors are very large. This means that the number of replicate should be large enough in order to strengthen the reliability of our extraction. Although each replicate was a composite sample of ten cores of soil, a significant difference between spore numbers was found between plots.

Table 11 Number of spores per 100g of soil dry weight (Means ± SE) in the experimental site of Minimana; Number of samples = 3.

Plot Number	Number of spores/ 100g soil dry weight
1	442 ± 86
2	148 ± 24
3	552 ± 57
4	365 ±146
5	280 ± 27
6	257 ± 98
7	57 ± 7
8	231 ± 31
9	346 ± 50
10	229 ± 71
11	62 ± 5

Work package 5: Socio economic surveys in Mali are the responsibility of Partner 3.
Work package 6: Soil and Plants nutrition,
Soil sample for chemical analyses were done in Burkina Faso (Partner 4) and the results were presented in the last Annual Report. Another set of soil samples will be taken one year after tree planting. Plant component of all the species used in the experiments have been collected and oven dried. These samples are waiting chemical analyses when project funds arrive.

Work package 7: **Planting stock quality**
In contrast to the plant production systems used with temperate tree seedlings, there is little information describing the desirable attributes of tropical tree seedlings for use in specific application. It's worthwhile to note that in this work package, seedlings are raised with normal nursery practice. This means that the plastic bags usually used in nursery practice are used here.

Six seedlings of each species were randomly removed from our planting stock of experiment 1 and experiment 2 at the nursery in Minimana before planting. Parameters such as root collar diameter, height, root length, shoot fresh and dry weight, root fresh and dry weight were measured. These parameters have been used to calculate seedling quality attributes which are: shoot: root ratio, sturdiness quotient, total plant dry weight and Dickson's quality index.

1. **Planting stock quality for species used in Experiment 1**

Planting stock quality was assessed for the tree species used in Experiment 1 (Table 12).

Table 12 Planting stock quality assessed by Shoot: Root ratio, Sturdiness quotient, Plant Total Dry Weight and Dickson's Quality Index (mean ± SE) for *Acacia angustissima, Gliricidia sepium, Khaya senegalensis* and *Leucaena leucocephala*

Species	Plant Dry Weight (g)	Shoot :Root ratio	Sturdiness quotient	Dickson's Quality
Acacia angustissima	8.26 ± 1.62 ab	2.87 ± 0.5 b	21.85 ± 2.2 a	0.35 ± 0.07
Gliricidia sepium	9.75 ± 1.41 ab	3.68 ± 0.4 ab	10.90 ± 1.2 b	0.70 ± 0.1
Khaya senegalensis	7.12 ± 1.74 b	2.92 ± 0.6 ab	9.28 ± 0.8 b	0.55 ± 0.1
Leucaena leucocephala	12.10 ± 0.5 a	4.09 ± 0.3 a	18.95 ± 1.5 a	0.53 ± 0.03

Values within a column with the same letter are not significantly different from each other at P= 0.05 (Fisher's pairwise comparison); number of repetition = 6

The assessment of these qualities is required in order to alleviate problems associated with handling stock of variable size and to predict field performance of seedlings (Deans et al; 1989).

- Total plant dry weight

Leucaena leucocephala has the highest total plant dry weight (Table 12), followed by *Gliricidia sepium, Acacia angustissima* and *Khaya senegalensis.* The total plant dry weight of *Leucaena leucocephala* was significantly higher than that of *Khaya senegalensis.*

- Shoot: root ratio

Shoot:root ratio of *Acacia angustissima* is consistently smaller than those of *Leucaena leucocephala. Leucaena* has the highest shoot: root ratio followed by *Gliricidia sepium* and *Khaya senegalensis.*

- Sturdiness quotient

Leucaena leucocephala and *Acacia angustissima* have the highest sturdiness quotient in value than those of *Khaya senegalensis* and *Gliricidia sepium.* It is surprising to see that *Khaya senegalensis* which is a local species has the best sturdiness quotient.

- Dickson's quality index

Dickson's quality index is higher for *Gliricidia sepium* followed by *Khaya senegalensis, Leuçaena leucocephala* and *Acacia angustissima.* There is no significant difference between the species concerning this parameter.

2. Planting stock quality for species used in Experiment 2

Table 13 shows the planting stock quality of the ten species used in the screening trial.

Table 13 Planting stock quality assessed by Shoot: Root ratio, Sturdiness quotient, Plant Total Dry Weight and Dickson's Quality Index (mean ± SE) for the ten species used in the screening trial.

Species	Plant Dry Weight (g)	Shoot :Root ratio	Sturdiness quotient	Dickson's Quality
Acacia angustissima	7.80 ± 2.04 b	1.85 ± 0.4 b	35.30 ± 7.35 a	0.21 ± 0.04 c
Acacia auriculiformis	7.29 ± 0.58 b	3.16 ± 0.6 a	33.55 ± 4.18 a	0.20 ± 0.03 c
Acacia crassicarpa	8.14 ± 2.62 b	4.39 ± 0.8 a	22.56 ± 7.06 b	0.35 ± 0.1 c
Acacia mangium	6.67 ± 0.31 b	1.35 ± 0.5 bc	19.89 ± 2.28 b	0.32 ± 0.05 c
Acacia senegal	7.23 ± 0.77 b	0.50 ± 0.1 c	7.83 ± 1.38 d	0.94 ± 0.2 a
Calliandra calothyrsus	3.96 ± 0.46 c	0.97 ± 0.3 c	11.15 ± 1.32 c	0.32 ± 0.02 c
Gliricidia sepium	8.45 ± 0.76 b	3.15 ± 0.2 a	14.49 ± 1.55 c	0.50 ± 0.09 b
Khaya senegalensis	5.88 ± 1.23bc	2.05 ± 0.3 b	6.95 ± 1.26 d	0.69 ± 0.1 b
Leucaena leucocephala	13.52 ± 1.69a	1.10 ± 0.07bc	21.67 ± 1.84 b	0.60 ± 0.08 b
Pterocarpus lucens	2.10 ± 0.45 c	1.61 ± 0.1bc	8.72 ± 1.94 d	0.20 ± 0.006 c

Values within a column with the same letter are not significantly different from each other at P= 0.05 (Fisher's pairwise comparison); n = 6

- Total plant dry weight

For (4) groups of species are presented with significant differences between them. *Leucaena leucocephala* has the highest plant total dry weight. The second group consist of species like *Acacia angustissima*, *Acacia auriculiformis*, *Acacia crassicarpa*, *Acacia mangium*, *Acacia senegal* and *Gliricidia sepium*. *Calliandra calothyrsus* and *Pterocarpus lucens* form the third group with the smallest total plant weight. *Khaya senegalensis* is an intermediary group between group two and three.

- Shoot: root ratio

For (4) groups of species are present with significant differences between the shoot: root ratio. The first group of species with the highest shoot: root ratios in value are: *Acacia auriculiformis*, *Acacia crassicarpa* and *Gliricidia sepium*. The species which form the second group are: *Acacia angustissima* and *Khaya senegalensis. Acacia mangium, Leucaena leucocephala* and *Pterocarpus lucens* constitute the third group. The last group, *Calliandra calothyrsus* and *Acacia senegal* have the smallest shoot: root ratio.

- Sturdiness quotient

For (4) distinct groups of species can be seen with significant differences between their sturdiness quotients (Table 13). *Acacia angustissima* and *Acacia auriculiformis* have the highest sturdiness quotient with respectively values of 35.30 and 33.55. This group is followed by species such as *Acacia crassicarpa, Acacia mangium* and *Leucaena leucocephala. Calliandra calothyrsus* and *Gliricidia sepium* constitute the third group with value of 11.15 and 14.49 respectively. In the last group with the smallest sturdiness quotient, we can find *Acacia senegal*, *Khaya senegalensis* and *Pterocarpus lucens.*

- Dickson's quality index

For (4) distinct groups of species can be seen with significant differences between their Dickson's quality index. From the Table 13, it is obvious that *Acacia senegal* has the highest quality index. A group of species following *Acacia senegal* are: *Leucaena leucocephala*, *Khaya senegalensis* and *Gliricidia sepium.* In the third group, we can find species like *Calliandra calothyrsus, Acacia mangium*, *Acacia crassicarpa*, *Acacia auriculiformis, Acacia angustissima* and *Pterocarpus lucens.*

Coordination meeting, visits and visitors:

The third coordination meeting have been held in Ouagadougou, INERA, Burkina Faso, from 3 to 4 May 2005. Two members of IER Mali Team have participated to the meeting

- Field Visits: Siribala Town house representatives, women association and breeders association have visited the experimental site of Minimana.

- The Deputy Director of IER and the Heads of Sotuba and Niono Research Station have visited the experimental site of Minimana. The head of Forestry Research Programme of IER has visited the experimental site. He was very delighted because of the success of our experimentation. He was very impressed by the growth of tree species, mostly the local ones.

Another PhD student Penda Sissoko is planning to carry out her research in Siribala on the socio-economic aspects of the project.

Partner 3: University of Mali, UMALI. DB.LMB

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Mr. Hamed BATHILY FAST University of Bamako, Mali

Summary

Liaison with partners: Good collaboration is established between local partners IER, AAVNU and FAST involved in the project for carrying out field experiments studies at the site of Minimana,
Françoise Bouroulet from Sub contractor SCP (Société Canal de Provence, France) has stayed in Mali from 23 to 28 November 2005. IER, FAST and Françoise visited the project experiments set up at Minimana.
Dr Inamoud Ibny YATTARA responsible of project at University of Mali attended the Coordination meeting held at Ouagadougou, Burkina Faso, during May 2005

Water, soil and plant nutrients. Main analysis were performed in Mali by different laboratories. Water quality control is made with the collaboration of « Laboratoire de la Qualité des Eaux » de la Direction Nationale de l'Hydraulique, Ministère des Mines et de l'Energie à Bamako. Water samples were collected at Minimana site in April 2005, August 2005 and November 2005.
Soil and plant chemical analysis were performed by the lab of IPR/IFRA at Katibougou.

Microsymbionts and N-fixation Plant growth and management. Inoculant potential assessment and molecular characterization were carried out using established experiments at Minimana under irrigated conditions. Detail of results concerned data obtained just before plantation in fields trials.

Pest monitoring and management. Nematodes were mainly investigated using nursery and field irrigated conditions according to the protocol defined during the meeting of Ouagadougou. In field conditions soil was analysed before planting tree species. In the nursery, nematodes were searched on plant roots and in soil of plastic bag. Other pests concerned attacks by insects, termites.

Economics. Economic studies on utilisation of wastewater for fuelwood and fodder production are in late.

Formal Training:

Mr Fallaye KANTE registered for Ph. D degree at ISFRA in Mali, and is now in the lab of partner IRD- Laboratory Commun de Microbiologie (LCM) in Dakar (Sénégal).

Results

All results presented in the report concerned the period before planting in field trials. Studies on field trials are continuing.

Work package 1: ***Water treatment and irrigation***

Dissemination of information The established water purification, irrigation, plant production systems has been used to inform local authority officers. Municipal authority, women's groups, NGO's and rural radio were involved step by step in the evolution of the project. To disseminate information, 3 meetings were held with the municipal authority, women groups and NGO. Local rural radio was used to inform population about the objective of project. Women's groups have visited the project site. Dissemination was documented by film and support materials.

Work Package 4: ***Microsymbionts and N-Fixation.***

Experiments 1 and 2 listed above were used to fix nitrogen, sequester nutrients to determine the microsymbiont's inoculum potential of irrigated soils and to characterize microbial diversity.

According to previous protocols, inoculation of selected trees species was performed using both rhizobial and mycorrhizal strains (R+M). In these study, assessment of rhizobial infection before planting was done on plants in experiments 1and 2. In nursery, five months after sowing, measurements of growth parameters: height, root collar diameter, biomass production, nodulation were performed for 4 tree species *A. angustissima, Gliricidia sepium, L. leucocephala and Khaya senegalensis*. The data were analysed by one-way ANOVA. Results are summarized in Table 14 and **Table 15**.

In field trials, plants are now 4 four months old and measurements are continuing (see report of partner 3).

Table 14. Results of growth parameters analysis of four tree species raised in nursery 5 months old, just before transplantation in field (Experiment 1)

Tree species	Treatments	Root collar diameter (cm)	Height (cm)	Dry biomass (g)		Nodules (/plt)	
				Shoots	Roots	number	Dry weight
A. angustissima	R + M	0,515 a	50,850 a	4,350 a	2,367 a	24,000 a	195,333 a
	Témoin	0,555 a	56,950 b	7,133 a	3,983 a	45,667 a	182,333 a
Gliricidia sepium	R + M	1,010 a	52,700 a	5,800 a	2,133 a	30,333 a	114,667 a
	Témoin	1,020 a	47,828 a	8,583 a	3,883 a	52,333 a	349,667 b
L. leucocephala	R + M	0,740 a	59,650 b	6,133 a	4,183 a	22,333 a	235,333 b
	Témoin	0,710 a	44,450 a	5,133 a	5,100 a	10,667 a	95,000 a
Khaya senegalensis	M	0,610 b	27,500 a	1,653 a	0,620 a		
	Témoin	0,540 a	26,300 a	1,267 a	0,493 a		

In conclusion (Table 14), double inoculation (R+M) improved the height of *L. leucocephala*. Mycorrhizal utilization enhanced the growth diameter of *K. senegalensis*. Inoculation has no significant effect on biomass production, growth of diameter of leguminous trees and nodulation of *A. angustissima* and *Leucaena leucocephala*. Height of *Acacia angustissima* and nodule dry biomass of *G. sepium* were better without inoculation.

Table 15 Results of growth parameters analysis of four tree species raised in nursery 5 months old, just before transplantation in field (Experiment 2)

Tree species	Diameter collar (cm)	Height (cm)	Dry biomass (g)		Nodules	
			Shoot	Roots	Number	Dry weight
A. anguistissima	0,530 a	52,350 c	9,000 ab	6,217 b	33,000 a	233,667 a
Gliricidia sepium	**1,100 c**	46,300 b	**14,733 b**	**7,133 b**	**34,333 a**	**291,000 a**
L. leucocephala	0,690 b	**58,350 d**	7,900 ab	6,800 b	13,667 a	288,000 a
Khaya sengalensis	0,605 ab	23,950 a	3,600 a	1,217 a		

In experiment 2 (Table 15) we concluded that relevant biomass and high nodulation were recorded with all leguminous trees and *Gliricidia sepium* is shown as the best species. *Leucaena leucocephala* grows faster than the other species.

Molecular Characterization Rhizobia diversity studies were performed using nodules. DNA was extracted from nodules collected from plants in experiment 1 and 2. DNA quality was checked using gel electrophoresis. PCR of rDNA IGS 16S-23S was performed in our lab at FAST. Main molecular studies were carried out at the laboratory of LCM (Partner 5) at Dakar using protocol described by Krasova Wade *et al.*, 2005. For each experiment, relevant results were illustrated using types of genetic profiles presented in Table 16 - Table 21 and Figure 16Figure 20.

Experiment 1

For each leguminous tree species, a total of 60 root nodules were used for strain molecular characterisation. 30 nodules were collected from trees inoculated with R+M and the other 30 nodules from control plants. Results (Table 16Table 21) showed a low frequency of occurrence of the inoculant strains. Among those strains only rhizobia strain 11c is found in nodules of *Acacia angustissima* and none of the inoculant strains were found with *Gliricidia sepium* or *Leucaena leucocephala*. This suggests that the inoculant strains were either non-infective, or they were not competitive with the indigenous strains.

Table 16 Types of profiles of rhizobia strains nodulating *Acacia angustissima*

	Types of genetic profiles							
	Inoculant strain		Indigenous strain					
Treatments	11c	13c	L	M	N	O	P	V
Inoculation (R +M)	5	0	2	6	1	1	1	0
Control	0	0	3	0	0	0	0	2
Total number of profiles	5	0	5	6	1	1	1	2

Table 17 Types of profiles of rhizobia strains nodulating *Gliricidia sepium*

	Types of genetic profiles	
	Inoculant strain	Indigenous strain
Treatments	GsK_4	A
Inoculation (R +M)	0	25
Control	0	22
Number of total profiles	0	47

Table 18 Types of profiles of rhizobia strains nodulating *Leucaena leucocephala*

	Types of genetic profiles			
	Inoculant strain	Indigenous strains		
Treatments	LdK_4	H	I	J
Inoculation (R +M)	0	28	0	0
Control (T)	0	22	1	1
Number of total profiles	0	50	1	1

Experiment 2

In this experimentat one treatment has been performed (R+M). Thirty (30) nodules were used for strain molecular characterization. Our results are similar to those found in experiment 1 above. However, the frequency of strain H is very high in nodules of *Leucaena leucocephala* (Table 21).

Table 19 Types of profiles of rhizobia strains nodulating *Acacia anguistissima*

Treatments	Types of genetic profiles													
	Inoculant strain		Indigenous strains											
	11c	13c	A'	B'	F	Q	R	S	T	U	V	W	X	Y	Z
Inoculation (R +M)	1	0	1	1	1	1	4	2	1	1	3	1	1	1	1

Table 20 Types of profiles of rhizobia strains nodulating *Gliricidia sepium*

Treatments	Types of genetic profiles				
	Inoculant strain	Indigenous strains			
	GsK_4	G	B	C	D	H
Inoculation (R +M)	0	4	2	1	3	1

Table 21 Types of profiles of rhizobia strains nodulating *Leucaena leucocephala*

Treatments	Types of genetic profiles	
	Inoculant strain	Indigenous strains
	LdK_4	H
Inoculation (R +M)	0	27

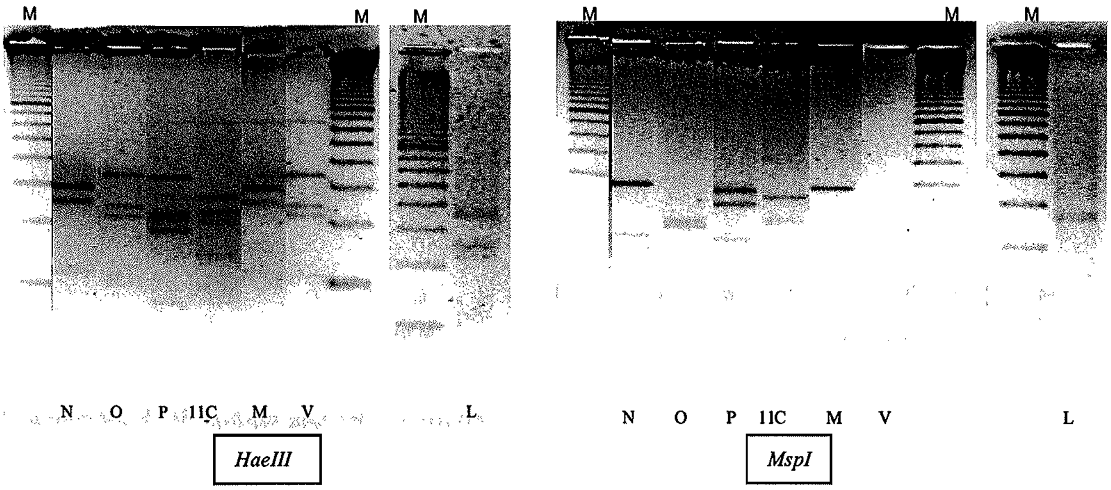

Figure 16 Types of genetic profiles of strains nodulating *A. angustissima* in Experiment 1

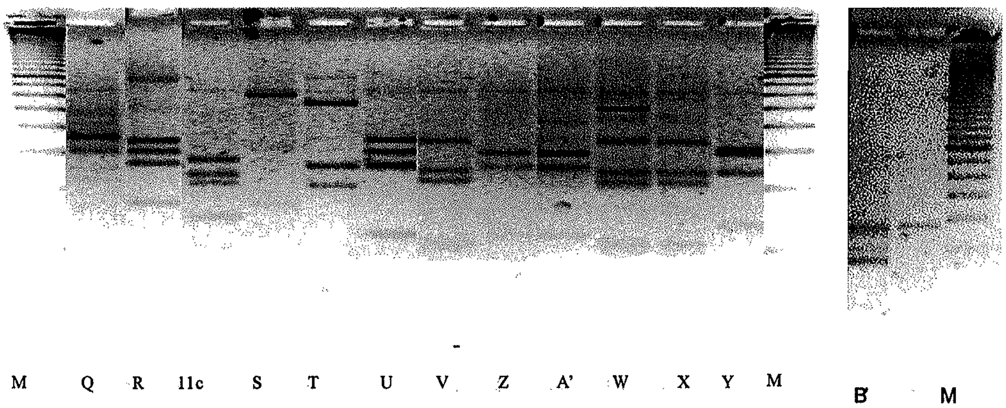

Figure 17 Types of genetic profiles of rhizobia nodulating *A. angustissima* in Experiment 2

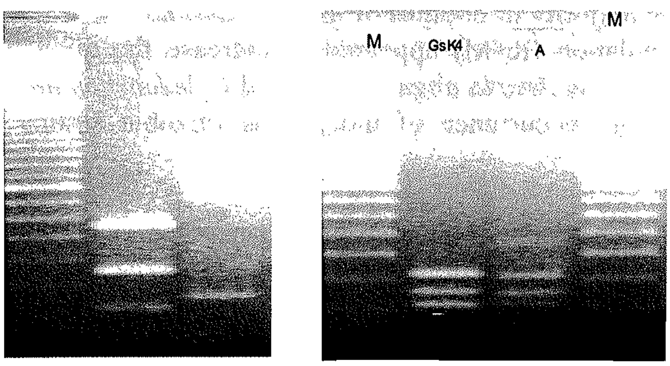

Figure 18 Types of genetic profiles of rhizobia nodulating *Gliricidia sepium* in Experiment 1

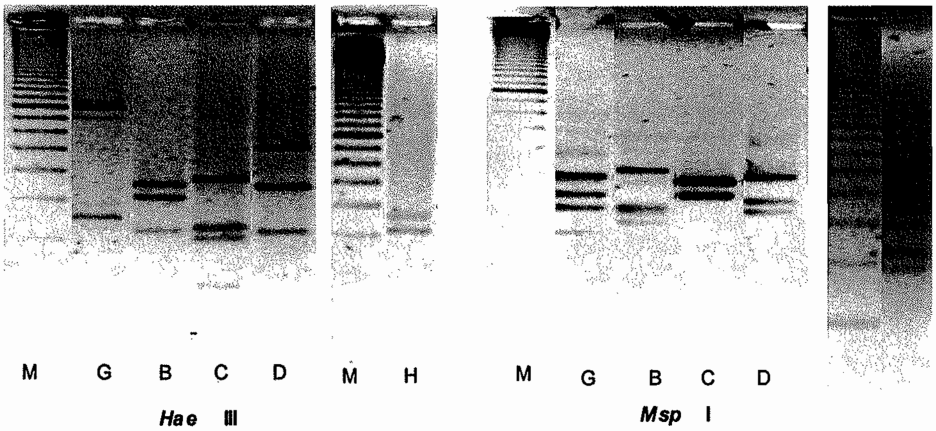

Figure 19 Types of genetic profiles of rhizobia nodulating *Gliricidia sepium* in Experiment 2

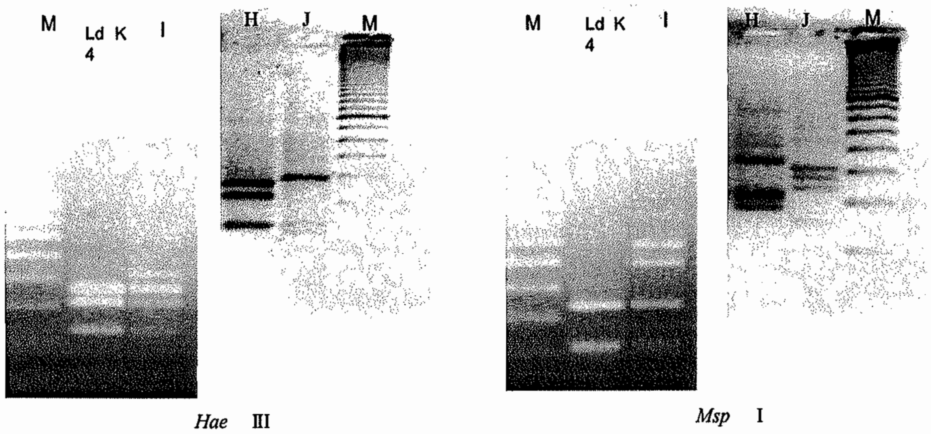

Figure 20 Types of genetic profiles of rhizobia nodulating *Leucaena leucocephala* in Experiment 1

In our experimental conditions using irrigated wastewater for plant production in experiment 1 and 2.

- strains used as inoculants for *Gliricidia sepium, L. leucocephala and A. angustissima* were infrequent in the harvested nodules. Only strain 11c was found in the majority of nodules of *A. angustissima.*
- double inoculation (R+M) appeared to increase the diversity of indigenous strains nodulating *Acacia angustissima* and *L. leucocephala*
- there was high occurrence of indigenous rhizobia strains in the collected nodules

Work Package 5. *Economics.* Main activities concerned elaboration and exchanges of questionnaires between different partners.

Work Package 6 : *Water, soil and plant nutrition*

Water was sampled for analysis in April 2005, August 2005 and November 2005. For each period three water samples were collected at Minimana and compared with other samples from different places: New channel of *Minimana* used for plant production,

old channel characterized by the occurrence of *Typha latifolia* and tank receiving irrigation water from *rice fields.* During November 2005 four samples have been collected and the fourth is taken from the tank receiving water coming from plantation. All samples were analysed with the collaboration of Laboratoire de la Qualité des Eaux (LQE) de la Direction Nationale de l'Hydraulique at Bamako (Mali). Results of water samples collected in April 2005 are presented in Table 22. Analysis of water sampled on August and November are being performed.
Before transplantation, sheet and roots of plants grown under irrigated conditions were collected and dried for chemical analysis. Analyses are being performed at the laboratory of IPR/IFRA.

Table 22 Results of irrigation water analysis site of Minimana 18 April 2005. Rizière: **Tank receiving water from ricefield** ; Minimana: **New channel** ; Typha: **Old channel.**

Eléments	Results of irrigation water analysis ($mg.l^{-1}$)		
	Minimana	Rizière	Typha
NO_2^-	0,051	0,051	0.021
NO_3^-	1,6	0.9	0.9
NH_4^+	0,41	0 ,02	0,02
PO_4^{3-}	0,92	0,46	0,24
SO_4^-	13	2	2
pH	6,3	6,42	6,57
Fe^{2+}	0,482	0,266	0,263
Ca^{2+}	3,60	3,20	4,73
Mg^{2+}	2,42	2,67	2,23
Na^+	5,3	4,7	4,0
K^+	2,1	1,5	1,5
Cl^-	3,1	0,4	0,8
Fluor	0,13	0,43	0,33
DBO5	16	0	8,8
DCO	20	0	11
Conductivité (µS/cm)	66	64	60
Turbidité	113	18	16
Couleur	403	86	71
Alcalin	6,3	22	21

Work Package 8: ***Pest monitoring and Management***

In nursery studies, nematodes were investigated in soil of plastic bags and in plant roots at 3 and 5 months of plant growth. Observations on aerial parts of plants were performed. Investigations were performed on plants from experiments 1 and 2.

At 3 months primary main results pointed out:

- morphological good aspect of plants, no attacks by pest, green plants are observed
- no phytophageous nematodes in the roots.
- occurrence of nematode species in the soils (Table 23).
- occurence of nematodes on uninoculant *Gliricidia sepium* and *Khaya senegalensis* tree species (Table 24)

At 5 months after growth just before transplantation in field trial no phytosanitary problems were observed in the 2 experiments, and there were no further observations of nematodes on the roots of *Gliricidia sepium* as indicated at 3 months. Possibly nursery conditions favour nematode populations on young, non-lignified plants. Field soil has 4800 nematodes/ litre of soil just before the planting.

Table 23 Occurrence of nematodes on the roots of trees species raised in nursery at Minimana (Siribala), 3 months after sowing.

Tree species (Treatments)	**Observation/Analyse des racines**	
	Index of galle	Number of nematodes / litre of soil
A angustissima **T**	-	-
A angustissima **RM**	-	-
L. leucocephala **T**	-	-
L .leucocephala **RM**	-	-
Gliricidia sepium **T**	+	-
Gliricidia sepium **RM**	-	-
Khaya senegalensis **T**	-	252 free living nematodes
Khaya senegalensis **M**	nd	nd

Table 24 Nematode populations occurring in the soil of site of Minimana (Siribala) 3 months after planting

Soil samples		Population of nematodes /litre of soil					
		Genus of nematodes				Free Nematodes	Total
	Trees species (Treatment)	*Helicotylenchus sp*	*Tricho sp*	*Scutellonema sp*	*Tylencchorhynchus sp*		
N	1. *A angustissima* T	28	20	-	-	148	196
U	*A angustissima* RM	-	-	-	-	168	168
R	2. *L.leucocephala* T	20	-	-	-	168	188
S	. *L.leucocephala* RM	40	-	-	-	178	218
E	3 *Gliricidia sepium* T	**356**	-	-	-	**680**	**1036**
R	*Gliricidia sepium* RM	64	-	-	-	32	96
Y	4. *Khaya senegalensis* T	4	-	-	-	112	116
	Khaya senegalensis M	nd	nd	nd	nd	nd	nd
Field trial		168	-	76	40	112	396

Table 25 Density of nematodes in soil of inoculated and uninoculated plants in nursery, 5 months after sowing, before planting in field trial:

(T) = Control, **(R x M)** = Rhizobia x Mycorrhizas

(Soil samples)/treatments	*Number and types of nematodes /litre of soil*	
	phytophageous	Free-nematodes
Acacia angustissima **(RXM)**	13.33	41
Acacia angustissima **(T)**	53.66	127.66
Gliricidia sepium **(RXM)**	13.66	54.66
Gliricidia sepium **(T)**	37	23
Leucaena leucocephala **(RXM)**	11	30.66
Leucaena leucocephala **(T)**	357.66	437.66
Khaya senegalensis **(RXM)**	17	38.33
Khaya senegalensis **(M)**	414.66	472
Acacia mangium **(RXM)**	46.66	255.66
Calliandra calothyrsus **(RXM) Exp. 2**	20.33	58.66
Acacia senegal **(RXM) Exp. 2**	77.33	156
Acacia auriculiformis **(RXM**	255.66	69
Acacia crassicarpa **(RXM)**	23	33.66
Pterocarpus lucens **(RxM)**	12.33	54.33

Formal Training: Formal Training

Mr Fallaye KANTE officially registered for Ph. D degree at ISFRA in Mali, and is now in Dakar (Sénégal).

Inamoud I. YATTARA, Fassé SAMAKE, Hamed BATHILY and Bakary SAMAKE were locally trained in irrigation system by sub contractor SCP (Société du Canal de Provence). This training was provided during 2 days by Françoise Bouroulet who has stayed in Mali from 23 to 28 November 2005.

M. Sc Youssouf CISSE from IER who is charged with economics workpackage is doing his thesis in the framework of this project.

Problem encountered:

Investigations on economic workpackage are in late. But this will be solved in due time.

Partner 4: INERA, Burkina Faso

M Dianda, K Sanon and J Bayala

Work package 1 Water treatment and irrigation

The works of construction and implementation of the wastewater treatment system have been delayed mainly because most of the site was flooded during the last rainy season. Finally, the work has been completed during the month of September. Following a 2-3 week test period of this system, the process of wastewater treatment was interrupted for corrections. The main failings noted at this time were (i) a lateral loss of water in the basins, probably attributable to the porosity of the basins' walls which are constructed of lateritic blocks, and (ii) a very limited effluent production of the system, due to the use of fine sand in its decontamination component. Important efforts have been made to overcome these constraints (an increase of the tightness of all parietal surfaces of the basins using additional layers, and the substitution of the sand by coarser materials). At present, the system of wastewater treatment is put back in function and seems capable of providing the water necessary for the plantating activities.

Work package 4 Microsymbionts and N fixing

- Determination of the potential of the inoculum (rhizobia and mycorrhiza) of soil (in progress)

- Determination of the efficiency of strains introduced in irrigation conditions.

A study of inoculation with introduced strains has been conducted in order assess the nodulation pattern in nursery and also after transplanting species in irrigation conditions. Parameters of stock quality have also been calculated (see below). The treatments consisted of a factorial combination of 2 different substrata (sand *vs.* soils mixtures), inoculation (non- inoculated vs. double inoculation with rhizobia and mycorrhiza), the size of the pot (small vs. large), and the species (6 different species). The details of this treatments and the experimental design are presented in Work package 7. When transplanting, half of the plants have been scarified for observations.

Results

Two months after transplanting there were large differences between treatments in nodule number and dry weight (Figure 21). Significant inoculation x substrate x tree species interactions, and inoculation x tree species x pot size interactions occurred for both nodulation parameters assessed. In general *Leucaena* species didn't form nodules in the pure sand unless they were inoculated with the *Rhizobium* mixture, indicating that bacteria able to nodulate these species are lacking in this substrate. Over all inoculation treatments, substrates and pot sizes, nodule number and dry weight tended to be higher in *Gliricidia sepium* compared with the other nodulating species. However, *Gliricidia sepium* performed the best for nodulation when plants were inoculated with *Rhizobium* in the small pots filled with the pure sand. The inoculum was apparently more infective then the indigenous bacteria when plants were nutrient-limited in this soil. *Acacia angustissima* showed nodulation pattern similar to *Leucaena* species except that it didn't form nodules in normal nursery substrate.

In general, all tree species were mycorrhizal at the harvest time except *Afzelia africana* which is known to be non-endomycorrhizal species (Figure 22). The mycorrhizal infection of species was not altered either by the pot size nor by the inoculation treatment. There were significant tree species x substrate interactions. Generally, the mycorrhizal infection was several time higher in the sand substrate as compared with the normal nursery soil. However, these differences were greatest in *A. angustissima* and *L. hybrid.*

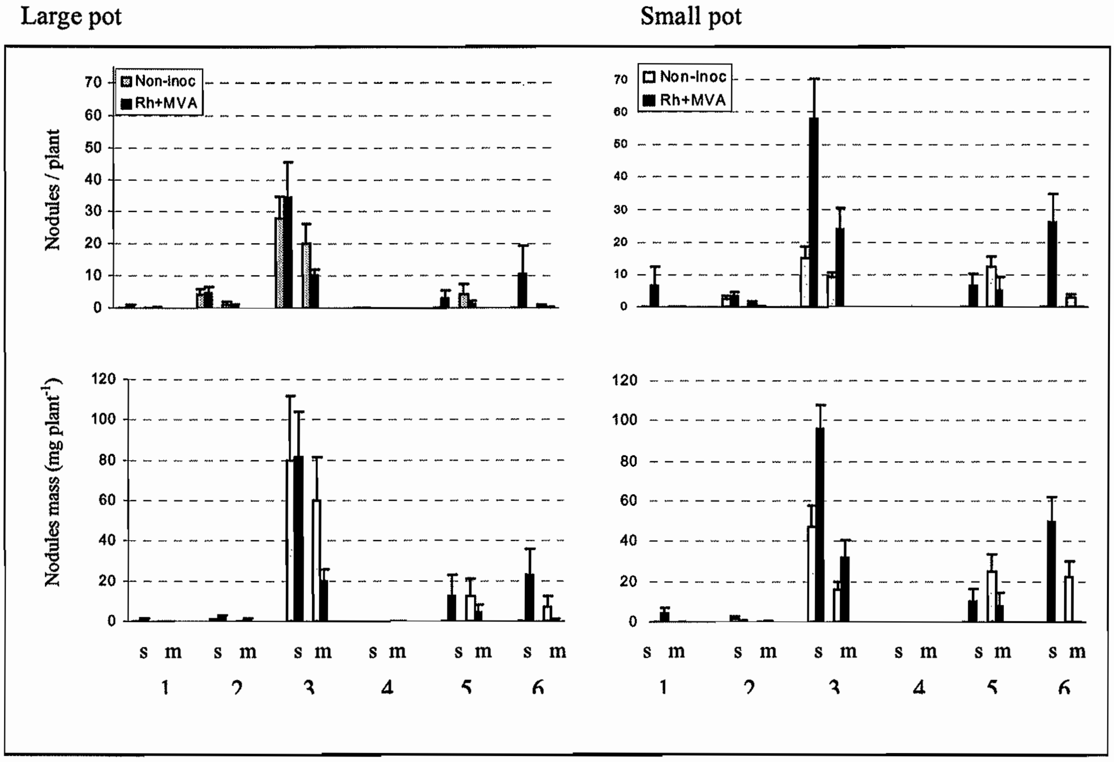

Figure 21 Nodule number and dry weight of six forage and wood producing species grown in sandy soil (s) and normal substrate (m). 1: ***Acacia angustissima*****; 2:** ***A. mangium*****; 3:** ***Gliricidia sepium*****; 4:** ***Afzelia africana*****; 5:** ***Leucaena leucocephala*****; 6:** ***L. hybrid.***

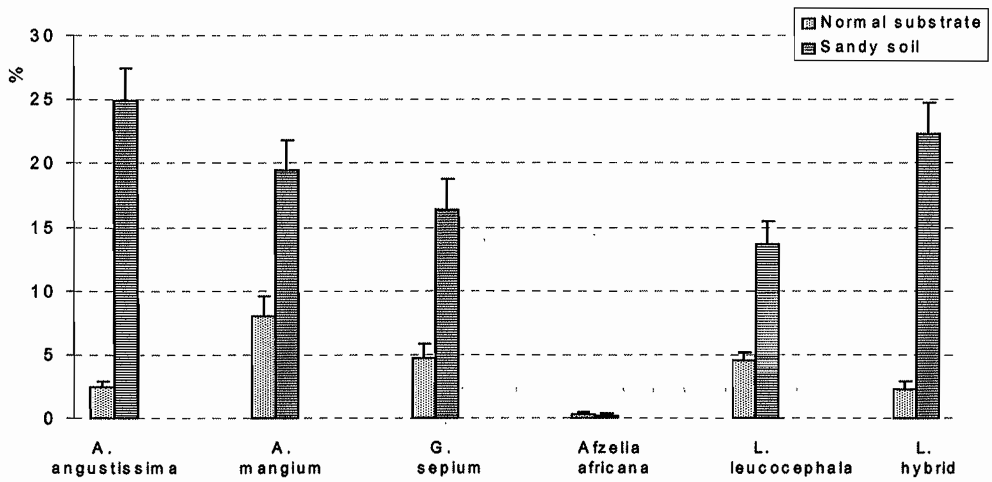

Figure 22 Mycorrhizal infection of six forage and wood producing species grown in sandy soil (s) and normal substrate (m). 1: ***Acacia angustissima*****; 2:** ***A. mangium*****; 3:** ***Gliricidia sepium*****; 4:** ***Afzelia Africana*****; 5:** ***Leucaena leucocephala*****; 6:** ***L. hybrid.***

Work package 5: Economics

Characterization of the traditional production systems of fuelwood and fodder for the town of Ouagadougou

Methodology

Fuelwood and charcoal

Supply of fuelwood and charcoal

The survey of fuelwood and charcoal supply was conducted by placing interviewers on 12 main roads that were identified by INSD (1987) and are used to introduce these products in the town of Ouagadougou. The roads taken into account are: Ouagadougou-Boassa, Ouagadougou-Bobo Dioulasso, Ouagadougou-Kamboinse, Ouagadougou-Kaya, Ouagadougou-Po, Ouagadougou-Bingo, Ouagadougou-Fada N'Gourma, Ouagadougou-Polsga, Ouagadougou-Komsilga, Ouagadougou-Ouahigouya, Ouagadougou-Sapone, Ouagadougou-Yemtemga. On these roads, 36 interviewers were recruited and placed 3 by road. The survey lasted one week and was done permanently all day long with one interviewer posted from 6 h to 14 h, the second from 14 h to 20 h and the third from 20 h to 6 h. The data were collected on sheet prepared to register the number of pedestrians, cyclists, carters, and cars of different sizes that transport wood and charcoal. This survey was carried out simultaneously on the 12 roads with the help of police and forest agents for security.

Retailers of fuelwood and charcoal

Ten quarters have been selected and within each quarter 5 retailers were retained for the survey. With each of the five retailers, 5 bundles of firewood per price were weighed and three piles of charcoal were weighed similarly.

Household survey on fuelwood and charcoal uses

Three main areas can be distinguished in the town of Ouagadougou, i.e. the old quarters, the residential zone and the new peripheral zones. In each of these three areas, 5 quarters were selected and within each quarter 20 households were surveyed, giving a total of 300 households.

Fodder

Supply of fodder

The 36 interviewers placed on the 12 roads for fuelwood and charcoal were also the ones in charge of collecting the data on fodder introduced in the town of Ouagadougou. That was done by distinguishing the transport means used similarly to the method used for the fuelwood and charcoal.

Retailers of fodder

The questionnaire of this survey was administered in three markets of livestock of the town of Ouagadougou. In each of the three markets, 20 retailers were interviewed.

Household survey on the use of fodder

The interviewers in charge of the survey on fuelwood and fodder administered also the questionnaire on fodder use in households where there was stock breeding.

Results

Supply of wood

The results revealed that the most important transportation means for wood in decreasing order were bicycles, carters, pedestrians, big trucks, small trucks and small cars. The road Ouaga-Ouahigouya displayed the highest number of cyclists 1237. The highest number of carters was registered on the road Ouaga-Kamboinsé whereas no big truck was encountered during the period of study on this way. This may be partly due to the poor conditions of the road for such big trucks and the limited availability of the resource on this direction. In turn, the road of Ouaga-Saponé, which is tarred and leads to areas where wood resource is still available (classified forests), was very frequented by a number of articulated trucks. On the same way, private vehicles and people back from duty travels play an important role in supplying themselves and therefore the town.

When comparing the data of the present study with those of a similar study undertaken by ISND (1987), there is an increase of the number of transportation means used in 2005, except for pedestrians and small trucks (Table 26). The decrease in the number of pedestrians is probably related to the decrease in the availability of wood resource in the vicinity of Ouagadougou due to the human pressure on the vegetation. There is also an increase in the number of trucks indicating the will to use engines with higher transportation capacity in view to minimize the expenses and therefore make this activity more profitable.

Table 26 Average daily entrees in Ouagadougou of transportation means of fuelwood in 1987 and 2005

Transportation means	1987	2005	Difference
Pedestrians	987	137	-850
Cyclists	356	744	+388
Carters	117	157	+40
Trucks	95	27	-68
Small trucks	18	29	+11
Big trucks	21	32	+11
Articulated trucks	2	37	+35

Based on the data of Table 26, the quantity of fuelwood introduced in Ouagadougou was worked out for the all year (Table 27). We can notice an increase by 83,200 tons in comparison with the 41,804 tons reported by Zida (1991).

Table 27 Quantity of fuelwood introduced in the town of Ouagadougou in 2005

Transportation means	Weekly frequency	Quantity of fuelwood per year (tons)
Pedestrians	956	832
Cyclists	5,208	5,252
Carters	1,100	21,320
Cars	188	14,508
Small trucks	204	31,616
Big trucks	460	38,688
Articulated trucks	426	118,872
Total		225,004

Suppliers of charcoal
The same categories of actors have been recorded for charcoal supplying the town of Ouagadougou on the same 12 roads. Bicyclists were again the most frequent on all the 12 roads with 810 passages in one week (Table 28).

Table 28 Average weekly entrees in Ouagadougou of transportation means of charcoal and the quantity of charcoal introduced in Ouagadougou in one year

Transportation means	Weekly frequency	Quantity per year (tons)
Pedestrians	125	104
Cyclists	810	3,380
Cars	162	624
Small trucks	63	2,600
Big trucks	-	-
Articulated trucks	-	-
Total		

Suppliers of fodder
Different types of fodders were encountered: annual grasses, annual leguminous, leaves of ligneous plants, crop residues and industrial byproducts. No specific difference was found in the transportation means compared with those used for fuelwood and charcoal transportation. Again cyclists were the most frequent on the roads transporting fodder to Ouagadougou (Table 29). Trucks did not transport fodder alone but animals and fodder at the same time.

Table 29 Weekly frequency passages of transportation means by road for fodder supply to the town of Ouagadougou in 2005

	Transportation means				
Road	Pedestrians	Cyclists	Carters	Trucks	Others
Ouagadougou-Ouahigouya	42	54	79	7	0
Ouagadougou-Kamboinsè	7	21	0	0	0
Ouagadougou-Tanghin Dassouri	14	55	0	8	0
Ouagadougou-Bingo	8	9	0	0	9
Ouagadougou-Komsilga	84	73	88	0	8
Ouagadougou-Polesgo	1	18	2	3	1
Ouagadougou-Kaya	0	19	0	0	0
Ouagadougou-Kombissiri	28	3	2	1	1
Ouagadougou-Boassa	0	38	14	0	17
Ouagadougou-Saponé	9	29	5	0	0
Ouagadougou-Fada N'Gouma	2	25	2	0	1
Total	201	344	192	19	37

Fuelwood and charcoal uses in households
Bendogo was the quarter where we registered the highest number households using wood as main energy source (57 households) followed by Paspanga with 40 households and the residential quarter (1200 logements) with 20 households (Table 5). Therefore we can notice in the new quarter (Bendogo), people are still having a behaviour closer to that of people from the village whereas inhabitants of the old quarter (Paspanga) are using gas in higher proportion. In residential area (1200

logements) people tend to replace the wood by the gas. The study showed that there are other factors that have an influence on the use of wood, for instance: instruction level of the decision maker of the household, the size of the household, frequency of preparation of "tô" (main dish in Burkina made from flour of cereals), kitchen position in the courtyard, the type of house and the religion. Thus households with a decision maker having a low instruction level (generally low income as well) tend to rely on wood as energy source. That was also the case as the number of people in a family increases, more frequent "tô" cooking, kitchen built separately from the main house, houses built following traditional models and Muslim families (this is rather due to the number of people in the family due to polygamy).

Table 30 Choices of energy source as related to the types of quarter in the town of Ouagadougou in 2005

	Quarters			
Main fuel	Bendogo (1)	Paspanga (2)	Cité 1200 Lgmt (3)	Total
Fuelwood	57	40	20	117
Charcoal	8	18	8	34
Gas	8	17	44	69
Total	73	75	72	220

NB : (1) peripheral quarter ; (2) old central quarter ; (3) residential quarter

Fodder uses in households

The main types of fodder in decreasing order are grasses, crop residues, cereal bran, tree leaves and cotton seeds. Tree fodder was not mentioned frequently because the survey period was not the most appropriate for this type of fodder. Another reason may be due to the fact that the pruning of trees even for fodder is prohibited by forest services.

Out of 75 households interviewed per zone, 62 households practice stock breeding in Paspanga, 49 households in Bendogo and only 4 households in the residential quarter (1200 logements). Thus, as the quarters become more modern people tend to abandon animal breeding in town. The most frequent types of animals are sheep (46 cases), goats (29 cases), and cattle (16 cases).

Commercialization of fuelwood and charcoal

Two types of actors are involved in commercializing fuelwood and charcoal: the suppliers and the retailers. A study of Ouedraogo (1996) revealed an increasing rate of 32.5% and 16.7% per year for suppliers and retailers, respectively. If the suppliers are dominated by men, the retailing is an activity conducted both by men (~50%) and women (~50%). This activity does not require any specific training so that we found people of a large range of instruction levels. However, retailing of fuelwood and charcoal appeared to be done mainly by people of 40 to 50 year old. A small percentage (12%) of the actors involved in fuelwood commercialization are members of professional organizations. Such organizations aim at improving the working conditions of these actors.

In general, retailers are supplied twice a month, rarely 3 or 4 times. They pay forest troutes of 1000 to 4000 F CFA per year for fuelwood, and 800 to 3000 F CFA for charcoal. Additionally, they also pay state troutes varying between 1250 to 2000 F CFA. The hiring of their working place costs 1000 to 2000 F CFA and the authorization to do the activity costs 2000 F CFA per year.

The fuelwood is sold at 50 to 500 F CFA the bundle but the price per kg does not vary too much (Table 31). The charcoal is sold in piles of 50 F CFA and 100 F CFA. Based their weights, the equivalents are 60 F CFA kg^{-1} and 110 F CFA kg^{-1}, respectively. The daily income evolves between 1,500 and 200,000 F CFA for fieldwood, and 4,500 to 200,000 F CFA for charcoal. These figures constitute an indication that the activity of commercializing fuelwood or charcoal yield substantial incomes for those involved in making them capable to cover the health, schooling and food charges of their families.

Table 31 Average price of firewood bundle in Ouagadougou in 2005

Bundle type	Number of observations	Average weight (kg)	Price kg^{-1} (F CFA)
50 F CFA	25	2.05	24.39
100 F CFA	25	4.50	22.22
125 F CFA	15	4.90	25.51
150 F CFA	10	9.50	15.78
200 F CFA	15	12	16.66
250 F CFA	8	12.85	20.83
500 F CFA	12	22	22.72

Commercialization of fodder

As for the animals, the fodder is sold on the same markets and therefore the survey was done in the markets of Tanghin, Tampouy and Gounghin. Two types of retailers were identified. The specialized retailers practice this activity as their main income generating activity and they represent 88% of the sample. The seasonal retailers are mainly pupils on holidays for who this activity constitutes a way to get financial resources to pay their school fees and their books.

Buyers encountered were from all social levels of the city. Almost all of them buy the ration of the day for their animals because of storage and conservation problems mainly for fresh fodder.

The prices evolved according to the season. At harvest the residues of peanut cost 50 or 75 F CFA kg^{-1}. The price becomes 100 F CFA during the dry cool period (Mi-December to the end of February) and reaches 175 F CFA kg^{-1} during the dry hot period (March- June). The cost of one pile of the grass fodder evolves from 25 F CFA during the rainy season to 50 F CFA during the dry season.

On average, the retailers of fodder earn 142,800 F CFA per year. Most of them (97%) invest this income in buying food for their family as well as school fees, health care, tools for their work, etc.

Conclusion

The present study yielded a set of recent data on the supplying, commercialization, uses of fuelwood, charcoal and fodder for the city of Ouagadougou. We noted that a large variety of transportation means is used in these activities going from pedestrians to articulated trucks. The uses of fuelwood, charcoal and fodder depend on the status of the quarter (residential or traditional), the instruction level of the decision maker of the family, the size of the family, etc. Commercialization of these products yield important incomes and constitutes the living basis of many families in Ouagadougou city for both suppliers and retailers.

Work package 7: Planting stock quality

Material and methods

Study site

The study was conducted in a nursery in the courtyard of Dépatement Productions Forestières (DPF) of Institut de l'Environnement et de Recherches Agricoles (INERA) in Ouagadougou, Burkina Faso, West Africa (12°22' N and 1°30' W and at an altitude of 306 m.a.s.l). Pure sand collected from the bottom of rivers and normal nursery substrate in Burkina Faso (mixture of arable soil, sand and manure 2:1:1) were used for the experiment. The rainfall of the site is unimodal with a mean annual rainfall of 804 mm. The mean annual temperature is 28°C with a minimum of 22°C and a maximum of 35°C.

Experimental design

Four factors were investigated:

1. Two substrates: pure sand and normal nursery substrate in Burkina Faso that consists of a mixture of arable soil, sand and manure in the proportions of 2:1:1;
2. Two inoculation levels: non-inoculated plants and double inoculated plants with Rhizobium and Mycorrhizas;
3. Six species: *Acacia angustissima, Acacia mangium, Afzelia Africana, Gliricidia sepium, Leucaena hybrid, Leucaena leucocephala*;
4. Two container sizes: small plastic pots and big plastic pots.

The design was a split split plot with the inoculation factor assigned to the main plot, the substrate to the sub-plot, the species (*Acacia angustissima, Acacia mangium, Afzelia Africana, Gliricidia sepium, Leucaena hybrid, Leucaena leucocephala)* to the sub-sub-plot and the pot size to the experimental plot. For each pot size 8 plants of each species were used. Seeds were pre-germinated and then transplanted in the containers at the end of June 2005. All treatments were watered twice a day.

At the beginning of September 2005, the plants from each treatment were removed and plant height, root collar diameter were measured. Shoot systems were severed at the root collar, then root systems were washed and dried separately with the above part to constant weight at 90°C during 48 h. The seedling quality and performance attributes were assessed through three main indexes: Shoot:root dry weight ratio, sturdiness quotient (height (cm)/root collar diameter (mm)), Dickson's Quality Index

(Dicksen et al., 1960). Dickson's Quality Index was calculated as followed:

$$\text{Quality index} = \frac{\text{Seedling dry weight (g)}}{\dfrac{\text{Height (cm)}}{\text{Root collar diameter (mm)}} + \dfrac{\text{Shoot weight (g)}}{\text{Root weight (g)}}} \qquad \text{Eq. 1}$$

The values of the generated indexes were subjected to ANOVA General Linear Model (GLM) using Minitab Software package.

Results

G. sepium displayed the lower values of the sturdiness quotient (height:collar diameter) followed by *A. africana*, the two *Leucaena* and the two acacias (Table 32). The analysis of this parameter per species showed a significant higher value for the ordinary nursery substrate compared to the sand in *A. africana, A. angustissima, G. sepium, L. hybrid,* and *L. leucocephala*. No inoculation effect was noted for *A. africana, A. angustissima,* and *L. leucocephala* whereas *A. mangium* showed higher value when inoculated (Table 32). *G. sepium,* and *L. hybrid* showed higher values when inoculated but only with the ordinary nursery substrate whereas *L. hybrid* showed the opposite on the sand substrate. No pot effect was noted for *A. Africana, A. angustissima, G. sepium, L. hybrid* and *L. leucocephala.* In turn, *A. mangium* displayed lower value when raised in small pots.

Table 32 Planting stock quality assessed by Sturdiness Quotient for five introduced and one local species in Burkina Faso, West Africa

Species	Substrate	Pot size	Non-inoculated	Inoculated	Mean
A. africana	Ordinary substrate	Big	3.8	4.2	4.0
A. africana	Ordinary substrate	Small	4.4	4.7	4.6
A. africana	Sand	Big	3.4	3.8	3.6
A. africana	Sand	Small	4.0	3.8	3.9
A. angustissima	Ordinary substrate	Big	13.1	15.4	14.3
A. angustissima	Ordinary substrate	Small	14.1	16.7	15.4
A. angustissima	Sand	Big	9.4	8.6	9.0
A. angustissima	Sand	Small	10.7	9.7	10.3
A. mangium	Ordinary substrate	Big	7.0	8.0	7.5
A. mangium	Ordinary substrate	Small	7.8	9.3	8.6
A. mangium	Sand	Big	7.8	7.8	7.8
A. mangium	Sand	Small	8.5	9.1	8.8
G. sepium	Ordinary substrate	Big	4.3	5.3	4.8
G. sepium	Ordinary substrate	Small	3.8	5.3	4.6
G. sepium	Sand	Big	3.1	2.8	2.9
G. sepium	Sand	Small	2.6	3.0	2.8
L. hybrid	Ordinary substrate	Big	5.9	10.0	8.0
L. hybrid	Ordinary substrate	Small	6.8	8.7	7.8
L. hybrid	Sand	Big	6.1	4.4	5.3
L. hybrid	Sand	Small	6.0	3.9	5.0
L. leucocephala	Ordinary substrate	Big	7.6	7.5	7.5
L. leucocephala	Ordinary substrate	Small	7.6	7.6	7.6
L. leucocephala	Sand	Big	5.5	5.8	5.7
L. leucocephala	Sand	Small	5.9	4.5	5.2

The two acacias displayed the highest shoot:root ratios followed by *G. sepium, L. leucocephala, L. hybrid* and *A. africana* (Table 33). *A. africana* did not show significant difference according to the level of inoculation for shoot:root ratio on sand while the value of this parameter was higher on the ordinary nursery substrate. In turn, *A. mangium* showed significant difference according to the level of inoculation for shoot:root ratio on sand while the difference was not significant on the ordinary nursery substrate (Table 33). *G. sepium, L. hybrid* displayed higher shoot:ratio on ordinary nursery substrate compared to the sand and *G. sepium* had higher value in this parameter when inoculated compared to non-inoculated plants. Shoot:root value was significant lower in big pots for *A. africana.* Inoculation induced a significant higher value of shoot:root ratio on ordinary nursery substrate when inoculated and the opposite on the sand substrate for *A. angustissima. A. africana* gave significant lower value of shoot:root ratio in big containers compared to small ones. *L. leucocephala* showed the opposite but only on the ordinary nursery substrate. No significant effect of container size was observed for this parameter with *A. angustissima, A. mangium, L. hybrid, L. leucocephala.*

Table 33 Planting stock quality assessed by Shoot:Root ratio for five introduced and one local species in Burkina Faso, West Africa

Species	Substrate	Pot size	Non-inoculated	Inoculated	Mean
A. africana	Ordinary substrate	Big	1.7	2.0	1.8
A. africana	Ordinary substrate	Small	1.8	2.4	2.1
A. africana	Sand	Big	1.2	1.2	1.2
A. africana	Sand	Small	1.8	1.7	1.8
A. angustissima	Ordinary substrate	Big	4.7	5.9	5.3
A. angustissima	Ordinary substrate	Small	4.0	6.5	5.3
A. angustissima	Sand	Big	4.9	2.5	3.7
A. angustissima	Sand	Small	4.9	2.8	4.0
A. mangium	Ordinary substrate	Big	5.5	5.8	5.7
A. mangium	Ordinary substrate	Small	5.6	4.6	5.1
A. mangium	Sand	Big	1.8	4.1	3.2
A. mangium	Sand	Small	1.7	4.2	2.9
G. sepium	Ordinary substrate	Big	2.9	4.4	3.7
G. sepium	Ordinary substrate	Small	2.4	3.8	3.1
G. sepium	Sand	Big	1.4	1.8	1.6
G. sepium	Sand	Small	1.1	1.5	1.3
L. hybrid	Ordinary substrate	Big	2.7	2.9	2.8
L. hybrid	Ordinary substrate	Small	2.5	2.5	2.5
L. hybrid	Sand	Big	1.5	1.6	1.6
L. hybrid	Sand	Small	1.5	1.6	1.6
L. leucocephala	Ordinary substrate	Big	3.0	2.2	2.6
L. leucocephala	Ordinary substrate	Small	2.1	2.0	2.1
L. leucocephala	Sand	Big	2.1	1.6	1.8
L. leucocephala	Sand	Small	2.2	2.1	2.1

The two acacias displayed the lowest Dickson's Quality Index values followed by the two *Leucaena*s, *G. sepium* and *A. africana* (Table 34). The value of quality index was higher for inoculated plants compared with the non-inoculation in *A. africana*, in ordinary nursery substrate when compared with sand substrate in *A. angustissima*, in big containers when compared with small ones in *A. angustissima*. No significant effect of substrate and container size was noted on the quality index for *A. africana*. There were significant interactions between substrate and container size for *A. mangium, G. sepium, L. hybrid.* Thus Dickson's Quality Index values were higher in big pots with the ordinary nursery substrate whereas no significant difference was found between big and small pots with sand. Similarly, there was significant interaction between substrate and inoculation for *G. sepium*. Therefore Dickson's Quality Index value was higher in inoculated plants with the ordinary nursery substrate whereas no significant difference was found between big and small pots with sand. Quality index value was also higher in big pots when the plants of *G. sepium* were inoculated with no difference between container sizes when not inoculated. A significant interaction was noticed between substrate, inoculation and container size in *L. leucocephala*. Thus significant higher values of Dickson's Quality Index were observed in ordinary nursery substrate for inoculated plants as well as in big pots for inoculated plants (Table 34).

Table 34 Planting stock quality assessed by Dickson's Quality Index for five introduced and one local species in Burkina Faso, West Africa

Species	Substrate	Pot size	Non-inoculated	Inoculated	Mean
A. africana	Ordinary substrate	G	0.815	0.584	0.700
A. africana	Ordinary substrate	p	0.712	0.386	0.560
A. africana	Sand	G	0.899	0.720	0.815
A. africana	Sand	p	0.819	0.704	0.765
A. angustissima	Ordinary substrate	G	0.160	0.114	0.136
A. angustissima	Ordinary substrate	p	0.072	0.052	0.062
A. angustissima	Sand	G	0.011	0.012	0.012
A. angustissima	Sand	p	0.005	0.005	0.005
A. mangium	Ordinary substrate	G	0.182	0.147	0.164
A. mangium	Ordinary substrate	p	0.123	0.099	0.111
A. mangium	Sand	G	0.018	0.019	0.018
A. mangium	Sand	p	0.017	0.012	0.015
G. sepium	Ordinary substrate	G	1.122	0.644	0.883
G. sepium	Ordinary substrate	p	0.592	0.379	0.486
G. sepium	Sand	G	0.275	0.210	0.242
G. sepium	Sand	p	0.248	0.245	0.247
L. hybrid	Ordinary substrate	G	0.481	0.604	0.543
L. hybrid	Ordinary substrate	p	0.288	0.330	0.309
L. hybrid	Sand	G	0.113	0.126	0.120
L. hybrid	Sand	p	0.080	0.117	0.099
L. leucocephala	Ordinary substrate	G	0.643	1.056	0.849
L. leucocephala	Ordinary substrate	p	0.414	0.454	0.434
L. leucocephala	Sand	G	0.157	0.139	0.148
L. leucocephala	Sand	p	0.128	0.120	0.124

Conclusion

Calculations of sturdiness quotient, and shoot: root ratios showed that these parameters usually had lowest values while Dickson's quality index had highest values. Furthermore, there are many interactions between factors that do not ease the interpretation of the results at the nursery. The experiment now needs to be extended to field conditions to determine plant performance after outplanting and the way these indexes should interpreted in irrigated conditions.

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Training and dissemination activities

Nursery studies were conducted by M. Lawa-Pan Paulin Honoré DRABO as part of his engineer degree (MSc equivalent). This degree was defended successfully on December 2005, at Katibougou (Mali).

A documentary film on the UBENEFIT project is being done (2/3 completed at this stage).
Two lectures on water treatment & utilisation by SCP (represented by Mme F. Bourroulet) were organised at the University of Ouagadougou.

Partner 5

Sanoussi Atta, Zoubeirou M. Alzouma, Germaine Ibro, Marafa Dahiratou Ibrahim, Mahamane Sani Laouali, Mahamane Saadou.

Introduction

During this third year of the project, a functioning waste water treatment and irrigation system was established. The second experiment was carried out. The sap flow measurements have also been measurements on plant from the first experiment. The physical and chemical characteristics of soil from the site were also analyzed. The socio-economic questionnaires were achieved and applied.

WP 1. Water irrigation and treatment

The station for water purification is now fully functioning (Plate 9). The final system of water purification is a lagoon accompanied with gravel filtration. Therefore the last basin contains about 1m of gravel and 30 cm of sand for water purification. Two pumps, one pump for waste water and the second one for irrigation, have been installed. Thereafter the irrigation system feeds the plants with purified water. The daily duration of irrigation has been calculated so that each plant receives 6 litres of water per day. Waste-water analyses have not yet been conducted because the chemicals for the analysis have not yet been obtained.

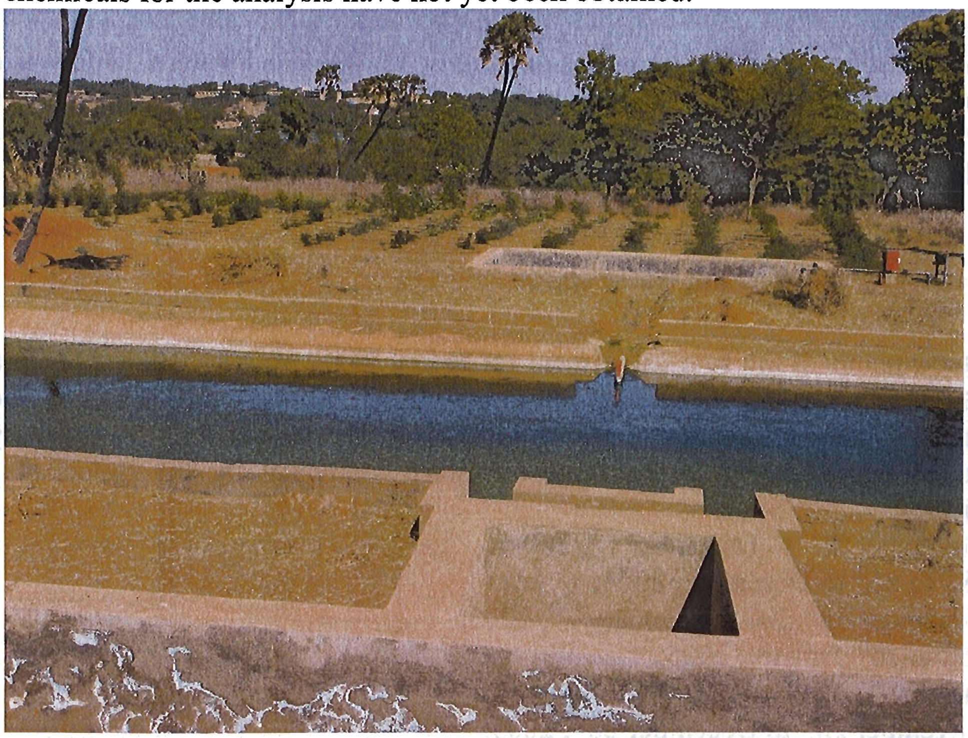

Plate 9 View of the water treatment facility with irrigation trials in the background

WP 2 and 4. Tree growth, management, and microsymbionts

The nursery phase for the second experiment, which aims to compare the growth of tree species under irrigated field conditions, began at the end of March 2005. Seed of five species were used : *Acacia angustissima, A. crassicarpa, A. seyal, Gliricidia sepium and Leucaena leucocephala.* Seeds were disinfected with 95°alcohol, then washed with sterilized water. After that, seeds were treated with sulfuric acid for different durations according to the species:

- *Leucaena leucocephala :* 15 mn;
- *Acacia angustissima* : 20 mn;
- *A. crassicarpa* : 25 mn;
- *A. seyal :* 30 mn;

Subsequently, seeds of all species were soaked in sterilized water for 8 hours and sown. The germination occurred after 2 days for *Acacia angustissima, A. seyal, Gliricidia sepium and Leucaena leucocephala* and 4 days for *A. crassicarpa.*

Thereafter, seeds were transferred into pots and inoculated with mycorrhiza on April 11, 2005. The inoculation with rhizobia strains (4 ml of inoculum/tree) was done on May 5, 2005 with the following inoculum strains:

- *Leucaena leucocephala :* LDK4;
- *Acacia angustissima* : 11c + ORS 324;
- *A. crassicarpa* : 11c;
- *A. seyal :* ORS 3324;
- *Gliricidia sepium :* GSK4.

Plants in pots were protected against insects with a mosquito net.

Plants were transferred to field conditions on August 13, 2005 and watered with waste water. Thereafter, the following measurements were carried out during plant growth for all species at weekly intervals: stem diameter, total plant height, total number of leaves. These data have not yet been analysed.

WP 3. Tree water use and soil water status

After nursery, plants of the first experiment (cf report 2004) were transferred to field conditions on May, 2004. Thereafter, the variation of sap flow according to the species and the whether conditions was studied from November 2004 to February 2005. Six (6) sets of sap flow measurements were conducted for the eleven (11) studied species:

1. from November 26th to December 7th, 2004;
2. from 18th to 26th to December, 2004;
3. from December 29^{th,} 2004 to January 7th, 2005;
4. from 16th to 25th January, 2005;
5. from January 27th to February 5th, 2005;
6. from November 26th to December 28th, 2005;

Sap flow of one plant of each species was studied over 10 days (1 day without power). Sap flow and meterological data were collected daily. Plants identified for this study were watered with waste water (6 liter/tree) during one week and during the sap flow measurements. At the same time, the soil water status was also determined using a profile probe.

WP 5. Economics and quality of produce

At the meeting held in Ouagadougou from May 3-4, 2005, Mrs Germaine Ibro, who is coordinating this work package, has registered the comments of her socio economic colleagues. Thereafter she elaborated a final version of questionnaires (Annex 2). These questionnaires are related to different aspects of wood production and commercialization such as :

- Production and commercialization of wood;
- Wood energy timber: questionnaire to wood cutters, wood sellers, and wood dealers.
- Utilization of energy source by householders;
- Description of actual system of fuel wood production

Objectives

The major objectives of the survey on wood trade are: the assessment of the samplings for Niamey urban centre, the knowledge of the supply and trading system of fuel wood, the knowledge of all the actors and profit margins made at each level.

Methodologies

Four types of questionnaires were administered to the main participants of the fuel wood industry: the woodcutters, the transporters, the retailers and the households.
Considering the importance of the supply routes of Niamey, the survey of the woodcutters concerned only three of the major routes because of the limited funds at our disposal.
Thirteen very mobile secondary routes whose purpose is to enable defrauders to escape the forest rangers' checkpoints were also identified. These routes are used by the non-motorised transporters who directly supply households or some sale outlets.
The second survey dealt with the transporters who travel to wood cutting areas to buy wood in order to resell it to retailers in Niamey.
The third category of the survey was concerned with the retailers who take over the marketing relay of wood marketing in the city.
In order to understand the aspects of wood consumption, another survey was carried out with the households who are the last participants in the fuel wood trade.

Characteristics of the operators

The survey conducted with the woodcutters showed that all the men were on the average aged 35 with a maximum age of 53. 89% of them are married; however, 11% are bachelors.
As far as education level is concerned, the majority of the woodcutters are illiterate, because 41% have never been to school, 26% attended a quranic school, 19% attended primary school, 15% were able to reach secondary school.

They are the heads of large families with an average of 4 persons and a maximum of 22 people. The average family has three men, three women and four children. The largest families have 7 men, 7 women and 10 children.

On the average, wood trade has been carried out by woodcutters for over 14 years. The most experienced traders have been practising this activity for more than 40 years.

The sources of wood supply

The unique sources of wood supply are the natural forests. Woodcutting is organised on an individual basis.

Woodcutters are allowed to cut live wood according to areas, dry wood only or both; according to whether he operates in a controlled or uncontrolled system.

Wood cutting is selective and is followed by a certain number of sustainable natural resources management (protection of young plants cut by area, plantation).

The different periods of woodcutting and the rationales

Woodcutting by wood-cutters is essentially carried out in two periods of the year. During the dry and cold season, 52% of the woodcutters take advantage of this period of inactivity to restock their wood supply in the local markets. The second category of woodcutters cuts wood at any period of the year according to their material needs.

The rationales for this organization are varied but one can retain: the need to have additional revenues to cover the period of hardship during which the granaries are empty and the crops not yet ripe, for the woodcutters who cut all the year round. Those who collect wood during the cold season when there are fewer demands on their time (lack of field work) but they also believe that this is the period which enables an easy regeneration of the trees and the roads are more passable in the dry season.

An average of 27 steres of wood per woodcutter is cut each month. This quantity varies according to the availability of the family labour and transportation (cart). According to the survey, this figure can fluctuate between 5 and 68 steres monthly and per woodcutter. Each village can have about 40 to 80 woodcutters.
Woodcutting is within the scope of men's activities; children follow them in some villages and help them load wood on the carts.

Wood trading is carried out by the rural market manager in 52% of the cases, or by the woodcutter himself.
Woodcutters do not transport wood to town, but they sell it to the transporters who take it to the towns located within a 30 to 50 km radius of the forests.

The major constraints

The principal constraints which the woodcutters face are the periods of poor sales at certain periods of the year and according to their location to the city. During the dry season, the transporters prefer to get their supply from the most remote areas where wood is sold cheaper because of the monopoly they exert on the woodcutters.
Woodcutters from the nearest and easily accessible areas have customers only during the season when the far away areas become impassable. 70% of the woodcutters mentioned this case of slump in sales. This issue is all the more important in that the revenues derived from the wood sale amount to more than 67% of the woodcutter's

revenues. While for more than 20% of the cases, the major problem remains the lack of means to transport wood from the cutting place to the market.

These revenues are used in 66% of the cases to purchase food, clothing (17%), family health care, troutes and other social needs.

The Wood transporters:

The supply routes
The primary routes
There are 7 routes in Niamey. They are the following: Kollo, Dosso, Ouallam, Say, Tillabéry, Torodi and Filingué.
Out of the 7 routes, 76% of the wood comes from a distance between 40 and 80 km. The quantity coming from less than 40 km is 2%, while the one coming from 80 km represents 20%. The pick up trucks get their supply in an 80 km radius around the town. On the primary routes, the carts represent 99.96% of the transportation of illegal wood trade, the Say axis is leading with 44%, followed by Torodi (37%).

The secondary routes
The secondary routes are: Fleuve Saga, Talladjé, Wadata, Airport, Kongou Gorou, Koiratagui, Liboré, Namaro, Fataye, Station avicole (Poultry farm), Lossa Googol, Tondobon, Saguia. On these routes too, the carts are the major means of transportation with 84%, while camels and donkeys only supply 7.93% and 6.97% respectively for the legal trading. The Tondobon axis is the leader, followed by the Station avicole, Fataye, Fleuve Saga and Kongou Gorou with 19%, 13%, 12%, and 8% respectively. As regards the origin of the wood on the secondary routes, there is a relatively identical use of the stretches of the distances in wood collection by the illegal trade, except for the donkey-drivers who collect the essential of their wood load at a distance of less than 20 km.

According to a January 2003 report by the Department of the Environment, the total quantity of wood that came into the town of Niamey is about 188,000 tons of which 95% came through the primary routes and approximately 5% through the secondary routes.

The transport of wood towards Niamey is ensured through two ways: the motorized way which transports 81% of wood and the non motorized means which ensures 19% of the wood traffic towards the city. The motorized way comes in mainly the primary routes where the trucks prevail (93%) whereas the vans ensure 71% of the transport of wood. Passenger and private vehicles transport 3% of the wood to Niamey, in certain routes like Kollo, Filingué and Tillabéry they rank second after the trucks.

As for the non motorized trading, it comes in both the primary routes as the secondary axis, by way of donkey carts, camels, and donkeys.
It carries out approximately 26,341 tons of wood through the primary routes, against 9,219 tons for the secondary routes.

The urban trade in fuel wood
The urban marketing of wood is carried out by male and female retailers. Truck-drivers drive around the main roads of the city to deliver their cargo to the retailers and the households who have the means of storing wood. A survey carried out with these retailers provided interesting information.

Characteristics of the retailers
A survey which was carried out in the town of Niamey gives the following characterization of the wood salespeople.
This trade is carried out to 30% by men and 70% by old women aged 29 to 65 with a mean of 42 years. The group is made up of married men and women but also of widowed or divorced women. 50% of the salespersons do not have any school education and 50% attended Quranic school.
They are heads of fairly large families; from 5 to 13 members. This wood business is the major activity for 80% of them; for the others, it is a secondary activity.

The period of activity
The retailers carry on this activity all the year round for 70% of the salespeople and 30% do it only in the dry season, a period when the truck-drivers' price is more affordable.
Experience in this activity varies between 2 and 19 years. The average length of time spent in the activity is 8 years.
Up to 99% of them are supplied by the truck-drivers on a weekly basis. 30% of the retailers who do not have many customers renew their stock every month.

The type of wood sold
The data collected on the urban wood market highlight the following routes: the products sold, the types of wood sold. It results that in all the communes, fuel wood is the first of the market products, followed by timber and to a lesser extent, charcoal.

It is noted that it is especially wood in bulk which is marketed the most. Firewood bundles are most frequent in Commune III which is the first district at the entrance of Niamey used by the cart-drivers travelling on the secondary routes to which they have in priority.
The type of wood sold shows the consumers' choice but above all the species of trees available in the forests.

The Torodi or Say axis supplies big logs which require splitting prior to being sold, whereas on the Filingué, Ouallam and Tillabéry routes, it is the bundles of firewood which predominate.

Trend in the sale price
The sale prices of a row of wood vary according to the period of the year. During the rainy season, a row of wood costs 35,000 or 40,000 francs.
In the dry season, the retailers buy a row of wood at 30,000 or 32,000 francs maximum.

The consumption of wood in Niamey

A survey on consumption was conducted among the households, namely women who are the prime users of fuel wood in the households. One hundred and seventy seven women aged between 20 and 70 were surveyed.

The sample was made up of 86% married women, 9% of widows, 4% of divorcees and 1% of single women. 34% of these women have not attended school, 28% have primary school level, 18% have attended Quranic School and 16% have secondary school level.
Each household has an average of 5 children (0 to 23). Families are more or less large; they have 2 to 40 members.

The source of energy used
All the households surveyed use fuel wood as a primary source of energy. 3% use butane gas, 2% use kerosene but just for the purposes of heating little quantities of water in the morning or for heating food.

The supply sources
Retailers make up the major supply source of the households in 72% of the cases, followed by cases where the households prefer to buy and stock their wood for a weekly or monthly period.
The budget allocated to the weekly purchase of fuel wood ranges from 700 francs CFA to 17,500 francs CFA monthly, according to the family size and the type of equipment used: 97% of the households reduce their amount of fuel wood.

The species used as fuel wood:

Species used
Consumers mentioned 26 species of ligneous used as fuel wood (Table 35). The most frequently used are sabara, gueza, kiriri, taramnia, kirya, and adoua.

Table 35 Species of ligneous used as fuel wood.

	Haoussa name	Djerma name	Scientific name
1	Sabara	Sabara	*Guiera sénégalensis*
2	Gueza	Kubu	*Combretum micranthum*
3	Adoua	Garbey	*Balanites aegyptiaca*
4	Kirya	Zamtouri	*Prosopis africana*
5	Kiriri	Déligna	*Combretum nigricans*
6	Gao	Gao	*Faidherbia albida*
7	Bagaroua	Baani	*Acacia nilotica*
8	Taramniya	Kokorbé	*Kigelia africana*
9	Lallé	Buburé	*Lawsonia inermis*
10	Kalgo	Kossey	*Piliostigma reticulatum*
11	Daachi	Korombé	*Commiphora africana*
12	Bedi	Milya	
13	Sahel vert	Hasu agahini	*Prosopis*
14	Akkora	Danga	*Acacia laéta*
15	Anza		*Boscia sénégalensis*
16	Danya	Diney	*Sclerocarya birrea*
17	Magaria	Darey	*Ziziphus mauritiana*
18	Dargaza	Saari	*Grewia bicolor*
19	Malga	Sisan	*Cassia sieberiana*
20	Marké	Kanfaley	*Anogeissus leiocarpus*
21	Dirga	Namari	
22	Gwanda	Mufa	*Bauhinia rufescens*
23	Erahi	Sakirey	
24	Tunfafi	Sageye	*Annona arenaria ou S.*
25	Kanya	Tokey	*Acacia seyal*
26	Tamatchi	Samsam barituri	*Calotropis procera*
			Diaspyros mespiliformis
			Acacia tortilis

Six major species are used as fuel wood (Table 36) :

Table 36 Major species used as fuel wood.

Haoussa name	Scientific name	% of answers
Sabara	*Guiera senegalensis*	23
Gueza	*Combretum micranthum*	15
Kiriri	*Combretum nigricans*	14
Taramniya	*Kigelia africana*	11
Kirya	*Prosopis africana*	6
Adoua	*Balanites aegyptiaca*	6

Preferred species

The preferred species which are generally used depend on the supply routes more than the consumer's choices. Nevertheless, the consumers express their preferences which relate to: sabara 52% of the respondants, kiriri 27%, Taramniya 6%, finally gueza, adoua and Kirya which receive the same response rate, i.e. 5%.

WP 6. Soil and plant nutrition

In order to determine the nutrient status of irrigation sites, soil samples where collected on May 21, 2005. Therefore 3 profiles, P1, P2 and P3 were done at approximately 2 m depth according to the heterogeneity of the site. The samples collected from the different horizons were analyzed at Soil lab of ICRISAT for nutrient such as C, N, P, K, Na, Mg, Ca. The results of the analysis are represented in Table 37.

The soil of the experimental site is mainly sandy at level of around 93%. The proportion of loam and clay turn around 2% and 3% respectively (Table 37). In all profiles, the level of organic carbon is very low (under 0.6%) and mainly concentrated in the surface horizon in a small layer (around 13 cm). Thereafter the organic carbon decreased with depth. According to the content of organic carbon the ranking of the three profiles is below : P3 ≥ P2 > P1.

Table 37 Physical and chemical characteristics of soils C, N, P content and pH in various profiles at the Niger site.

Profiles	Depth (cm)	C-org (%)	Total N ($g.kg^{-1}$)	C/N ($g.kg^{-1}$)	Total P ($mg.kg^{-1}$)	pH (H_2O)	pH (KCl)	CEC-Ag cmol+/kg	Sand (%)	Loam (%)	Clay (%)
Profil n°1 (P1)	0-10	0.16	0.162	9.88	190	6.6	5.9	1.68	94.0	3.2	2.8
	10-26	0.09	0.094	9.57	193	6.2	4.9	1.29	95.5	1.7	2.8
	26-47	0.10	0.097	10.31	229	5.7	4.2	2.01	95.1	1.3	3.6
	47-81	0.06	0.063	9.52	193	5.7	4.4	1.07	94.8	1.6	3.6
	81-112	0.05	0.056	8.93	179	5.8	4.6	1.73	94.9	2.2	2.9
	112-141	0.07	0.083	8.43	306	5.9	4.9	4.18	90.3	2.9	6.9
	141-178	0.11	0.180	6.11	435	6.9	5.6	6.76	84.3	3.2	12.5
Profil n°2 (P2)	0-13	0.28	0.313	8.95	258	6.6	5.7	2.28	91.7	4.7	3.6
	13-35	0.09	0.107	8.41	258	5.9	4.3	1.91	92.7	2.7	4.6
	35-57	0.06	0.092	6.52	281	5.3	4.0	1.56	92.0	2.8	5.2
	57-82	0.04	0.063	6.35	223	5.2	3.9	1.85	92.1	2.4	5.5
	82-112	0.04	0.060	6.67	174	5.6	4.2	2.28	92.5	2.6	4.9
	112-143	0.03	0.051	5.88	134	6.3	4.8	1.74	93.6	1.8	4.6
Profil n°3 (P3)	0-11	0.33	0.332	9.94	281	6.6	5.7	2.18	92.5	3.7	3.8
	11-30	0.07	0.081	8.64	171	7.2	6.1	1.60	94.2	2.4	3.4
	30-52	0.08	0.076	10.53	195	7.0	5.9	2.43	92.8	1.8	5.4
	52-74	0.05	0.057	8.77	188	6.5	5.1	2.20	93.5	1.8	4.7
	74-97	0.04	0.052	7.69	189	7.0	5.3	1.85	93.6	1.4	5.0
	97-126	0.04	0.082	4.88	217	6.7	5.2	3.99	89.2	1.5	9.3
	126-162	0.04	0.088	4.55	236	7.0	5.3	4.98	87.6	1.4	11.0

Like organic carbon, the level of total N is very low in all profiles (< 0.05%) and concentrated in a small layer in the surface horizon. However, with a pH of 6.6. the surface horizon of profiles P2 and P3 had a moderate nitrogen content indicating good conditions for mineralization. The value of the ratio C/N for all horizons is low. This indicates mineralized soil with a low organic matter. Therefore the soil of the site is exhausted. For total P, all profiles indicated a level of deficiency, between 200 and 600 $mg.kg^{-1}$. The lowest values of total P content (< 200 $mg.kg^{-1}$) occurred at the surface horizon of P1. All profiles showed a neutral pH (H_2O) on the surface. For P1 and P2 profiles, the pH become slightly to highly acid with depth before becoming again slightly acid to neutral in the deepest horizons. However for P3, the pH (H_2O)

remained neutral in the whole profile. Therefore for these soils, the assimilability of nutrients is maximum on the surface than decreases with depth for P1 and P2 profiles, but remains steady for P3. The pH (KCl) is slightly acid in surface and become highly to very highly acid with depth. The value of the difference between pH (H_2O) and pH (KCl) with is equal or superior to one unit of pH indicated that the soil has a high acidity of exchange probably due to a high content of exchangeable aluminum. The CEC is very low (< 5 cmol+/kg) in all horizons of the 3 studied profiles except in the deepest horizon (141-178 cm) of P1 where a value of 6.76 was recorded. This indicates a soil with a low absorbent complex and which is therefore poor. For the exchangeable calcium (Figure 23), all profiles showed mean to high content of Ca2+ which remained steady with depth for P2 but increased for P1 and P3. These results indicated that the soil of the site has a good content of exchangeable calcium.

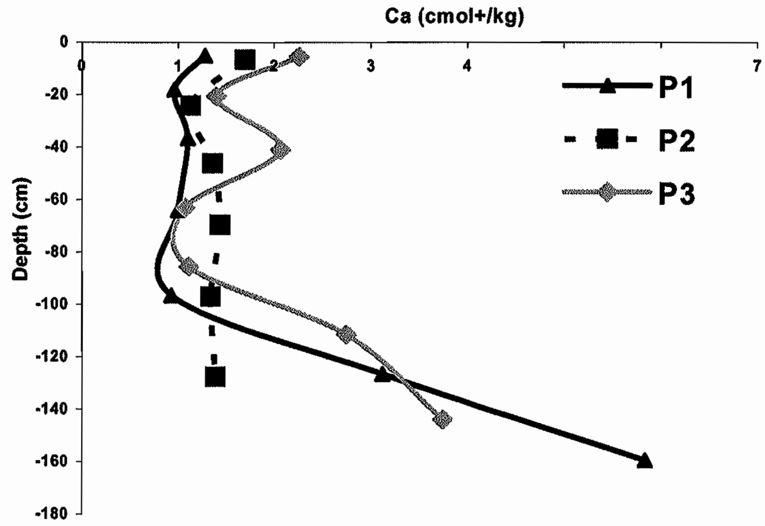

Figure 23 Variation of calcium content according to soil depth in 3 profiles of the UBENEFIT site

In all profiles, the level of exchangeable magnesium (Figure 24) is high, and increases with depth, particularly for profiles P1 and P3.

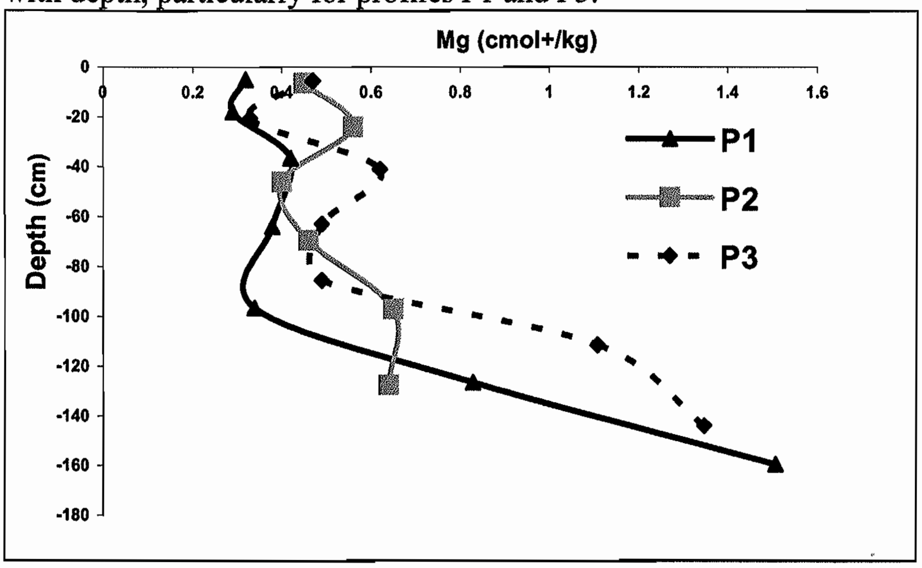

Figure 24 Variation of magnesium content according to soil depth in 3 profiles of the UBENEFIT site

Like magnesium, the level of exchangeable potassium (Figure 25) is high to very high in all profiles. Thereafter, the potassium content seemed to decrease slightly with depth in P2 while it increased dramatically at a 100 cm depth for P1 and particularly for P3. The balance between the main nutrients Ca, Mg and K is optimal in all profiles.

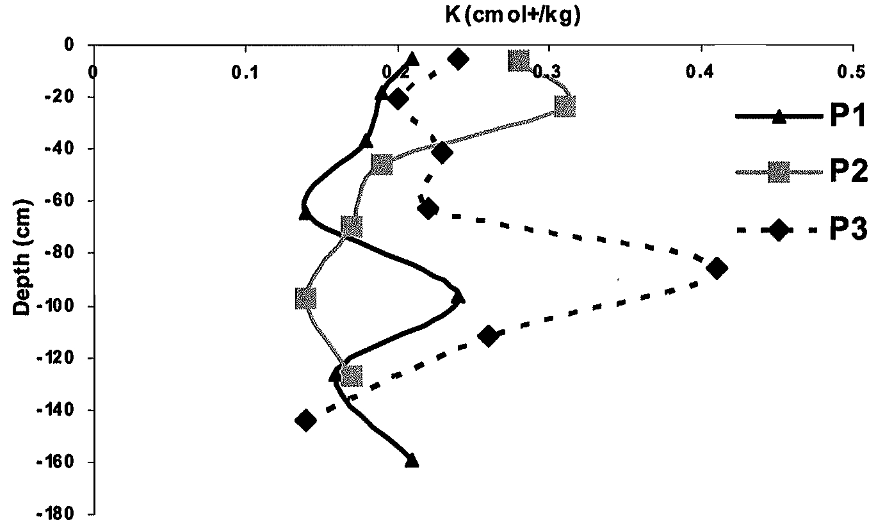

Figure 25 Variation of potassium content according to soil depth in 3 profiles of the UBENEFIT site

The content of exchangeable Na is low for the profiles in all horizons except for P3 which has a middle content in the deeper horizons (Figure 26).

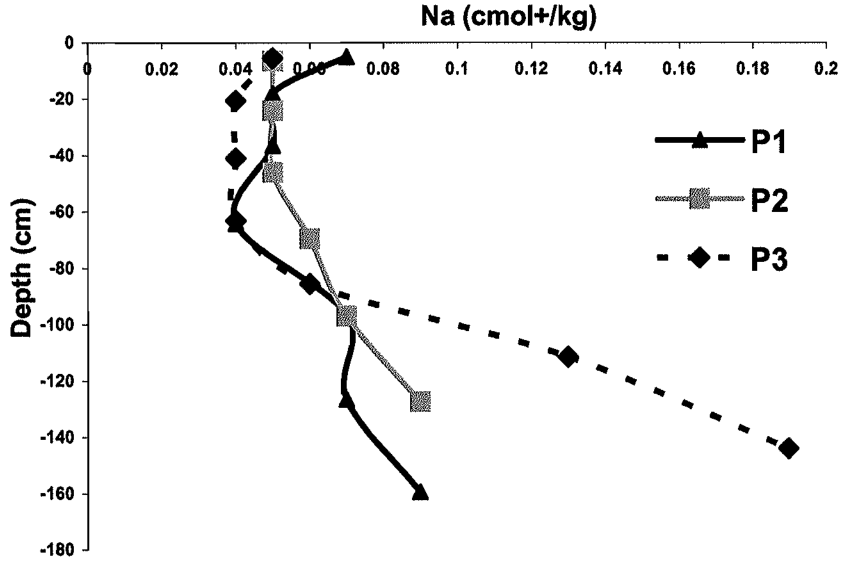

Figure 26 Variation of sodium content according to soil depth in 3 profiles of the UBENEFIT site

PARTICIPATION TO THE THIRD COORDINATION MEETING AT OUAGA

Mrs Germaine Ibro and Mr Sanoussi Atta have attended to the third coordination meeting held in Ouagadou (Burkina Faso) from 3 to 4 May, 2005. During this meeting, some preliminary results of sap flow measurements and soil water status were presented. In addition, the participants were also informed in the progress registered in Niger in the different work packages of the Project.

VISIT OF FRANCOISE BOUROULET FROM SCP

From November 28th to December 3th, from the Sociélé Canal de Provence has visited the station of purification of waste water of Niger. The discussion with Françoise revealed that the actual system of water purification is a lagoon accompanied with a filtration on gravel.

PROBLEMS AND DIFFICULTIES

The main problem was the delay in the second payment of the project. Therefore the lack of money slowed our activities, and moreover didn't' allowed us to order the irrigation equipment at time.

PLAN OF ACTIVITIES

-The measurements of plant growth in field conditions using parameters such as stem diameter, plant height and number of leaves will be pursued ;
- The test of pruning will be carried out when plant will have sufficient growth;
- The third experiment of the project will also be carried out.

Partner 6 IRD

Tatiana Krasova-Wade and Marc Neyra

Due to the serious delays for the purchase of items for water treatment and irrigation, and subsequent delays for establishing experimental trials of fuelwood and fodder trees at irrigated sites in Mali, Burkina Faso and Niger, part of the work dedicated to IRD was not possible (in particular, verification, in collaboration with Partners 3, 4 and 5, of persistence of inoculant and "wild type" strains in the field). During this period, work focused on development of molecular techniques, especially to improve and test a reproductive, safe and rapid method to isolate DNA from nodules of the different legume species targeted in this project.

Work package 4 (Microsymbionts and Nitrogen-Fixation)

Development of molecular techniques

Nodules of woody legumes were previously obtained by inoculation with their corresponding strains: Aust 13C for *A. mangium*, Aust 13C for *A. crassicarpa*, Aust 11C for *A. auriculiformis*, mixture of CIRAD 300, 301 and 302 for *A. senegal*, LDK4 for *Leucaena leucocephala*. DNA of the tree nodules was obtained by the improved DNA extraction method (Guanidine Thiocyanate 0.0005 M and 15 min incubation at 65°C) described in the previous report.

To test the quality of extracted DNA for PCR amplification, two 16S-23S rDNA IGS prokaryotic specific primer FGPS1490-72 (5'-TGCGGCTGGATCCCCTCCTT-3') (Normand *et al.*, 1996) and FGPL132-38 (5'-CCGGGTTTCCCCATTCGG-3') (Normand *et al.*, 1992) designed from conserved regions of rrs and rrl sequences of *Frankia* sp. were used for PCR amplification of 16S-23S rDNA IGS region. PCR was carried out in 25 µl reaction volume containing 50 ng of pure total DNA extract, one dried bead (Ready-to-Go PCR beads, Pharmacia Biotech) containing 1.5 U of *Taq* polymerase, 10 mM Tris-HCl, (pH 9 at room temperature), 50 mM KCl, 1.5 mM $MgCl_2$, 200 µM of each dNTP and 2.5 µl of each primer (1 µM). PCR amplification was performed in a GeneAmp PCR System 2400 (Perkin Elmer) thermal cycler adjusted to the following temperature profile: initial denaturation at 95°C for 5 min; 35 amplification cycles of denaturation at 95°C for 30 sec, annealing at 55°C for 30 sec, and extension at 72°C for 1 min; and final extension at 72°C for 7 min.

The extracted DNA has been amplified. However, PCR yielded multiple IGS PCR products (Figure 27). The bands around 1000 bp size correspond to the sizes of amplified 16S-23S rDNA IGS product of inoculated strains (data not shown), whereas the lower bands could correspond to non-specifically primers binding. This can be due to high DNA quantity used for PCR or to not sufficiently stringent PCR conditions (annealing at 55°C), inducing random amplification of non-targeted DNA zones.

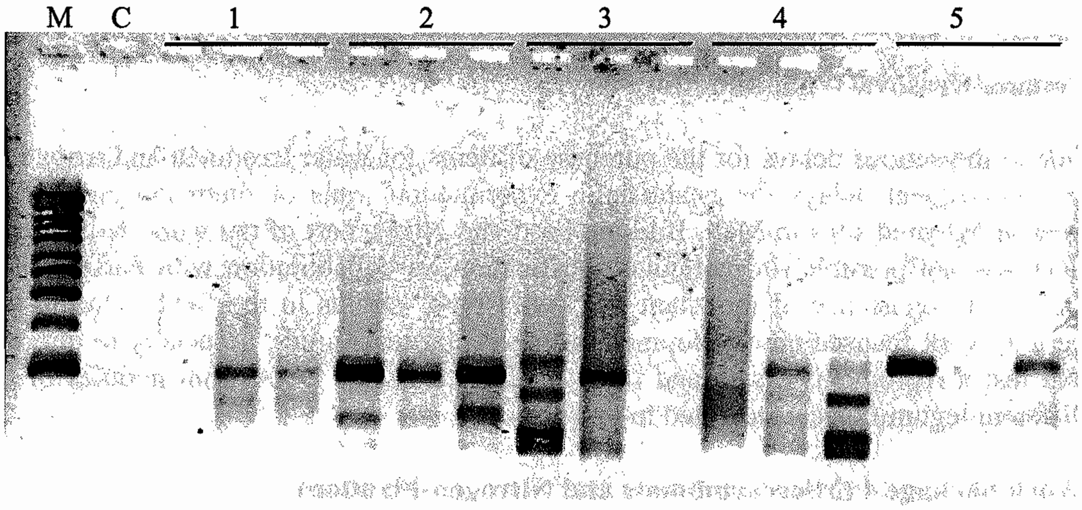

Figure 27. Gel electrophoresis of amplified 16S-23S rDNA obtained on individual crushed nodules of *A. mangium* (1), *A. crassicarapa* (2), *A. auriculiformis* (3), *A. senegal* (4), *Leucaena leucocephala* (5) .

Lane M, 1 kb size marker (Pharmacia Biotech); C, PCR control

To improve these results, further studies have been performed on more diluted DNA, with different primers concentrations and at more stringent annealing temperatures. PCR was carried out as previously, expected for concentration of primers FGPS1490-72 and FGPL132-38 (1.25 or 2.5 µl of each, corresponding to 0.5 or 1 µM final concentration) and annealing temperature (55°C or 58°C for 30 sec).

With combination of different parameters presented in Table 38, the quality of PCR product has been improved (Figure 28). According to plant species, it was possible on account of primer's annealing temperature (*A. crassicarpa*, *A. mangium*) or primer's concentration (*A. senegal*) or increasing of DNA dilution (*A. auriculiformis, A. senegal*, *A. mangium*).

Table 38. Comparison of different PCR conditions

Tree species	Primers annealing temperature (°C)		Primers concentration (µM)		DNA dilution	
	First	Final	First	Final	First	Final
Acacia auriculiformis	55	55	0.5	0.5	4th	10th
A. crassicarpa	55	58	0.5	0.5	3rd	3rd
A. senegal	55	55	0.5	1.0	2	5th
A. mangium	55	58	0.5	0.5	4th	7th
A. anguistissima	55	55	0.5	0.5	20th	20th
Leucaena leucocephala	55	55	0.5	0.5	3rd	3rd
Gliricidia sepium	55	55	0.5	0.5	20th	20th

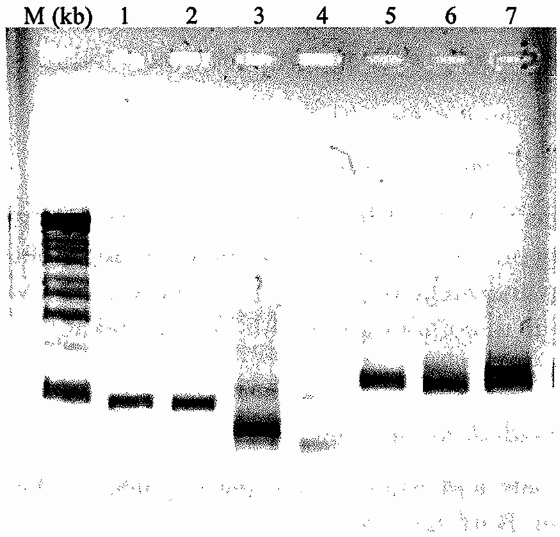

Figure 28 PCR electrophoresis of 16S-23S IGS rDNA of total DNA isolated from nodules of different tree legumes. Lanes M, KiloBase DNA Marker; 1 to 7, individual nodules of *Acacia auriculiformis*, *A. crassicarpa*, *A. senegal*, *A. mangium*, *A. anguistissima*, *Leucaena leucocephala*, and *Gliricidia sepium*

DNA probe design for inoculants

16S-23S rDNA IGS region of selected rhizobia strains Aust 11 C and Aust 13 C were entirely sequenced. The sequences of the strains GsK4 and LdK4 were partially obtained. A complete sequencing will be finished later. The sequences of Aust 11C and 13C were used for development of strain-specific DNA probes. The specificity of the probes was checked by alignments of their sequences with those available in laboratory and in international GenBank database by using the algorithm BLAST (Altschul *et al.*, 1997). The designed specific probes are presented in Table 39.

Table 39 Designed probes

Probe	Target strain	Sequence 5' - 3'	% G+C[a]	l[b]
Aust 13C	Aust 13C	CGCTTGTTCATCGCGGCTCATCG	61	23
Aust 11C	Aust 11C	GGTGAGCGGGTTGTAAATGATCCC	54	24

[a]G/C content of the oligonucleotide;

[b]l is the length of the oligonucleotide

These probes are being actually in synthesis with a 5', 3' and internal Dig-labeling.

The specific hybridization conditions will be determined empirically by probe hybridization on strain DNA on the basis of calculated hybridization temperature as a starting point. The best stringent conditions will be tested further on DNA extracted from crushed nodules that have been formed by the corresponding strain.

Training of scientists from developing countries

Falaye Kanté (partner 3, Univ. Mali) spent six months (from July to December 2005) in LCM for training on DNA characterization of nodules obtained in nursery trials on plants inoculated with selected strains in conditions of wastewater irrigations, by PCR-RFLP technique in collaboration with IRD in Dakar.

Participation to coordination meeting

Tatiana Krasova-Wade and Marc Neyra participated to the annual meeting held in May in Ougadougou, Burkina-Faso.

Publication in refereed international scientific literature

The results obtained on the optimization of DNA extraction procedure is under submission to BioTechniques (T. Krasova-Wade and M. Neyra, Optimization of DNA isolation from legume nodules).

Work to be done in the next months

According to the the extension for one year of the project, which has been agreed due to the delays in setting up the irrigation systems and field plantings requiring the irrigation systems, we shall realize the work which was devoted to IRD in these aspects. In particular, in collaboration with partners 3, 4 and 5, we shall study the effects of wastewater on rhizobia survival and effectiveness in field studies.

References

Altschul SF, Madden TL, Schäffer AA, Zhang J, Zhang Z, Miller W., and Lipman DJ (1997) Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. Nucleic Acids Res 25:3389-3402.

Normand P, Cournoyer B, Simonet P, Nazaret S (1992) Analysis of a ribosomal RNA operon in the actinomycete *Frankia*. Gene 111:119-124.

Normand P, Ponsonnet C, Nesme X, Neyra M, and Simonet P (1996) ITS analysis of procaryotes. Molec Microbial Ecology Manual 3.4.5:1-12.

Annex 1

Minutes and action points of the UBENEFIT meeting, May 3 – 4 2005, INERA, Burkina Faso

The meeting was opened by Julia Wilson (Coordinator) and M. Boly, Director of INERA. M. Boly stressed the importance of the north-south collaboration, the relevance of the project to the region and the wider world in terms of evaluating the growth of trees under irrigation, and declared the meeting open.

Administration
Julia Wilson commenced with a brief summary of the administrative situation and reminded colleagues of the importance of sending both cost statements and annual reports on time and to a high quality so that it is not necessary to ask partners for clarification and correction. The EU will not start to examine the cost statements until the technical report has also been received. Some partners are ignoring instructions and sending inaccurate information in the wrong format. This is creating delays for everyone.

The scientific meeting was then opened. The presentations followed the order in the programme (attached). The notes below record the action points and time frame for deliverables (using deliverables as defined in the Technical Annex).

WP1. **Water treatment and irrigation**

a) Partners in Mali need to agree the noticeboard of the experiment and ensure that the funding of the EU is acknowledged.
b) The purchase of pumps was discussed by Niger and Burkina. Please can they continue to liaise over this issue.
c) Deliverable 1.1 (three functioning wastewater treatment systems established)
   Mali complete
   Niger will be complete end of May 2005
   Burkina will be complete middle of June 2005
d) Deliverable 1.2 (three functioning irrigation systems established)
   Mali complete
   Niger middle of June 2005
   Burkina middle of June 2005
e) Deliverable 1.3 (workshop to train DC partners in wastewater recycling and irrigation techniques)
   Combined visit by SCP to be arranged

WP2 Tree growth and management

a) There were many questions about nursery practice. In the absence of functioning water treatment plants, what water should be used for irrigation in the nursery? It was agreed that partners should be pragmatic about this and adopt the most sensible approach for their circumstances. <u>But they must record what they did.</u> The importance of assessing mycorrhizal formation at the time of planting was stressed, to enable the benefits of nursery inoculation to be assessed.
b) Deliverable 2.1 (multi-species trials established on the three irrigation sites)
   Mali established by the end of May
   Niger established by the end of July

Burkina established by the end of July (grown with tap water)

c) Deliverables 2.2 – 2.5 cannot be completed until 2.1 is completed.

WP3 Tree water use and soil water status

a) there were questions about the soil water data presented by Dr Atta. It would be interesting to check the site-specific calibration against the manufacturer's calibration. There is a possibility that the sensor at 40cm depth is not functioning correctly.

b) There were discussions about the difficulties of replicating sapflow measurements when several tree species need to be measured. If between-species comparisons are required the species must be measured at the same time because meteorological conditions may vary. One possible approach is to have a single tree species used as a standard throughout the experimental runs, and to measure the behaviour of other tree species against this.

c) Deliverable 3.1 (annual reports on tree water-use efficiency in production)

Niger preliminary data being processed
Mali data collection commencing
Burkina work not yet commenced

d) Deliverable 3.2 (simple irrigation-needs model developed)

Not yet commenced

e) Deliverable 3.3 (training on plant water use monitoring techniques)

Niger completed
Mali completed
Burkina will be completed in 2006

WP4 Microsymbionts and N fixation

a) there was a discussion about the use of single strain inoculants or mixtures. All partners are using a mixture of mycorrhizal inoculants in field experiments. One problem with this is that it is being cultured as a mixture, rather than as separate species. It is possible that the species balance will change as some species sporulate more than others. It would have been better to maintain cultures separately and mix them before use.

b) Deliverable 4.1 (development of strain-specific DNA probes)

IRD will be completed by the end of June 2005

c) Deliverable 4.2 (definition of soil inoculum potential for rhizobia and mycorrhiza)

SOME EXPERIMENTS NEED TO BE CONDUCTED TO MEASURE INOCULUM POTENTIAL AT YOUR IRRIGATED SITES.

d) Deliverable 4.3 (report on effectiveness of indigenous strains in irrigated conditions) linked with 4.2 and requires experiments to be planted at field sites with inoculated and non-inoculated plants, plant growth to be determined and infection assessed. Not yet done

e) Deliverable 4.4 (Report on effectiveness of introduced strains in irrigated conditions)

Work in progress, several partners (depending on experimental design, work may be combined with 4.2 and 4.3

f) Deliverable 4.5 (report on DNA profiles of new effective isolates)

Nearly complete IRD

g) Deliverable 4.6 (Report on field N fixation)

This activity was discussed. The methods detailed in the proposal are inappropriate and alternative methods are unreliable. For this project, the best measure is good plant growth and it was decided that field N fixation measurements would not be made.

h) Deliverable 4.7 (new effective microsymbionts for irrigated conditions characterised and stored)
   In progress
i) Deliverable 4.8 (training of DC researchers in molecular biological techniques completed)
   In progress

WP5 Economics

a) deliverable 5.1 (report on costs and sociological aspects of existing production chains)

Niger	completed end of July
Burkina	completed end of October
Mali	completed end of July

b) deliverable 5.2 (information package developed)

Mali	a film has been produced

c) deliverable 5.3 (evaluation of socioeconomic implications of change)

Niger	completed end of October 2005

d) deliverables 5.4 – 5.8 awaiting establishment of plantations

WP6 Soil and Plant nutrition

a) deliverable 6.1 (report on nutrient status of irrigation water – pre and post treatment) all partners initial measurements complete, new measurements ongoing
b) deliverable 6.2 (report on soil nutrient status of irrigation sites)
   Mali complete
   Niger and Burkina to be done
c) deliverable 6.3 (report on nutrient use efficiency in wood and fodder of different species)
   will be done once trials have been established
d) deliverable 6.4 (report on overall nutrient balance of production systems)
   will be done once trials have been established
e) deliverable 6.5 (report on risks from heavy metals and pesticide residues)
   will be done once all irrigation systems are running and water has been monitored)

WP7 Planting stock quality

a) Jules Bayala presented the results of a pot experiment in which 6 tree species were grown with and without mycorrhizal and rhizobial inoculum (as appropriate), in containers of two different sizes. A nutrient-poor sand was used as the substrate. Generally, inoculation effects on growth were greatest in the large containers. Calculations of sturdiness quotient, Dickson's quality index and shoot: root ratios showed that these parameters usually had highest values in the larger pots. The experiment now needs to be extended to field conditions to determine plant performance after outplanting.

b) Deliverable 7.1 Report on seedling quality attributes for different seedling types and the nursery practises required to produce them.
   Will be completed for Burkina soon
c) Deliverable 7.2 Report on establishment success and verification of ideal seedling quality attributes for irrigated sites
   Will be completed for Burkina after the second phase of the experiment is conducted

WP8 Pest monitoring and management

Inamoud Yattara presented some preliminary data from Mali.

FINAL DISCUSSION

The **experimental design of field experiment 1** was discussed. Partners were reminded that in addition to these experiments which need to be standardised between countries, they can set up their own experiments as well.

Activity of symbionts There was a decision to omit measurement of field N fixation.

Socioeconomics Germaine Ibro was the only socioeconomist present at the meeting. She will communicate with other partners by email and it is important that they ensure that progress is made on the socio-economic work package.

Planting stock quality Mali have not yet started work on this area. It was agreed that they do not have to replicate what Burkina has done, they can plan their own studies.

Time of coppicing 12 months after planting for forage and 15 months for wood (?)
There is need for interactions between growers and economists on this to make sure that material is of appropriate size.

Due to delays in setting up the irrigation plants, it was agreed that a 12 month extension to the project should be requested

MEETING UBENEFIT
May, 3, 4 and 5, 2005,
Ouagadougou, Burkina Faso

(Tentative programme)

Day 1 (May 3rd , 2005)

8h – 9h : Inscriptions / other formalities
Session one: Opening ceremony, general considerations

9h -10h :

- Introductory / Ubenefit (co-ordinator- Julia)
- Welcome / opening (INERAs staff member)

Work package 1
Water treatment and irrigation (Work package leader IRD, through SCP) (including progress with irrigation set up and site characterisation studies)

IER Mali *Daouda Sidibe*
Univ Abdou Moumouni Niger *Sanoussi Atta*
INERA Burkina *Dianda Mahamadi*
Discussion

Work package 2 (leaders IER Mali, INERA Burkina, Univ Abdou Moumouni)
Tree growth and management
IER Mali and Univ Mali *Daouda Sidibe*
Univ Abdou Moumouni *Sanoussi Atta*
Discussion

Work package 3 (leader CEH)
Tree water use and soil water status
CEH UK *Julia Wilson*
Univ Abdou Moumouni *Sanoussi Atta*
IER Mali *Kalifa Traoré*
Discussion

Work package 4 Microsymbionts and N fixation (leaders IRD and CEH)
IRD *Tania Wade*
Univ Mali *Inamoud Yattara*
IER Mali *Daouda Sidibe*
Univ Abdou Moumouni *Sanoussi Atta*

Day 2 (May 4th, 2005)

Work package 4 .... continued
CEH UK *Julia Wilson*

Work package 5 Economics (leader Univ Abdou Mounouni)
Univ Abdou Mounmouni *Germaine Ibro*

Discussion

Work package 6 Soil and plant nutrition (leader IER Mali)
IER Mali *Kalifa Traoré*
Discussion

Work package 7 Planting stock quality (leader CEH)
INERA Burkina *Jules Bayala*
Discussion

Work package 8 Pest monitoring and management (leader Univ Mali)
Univ Mali *Inamoud Yattara*

Discussion

Summing up

12h-14h Pause diner

14h-16h Field visits
(1. Local UBENEFITs station,
2. Station of wastewater treatment in Ouagadougou town)
16h- 17h closure

Day 3 (May 5th) optional field visits (continue)

1. Lango: sculptures on Granite
2. Barrage de Lango

Those present

Julia Wilson	Coordinator (leader WP3, co leader WP4, 7)	CEH (Partner 1)	jwi@ceh.ac.uk
Robert Munro	Ecologist	CEH (Partner 1)	rcmu@ceh.ac.uk
Kalifa Traoré	Soil scientist (leader WP6)	IER (Partner 2)	Kalifa.traore@ier.ml
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Inamoud I Yattara	Leader WP8	Univ. Mali (Partner 3)	iiyattara@yahoo.fr
Kaborè Blaise	Plant pathologist	INERA chef DPU (partner 4)	kaboreb@fasonet.bf
Bayala Jules	Ecophysiologist	INERA DPF (partner 4)	jules.bayala@coraf.org
Sanon Kadidia	Microbiologist	INERA DPF (partner 4)	sanonkady@yahoo.fr
Sougoti Moussa	Physicist	Univ. Ouga (Institute du Génie de l'Environment et du Developpement Durable)	sougoti@univ.ouga.bf
Dianda Mahamadi	Microbiologist (Country leader WP2)	INERA DPF (partner 4)	dmahamadi@yahoo.fr
Sanoussi Atta	Plant Physiologist (Country leader WP2)	Univ AM/CRA (Partner 5)	Atta13@yahoo.fr
Germaine Ibro	Economist, leader WP5	INRAN/Univ AM (Partner 5)	geribro@yahoo.fr
Marc Neyra	Microbiologist, leader WP4 (and leader WP1 via subcontract)	IRD (LCM) (Partner 6)	Marc.Neyra@ird.sn
Tatiana Wade	Molecular biologist	IRD (LCM) (Partner 6)	Tania.Wade@ird.sn

Annex 2 Questionnaires for socioeconomic studies

Questionnaire 1 : Etude de la Filière Bois de Chauffe

(Questionnaire aux approvisionneurs en bois de chauffe)

Nom de l'enquêteur : .... Date : ....
Nom : ....
Sexe : ....
Poste de Contrôle : ....

Identification

<table>
<tr><td colspan="2"></td><td colspan="3">Réponses</td></tr>
<tr><td>Genre (SEX)</td><td>1 = masculin 2 = féminin</td><td colspan="3"></td></tr>
<tr><td>Age (AGE)</td><td></td><td colspan="3"></td></tr>
<tr><td>Situation familiale (MSTATUS)</td><td>1=marié(e) 2=divorcé(e) 3=veuf(ve)
4=célibataire</td><td colspan="3"></td></tr>
<tr><td>Niveau d'éducation du répondant (EDUC)</td><td>0= aucune 1= étude primaire
2= étude secondaire 3= étude supérieure
4= coranique 5= autres</td><td colspan="3"></td></tr>
<tr><td rowspan="3">Taille de famille (TAILLE)</td><td></td><td>E</td><td>H</td><td>F</td></tr>
<tr><td>< 15 ans
15 à 50 ans</td><td></td><td></td><td></td></tr>
<tr><td>> 50 ans</td><td></td><td></td><td></td></tr>
<tr><td>Activité principale (PACT)</td><td>1=agriculture 2=commerce
3= élevage 4= autres (à préciser)</td><td colspan="3"></td></tr>
<tr><td>Activité secondaire</td><td>1=agriculture 2=commerce
3= élevage 4= autres (à préciser)</td><td colspan="3"></td></tr>
</table>

1. Depuis quand exercez-vous cette activité ? ....
2. Quelles sont vos zones d'approvisionnement et leur distance du centre ville ?

Zones d'approvisionnement	Espèces achetées	Distance

3. Comment est organisé la collecte de bois?..
 3.1 achat auprès du bûcheron du village
 3.2 bûcherons contractuels

4. Comment transportez-vous le bois des zones rurales en zones urbaines ?.................
 4.1 Automobile 4.3 charrette 4.5 pied
 4.2 âne 4.4 pirogue 4.6 vélo 4.7 autre à préciser

5. Quelle est l'évolution du prix de bois par période ?

Période	Volume acheté	Prix d'achat	Prix de vente

6. Quelles sont les troutes liées au transport de bois et leurs montant ?.................

7. Quelles sont les coûts liés à la commercialisation du bois ?

Poste de dépense	Montant mensuel

8. Quelles sont les différentes périodes de commercialisation du bois ?.............. ......

Période	Volume commercialisé/ mois	observation

9. Combien de voyages faites vous par mois selon les périodes, et quelle quantité est transportée par période et par voyage...

Périodes	Nombre de voyage /mois	Quantité de bois transporté

10. Le moyen de transportez- vous appartient-il ?...

11. Quels sont les coûts liés à son entretien ? ....

12. Quelles sont les espèces les mieux appréciées pour le bois de chauffe ?

13. Quelles sont vos principales contraintes ?..

14. Le système actuel de production de bois de chauffe permet –il de satisfaire tous les besoins en bois de chauffe de la ville? ....
15. Si non que proposez-vous ?..
16. Que pensez –vous de la mise en valeur d'une plantation personnelle en vue de l'exploitation du bois de chauffe pour la vente ?...
17. A qui revendez vous le bois en ville ?
    17.1 Aux détaillants   17.2 Aux demi- grossistes
    17.3 Aux consommateurs
18. Quelles sont les modalités de paiements ? ....
    17.1 vente à crédit
    17.2 vente au comptant
19. Quel pourcentage représente le revenu tiré de la vente de mois (%)?..................
20. Quelle utilisation faite vous des revenus tirés de la vente du bois ?

Questionnaire 2 : Etude de la Filière Bois de Chauffe

ENQUÊTE PRODUCTION ET COMMERCIALISATION
(questionnaire aux bûcherons)

(Nous entendons par bûcherons ceux qui coupent le bois de chauffe pour la vente).

Zone : .... Date : ....

Nom de l'enquêteur : ....

Nom du répondeur : ....

Profession du répondeur : ....

Identification

		Réponses		
Genre **(SEX)**	1 = masculin 2 = féminin			
Age **(AGE)**				
Situation familiale **(MSTATUS)**	1=marié(e) 2=divorcé(e) 3=veuf(ve) 4=célibataire			
Niveau d'éducation du répondant **(EDUC)**	0= aucune 1= étude primaire 2= étude secondaire 3= étude supérieure 4= coranique 5= autres			
Taille de famille **(TAILLE)**		**E**	**H**	**F**
	< 15 ans			
	15 à 50 ans			
	> 50 ans			
Activité principale **(PACT)**	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			
Activité secondaire	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			

3. Depuis quand exercez-vous cette activité ? ....

2. D'où provient le bois que vous coupez ? ....

2.1 = plantation

2.2 = forêts naturelles

A. Exploitation des forêts naturelles :

3. Comment est organisée la coupe du bois dans les forêts naturelles ?

3.3 de manière collective

3.4 de manière individuelle

4. Quels type de bois êtes vous autorisé à couper ?

4.1 Bois mort

4.2 Bois vif

4.3 Les deux

5. quelles sont les mesures de gestion adoptées pour une bonne régénération de la forêt ?

5.1 Coupe sélective (selon le diamètre)

5.2 Protection des jeunes plans

5.3 Coupe par zone

5.4 Plantation

5.5 Autre à préciser.

6. Quelles sont les différentes périodes de coupes et les raisons?.............................

Période de coupe	Raisons

7. Combien de stère coupez-vous par mois ? et par période ? ....

Période de coupe	**Espèces coupées**	**Fréquence de coupe par mois**	**Quantité coupée**

8. S'il existe une différence entre les périodes de coupe, donnez les raisons : ....

9. Qui se charge de la coupe dans la famille ? ....

9.1 Les hommes
9.2 Les femmes
9.3 Les enfants
9.4 Les hommes et les femmes

10. Qui s'occupe de la commercialisation du bois ?..

10.1 Les hommes
10.2 Les femmes
10.3 Les enfants
10.4 Les hommes et les femmes

(Précisez le rôle de chaque intervenant)

11. Où se fait la vente du bois ? ....

11.1 au village
11.2 en ville

12. Décrivez le processus de la vente sur place ....

13. Comment transportez-vous le bois du lieu de coupe au lieu de vente ?

131 = charrette
132 = dos d'âne
133 = dos de dromadaire
134 = autre à préciser

14. Quel coût cela engendre t-il (par quantité transportée et par voyage ?

- un voyage par charrette...FCFA
- un voyage à dos d'âne...FCFA
- un voyage à dos de dromadaire..FCFA

15. A quelle distance se situe le lieu de prélèvement du bois par rapport au village

16. Quelles sont les charges mensuelles auxquelles vous faites face ?

Rubrique de dépense	Montant mensuel

17. Combien y a t-il d'exploitants de bois au village

Hommes Femmes

18. Combien de temps passez –vous à cette activité ?

Combien de mois dans l'année ?
Combien de jours par mois ?

19. Est ce que vous utilisez la main d'œuvre salariée ? si oui ____ non ____

Si oui, quelle est le mode de rémunération ? ....

20. A quelle distance se situe votre zone de coupe par rapport au centre urbain le plus proche ?

21. Existe t-il un marché rural de bois dans votre village ? oui ----- non ------

22. De quel type de marché s'agit –il ? ....

22.1. Contrôlé
22.2. Orienté

23. Si non comment transportez-vous le bois jusqu'au centre urbain ? (Lieu de vente)

23.1 Charrettes

23.2 Dos d'âne
23.3 Dos de dromadaire
23.4 À Vélo
23.5 Autre à précisez.

24. Combien vous coûte un voyage (selon le moyen de transport)..........................
- Charrette... Chargement d'âne ....
- Chargement d'âne .... A Chargement d'âne Vélo..............

25. A combien vendez – vous un voyage en centre urbain (selon le moyen de transport)
- Charrette... Chargement d'âne ....
- Chargement d'âne .... A Chargement d'âne Vélo..............

26. Combien de jours vous restez en ville pour vendre le chargement ?.................

27. Quèlles sont les espèces de bois que vous coupez ? ....

28. Quelles sont les espèces de bois préférées par les consommateurs

1 ....
2 ....
3 ....

29. Quelles sont les espèces protégées

30 Quelles sont les principales contraintes rencontrées dans l'exercice de cette activité ?

30.1 Insuffisance de bois
30.2 Insuffisance de main d'œuvre
30.3 Troutes insupportables
30.4 Mévente
30.5 charges importantes
30.6 Eloignement du lieu de coupe
30.7 Autres à préciser

31. Quel pourcentage ce votre revenu total représente les revenus tirés de la vente du bois ?..

- Quelle utilisation faite-vous des revenus tirés du bois.

31. Que pensez vous d'une plantation privée pour la production du bois de chauffe.

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Questionnaire 3 : Etude de la Filière Bois de Chauffe

ENQUÊTE PRODUCTION ET COMMERCIALISATION

(questionnaire aux bûcherons)

(Nous entendons par bûcherons ceux qui coupent le bois de chauffe pour la vente).
Zone : .... Date : ....

Nom de l'enquêteur : ....

Nom du répondeur : ....

Profession du répondeur : ....

Identification

		Réponses		
Genre (SEX)	1 = masculin 2 = féminin			
Age (AGE)				
Situation familiale (MSTATUS)	1=marié(e) 2=divorcé(e) 3=veuf(ve) 4=célibataire			
Niveau d'éducation du répondant (EDUC)	0= aucune 1= étude primaire 2= étude secondaire 3= étude supérieure 4= coranique 5= autres			
Taille de famille (TAILLE)		E	H	F
	< 15 ans			
	15 à 50 ans			
	> 50 ans			
Activité principale (PACT)	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			
Activité secondaire	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			

4. Depuis quand exercez-vous cette activité ? ....

2. D'où provient le bois que vous coupez ? ....

2.3 = plantation

2.4 = forêts naturelles

B. Exploitation des forêts naturelles :

3. Comment est organisée la coupe du bois dans les forêts naturelles ?

3.5 de manière collective

3.6 de manière individuelle

4. Quels type de bois êtes vous autorisé à couper ?

4.1 Bois mort

4.2 Bois vif

4.3 Les deux

5. quelles sont les mesures de gestion adoptées pour une bonne régénération de la forêt ?

5.1 Coupe sélective (selon le diamètre)

5.6 Protection des jeunes plans

5.7 Coupe par zone

5.8 Plantation

5.9 Autre à préciser.

6. Quelles sont les différentes périodes de coupes et les raisons?............................

Période de coupe	Raisons

7. Combien de stère coupez-vous par mois ? et par période ? ....

Période de coupe	Espèces coupées	Fréquence de coupe par mois	Quantité coupée

8. S'il existe une différence entre les périodes de coupe, donnez les raisons : ....
9. Qui se charge de la coupe dans la famille ? ....

9.1 Les hommes
9.5 Les femmes
9.6 Les enfants
9.7 Les hommes et les femmes

10. Qui s'occupe de la commercialisation du bois ?..

10.1 Les hommes
10.2 Les femmes
10.3 Les enfants
10.4 Les hommes et les femmes

(Précisez le rôle de chaque intervenant)
11. Où se fait la vente du bois ? ....

11.3 au village
11.4 en ville

12. Décrivez le processus de la vente sur place ....
13. Comment transportez-vous le bois du lieu de coupe au lieu de vente ?
131 = charrette
132 = dos d'âne
133 = dos de dromadaire
134 = autre à préciser
14. Quel coût cela engendre t-il (par quantité transportée et par voyage ?
- un voyage par charrette..FCFA
- un voyage à dos d'âne..FCFA
- un voyage à dos de dromadaire...FCFA

15. A quelle distance se situe le lieu de prélèvement du bois par rapport au village
16. Quelles sont les charges mensuelles auxquelles vous faites face ?

Rubrique de dépense	Montant mensuel

17. Combien y a t-il d'exploitants de bois au village

Hommes Femmes

18. Combien de temps passez –vous à cette activité ?

Combien de mois dans l'année ?
Combien de jours par mois ?

19. Est ce que vous utilisez la main d'œuvre salariée ? si oui ____ non ____
Si oui, quelle est le mode de rémunération ? ....
20. A quelle distance se situe votre zone de coupe par rapport au centre urbain le plus proche ?
21. Existe t-il un marché rural de bois dans votre village ? oui ----- non ------
23. De quel type de marché s'agit –il ? ....

22.1. Contrôlé
22.2. Orienté

23. Si non comment transportez-vous le bois jusqu'au centre urbain ? (Lieu de vente)

23.1 Charrettes
23.2 Dos d'âne
23.3 Dos de dromadaire
23.4 À Vélo
23.5 Autre à précisez.

24. Combien vous coûte un voyage (selon le moyen de transport).........................

- Charrette.. Chargement d'âne ....
- Chargement d'âne .... A Chargement d'âne Vélo............

26. A combien vendez – vous un voyage en centre urbain (selon le moyen de transport)

- Charrette.. Chargement d'âne ....
- Chargement d'âne .... A Chargement d'âne Vélo............

26. Combien de jours vous restez en ville pour vendre le chargement ?................

27. Quelles sont les espèces de bois que vous coupez ? ....

28. Quelles sont les espèces de bois préférées par les consommateurs

1 ....
2 ....
3 ....

29. Quelles sont les espèces protégées

30 Quelles sont les principales contraintes rencontrées dans l'exercice de cette activité ?

30.1 Insuffisance de bois
30.2 Insuffisance de main d'œuvre
30.3 Troutes insupportables
30.4 Mévente
30.5 charges importantes
30.6 Eloignement du lieu de coupe
30.7 Autres à préciser

31. Quel pourcentage ce votre revenu total représente les revenus tirés de la vente du bois ?...

- Quelle utilisation faite-vous des revenus tirés du bois.

31. Que pensez vous d'une plantation privée pour la production du bois de chauffe.
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Questionnaire 4 : Utilisation des sources d'énergie par les ménages (Bois de chauffe et charbon de bois) (Adressé à la mère de famille)

1. Identification

		Réponses		
Genre **(SEX)**	1 = masculin 2 = féminin			
Age **(AGE)**				
Situation familiale **(MSTATUS)**	1= marié(e) 2=divorcé(e) 3=veuf(ve) 4=célibataire			
Niveau d'éducation du répondant **(EDUC)**	0= aucune 1= étude primaire 2= étude secondaire 3= étude supérieure 4= coranique 5= autres			
Taille de famille **(TAILLE)**		**E**	**H**	**F**
	< 15 ans 15 à 50 ans > 50 ans			
Activité principale **(PACT)**	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			
Activité secondaire	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			

1 Quelles sont les espèces d'animaux que vous possédez ?

- **1.0** Ânes: Nombre
- **1.1** Chevaux: Nombre
- **1.2** Ovins: Nombre
- **1.3** Caprins: Nombre
- **1.4** Bœufs de traction : Nombre
- **1.5** Bovins d'élevage: Nombre
- 1.6 Autres: Nombre

2 Quels sont les types de fourrage que vous utilisez ?..

- Feuilles d'arbres : espèces d'arbre .... État des feuilles: Vertes.............. séchées
- Herbes:
- Pailles

3. Quelles sont vos sources d'approvisionnement par type de fourrage ?

4. Quels sont les types de fourrage que vous achetez

- Herbe
- Pailles

5.A A Combien s'élèvent vos dépenses hebdomadaire pour l'achat de fourrage ?.................

5.B A Combien s'élèvent vos dépenses hebdomadaire pour l'achat de fourrage aérien ?..

6 Quel type de fourrage pour quelles espèces animales ?

Type de fourrage	Espèces animales

7. Est-ce que vous trouvez à tout moment de l'année le type de fourrage préféré ?
Oui.... ....non...
Si non pourquoi ? ....

8. Quels types d'équipement utilisez-vous ? ....

a. foyer à 3 pieds traditionnel
b. foyers améliorés
c. fourneau à charbon

9. Quelles sont les contraintes que vous rencontrez pour votre approvisionnement en fourrage pour les animaux ? ……………………………………………………………………………………………..

10. Quelles solution envisagez-vous ?..

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Questionnaire 5 : Etude de la Filière Bois de Chauffe

ENQUÊTE PRODUCTION ET COMMERCIALISATION

(Questionnaire Bois d'oeuvre)

Zone : .... Date : ....

Nom de l'enquêteur : ....

Nom du répondeur : ....

Profession du répondeur : ....

<u>Identification</u>

		Réponses		
Genre **(SEX)**	1 = masculin 2 = féminin			
Age **(AGE)**				
Situation familiale **(MSTATUS)**	1=marié(e) 2=divorcé(e) 3=veuf(ve) 4=célibataire			
Niveau d'éducation du répondant **(EDUC)**	0= aucune 1= étude primaire 2= étude secondaire 3= étude supérieure 4= coranique 5= autres			
Taille de famille **(TAILLE)**		**E**	**H**	**F**
	< 15 ans 15 à 50 ans > 50 ans			
Activité principale **(PACT)**	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			
Activité secondaire	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)			

5. Depuis quand exercez-vous cette activité ? ....

2. D'où provient le bois d'œuvre que vous coupez ? ....

2.5 = Plantation

2.6 = Forêts naturelles

2.7 = Ailleurs (préciser)

C. Exploitation des forêts naturelles :

3. Comment est organisée la coupe du bois dans les forêts naturelles ?

3.7 de manière collective

3.8 de manière individuelle

4. Quels types de bois êtes vous autorisé à couper ?

4.1 Bois mort

4.2 Bois vif

4.3 Les deux

5. Quelles l'utilisation des différentes espèces de bois d'oeuvre

1. Fabrication escabeaux
2. Statuts
3. Chaises
4. Tables
5. Mortier, Pilon

6. quelles sont les mesures de gestion adoptées pour une bonne régénération de la forêt ?

6.1 Coupe sélective (selon le diamètre)

6.2 Protection des jeunes plans

6.3 Coupe par zone

6.54 Plantation

6.5 Autre à préciser.

7. Quelles sont les différentes périodes de coupes et les raisons?.............................

Période de coupe	Raisons

8. Combien de stère coupez-vous par mois ? et par période ? ....

Période de coupe	**Espèces coupées**	**Fréquence de coupe par mois**	**Quantité coupée**

9. S'il existe une différence entre les périodes de coupe, donnez les raisons : ....

10. Qui se charge de la coupe dans la famille ? ....

10.1 Les hommes
10.2 Les femmes
10.3 Les enfants
10.4 Les hommes et les femmes

11 Comment est vendu le bois d'œuvre

11.1 Sans aucune transformation
11.2 Après sculpture

12. Qui s'occupe de la commercialisation du bois ?..

12.1 Les hommes
12.2 Les femmes
12.3 Les enfants
12.4 Les hommes et les femmes

(Précisez le rôle de chaque intervenant)

13. Où se fait la vente du bois d'œuvre? ....

13.1 au village
13.2 en ville

14. Décrivez le processus de la vente sur place.. ....

15. Comment transportez-vous le bois du lieu de coupe au lieu de vente ?

15.1 = charrette
15.2 = dos d'ânes
15.3 = dos de dromadaire
15.4 = autre à préciser

16. Quel coût cela engendre t-il (par quantité transportée et par voyage ?

- un voyage par charrette..FCFA
- un voyage à dos d'âne..FCFA
- un voyage à dos de dromadaire..FCFA

17. A quelle distance se situe le lieu de prélèvement du bois par rapport au village

18. Quelles sont les charges mensuelles auxquelles vous faites face ?

Rubrique de dépense	Montant mensuel

19. Combien y a t-il d'exploitants de bois au village

Hommes Femmes

20. Combien de temps passez –vous à cette activité ?
Combien de mois dans l'année ?
Combien de jours par mois ?
21. Est ce que vous utilisez la main d'œuvre salariée ? si oui ____ non ____
Si oui, quelle est le mode de rémunération ? ....
22. A quelle distance se situe votre zone de coupe par rapport au centre urbain le plus proche ?
23. Comment transportez-vous le bois jusqu'au centre urbain ? (Lieu de vente)
23.1 Charrettes
23.2 Dos d'âne
23.3 Dos de dromadaire
23.4 À Vélo
23.5 Autre à précisez.
24. Combien vous coûte un voyage (selon le moyen de transport)..........................
- Charrette... Chargement d'âne ....
- Chargement d'âne .... A Chargement d'âne Vélo.............
27. A combien vendez – vous un voyage en centre urbain (selon le moyen de transport)
- Charrette... Chargement d'âne ....
- Chargement d'âne .... A Chargement d'âne Vélo.............
26. Combien de jours restez- vous en ville pour vendre le chargement ?.................
27. Quelles sont les espèces de bois que vous coupez ? ....
28. Quelles sont les espèces de bois préférées par les consommateurs
1 ....
2 ....
3 ....
29 Quelles sont les principales contraintes rencontrées dans l'exercice de cette activité ?
29.1 Insuffisance de bois
29.2 Insuffisance de main d'œuvre
29.3 Troutes insupportables
29.4 Mévente
29.5 charge importantes
29.6 Éloignement du lieu de coupe
29.7 Autres à préciser
31. Quel pourcentage de votre revenu total représente les revenus tirés de la vente du bois ?...
32 Quelle utilisation faite-vous de revenu tiré du bois d'œuvre ?.......................................
33. Que pensez vous d'une plantation privée pour la production du bois de chauffe.
....
....
....

Questionnaire 6 : Description du système actuel de production de bois de chauffe

ENQUÊTE PRODUCTION ET COMMERCIALISATION

(Questionnaire charbon de bois)

Zone : .... Date : ....

Nom de l'enquêteur : ....

Nom du répondeur : ....

Profession du répondeur : ....

Identification

		Réponses
Genre **(SEX)**	1 = masculin 2 = féminin	
Age **(AGE)**		
Situation familiale **(MSTATUS)**	1=marié(e) 2=divorcé(e) 3= veuf (ve) 4=célibataire	
Niveau d'éducation du Répondant **(EDUC)**	0= aucune 1= étude primaire 2= étude secondaire 3= étude supérieure 4= coranique 5= autres	
Taille de famille **(TAILLE)**	< 15 ans 15 à 50 ans > 50 ans	**E** **H** **F**
Activité principale **(PACT)**	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)	
Activité secondaire	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)	

6. Depuis quand exercez-vous cette activité ? ....

2. D'où provient le charbon de bois que vous vendez ? ....

2.8 = plantation

2.9 = forêts naturelles

2.10 = d'un autre pays

D. Exploitation des forêts naturelles :

3. Comment est organisée la production du charbon de bois ?

3.9 de manière collective

3.10 de manière individuelle

4. Quels type de bois êtes vous autorisés à couper pour la production du charbon de bois ?

4.1 Bois mort

4.2 Bois vif

4.3 Les deux

5. quelles sont les mesures de gestion adoptées pour une bonne régénération de la forêt ?

5.1 Coupe sélective (selon le diamètre)

5.10 Protection des jeunes plans

5.11 Coupe par zone

5.12 Plantation

5.13 Autre à préciser.

6. Quelles sont les différentes périodes de production de charbon et les raisons?..........

Période de production	Raisons

7. Combien de sacs de charbon de bois produisez -vous par mois ? et par période ?

Période de coupe	**Espèces coupées**	**Fréquence de coupe par mois**	**Quantité Produite** **(Sacs)**

8. S'il existe une différence entre les périodes de production, donnez les raisons :
9. Qui se charge de la production de charbon dans la famille ? ....
9.1 Les hommes
9.8 Les femmes
9.9 Les enfants
9.10 Les hommes et les femmes
10. Qui s'occupe de la commercialisation du charbon?...
10.1 Les hommes...
10.2 Les femmes...
10.3 Les enfants...
10.4 Les hommes et les femmes...
(Précisez le rôle de chaque intervenant)
11. Où se fait la vente du charbon ? ....
11.5 au village
11.6 en ville
12. Décrivez le processus de la vente pour chacun des lieux de vente ....
13. Comment transportez-vous le bois du lieu de coupe au lieu de vente ?
131 = charrette
132 = dos d'âne
133 = dos de dromadaire
134 = Vélo
135 = Camion
136= Autre à préciser.
14. Quel coût cela engendre t-il (par quantité produite ?)................
15. A quelle distance se situe le lieu de production du charbon de bois par rapport au village...
16. Quelles sont les charges mensuelles auxquelles vous faites face ?

Rubrique de dépense	Montant mensuel

17. Combien y a t-il d'exploitants de charbon de bois au village
Hommes femmes
18. Quel pourcentage représente-ils par rapport à la population du village ?
19. Combien de temps passez –vous sur cette activité ?
combien de mois dans l'année ?..
combien de jours par mois ?..
20. Est ce que vous utilisez la main d'œuvre salariée ? oui ____ non ____
Si oui, quel est le mode de rémunération ? ....
....
21. A quelle distance se situe votre zone de production par rapport au centre urbain le
21. Comment transportez-vous le bois jusqu'au centre urbain ?
241 charrettes
242 dos d'âne
243 dos de dromadaire
244 autre à précisez.
25. Combien vous coûte un voyage (selon le moyen de transport)........................

26. A combien vendez – vous un sac de charbon en centre urbain (selon le moyen de transport)……………………………………………………………………………………

27. Combien de jours vous restez en ville pour vendre le chargement ?…………………………

28. Quelles sont les espèces de bois que vous utilisez pour le charbon de bois ? ……….

29. Quelles sont les espèces de bois préférées pour le charbon par les consommateurs

1 ……………………………………………………………………………………..
2 ……………………………………………………………………………………..
3 ……………………………………………………………………………………..

30. Est-ce que vous parvenez à satisfaire les préférences des consommateurs ?

oui non

Si non pourquoi ?…………………………………………………………………………………………

31. Quelles sont les principales contraintes rencontrées dans l'exercice de cette activité ?

311 insuffisances de bois
312 insuffisances de main d'œuvre
313 troutes insupportables
314 mévente
315 charge importantes
316 autres à préciser

32. Quelle pourcentage de votre revenu total représente les revenus tirés de la vente du charbon de bois ?………………………………………………………………………………...

33. Quelle utilisation faite-vous du revenu tiré du charbon de bois………………………..

……………………………………………………………………………………………

Questionnaire 7 : Description du système actuel de production de bois de chauffe

Questionnaire revendeur

Date : ……………………………………………………………………………………………

Nom de l'enquêteur : ………………………………………………………………………

Nom du répondeur : …………………………………………………………………………

1. Identification

		Réponses
Genre **(SEX)**	1 = masculin 2 = féminin	
Age **(AGE)**		
Situation familiale **(MSTATUS)**	1=marié(e) 2=divorcé(e) 3= veuf (ve) 4=célibataire	
Niveau d'éducation du Répondant **(EDUC)**	0= aucune 1= étude primaire 2= étude secondaire 3= étude supérieure 4= coranique 5= autres	
Taille de famille **(TAILLE)**		**E** **H** **F**
	< 15 ans 15 à 50 ans	
	> 50 ans	
Activité principale **(PACT)**	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)	
Activité secondaire	1=agriculture 2=commerce 3= élevage 4= autres (à préciser)	

1 A quelle période de l'année exercez vous cette activité ?

Saison de pluies…………………………………………………………………………

Saison sèche……………………………………………………………………………

Toute l'année……………………………………………………………………………

2 Depuis quand exercez vous cette activité ?…………………………………………

3. Quelles sont les sources d'approvisionnement en bois?……………………………

1. les camionneurs
2. les charretiers
3. les âniers

4. Quelle est votre fréquence d'approvisionnement ?

1. Par semaine
2. Par mois
3. Autres (préciser)

5. Quel type de bois commercialisez-vous ?

1. Bois rond Vrac
2. Bois fendu
3. bois rond fagot

6. Quelle est votre unité de quantification de bois ?

1. Rangée
2. Charrette
3. Chargement d'âne
4. Chargement de dromadaire
5. Autres (Préciser)

7. Quelle est la quantité de bois achetée par unité de temps (Préciser l'unité)?

8. A combien vous revient une rangée de bois selon les périodes ?

Saison des pluies ……………………………………

Saison sèche…………………………………………

9. Quel sont les prix de revient selon les périodes

Période	Quantité	Prix de revient
Saison des pluies	Rangée	
	Charrette	
	Chargement d'âne	
	Chargement de dromadaire	
Saison sèche	Rangée	

	Charrette	
	Chargement d'âne	
	Chargement de dromadaire	
	Rangée	

10. Quel sont les prix de vente selon les périodes ?

Période	Quantité	Prix de vente
Saison des pluies	Rangée	
	Charrette	
	Chargement d'âne	
	Chargement de dromadaire	
Saison sèche	Rangée	
	Charrette	
	Chargement d'âne	
	Chargement de dromadaire	
	Rangée	

11. Quelles sont les espèces les plus vendues………………………………………………………………

12 Quelles sont les sources de revenu dans le foyer engendrée par

1. l'époux (se) ?
2. les enfants ?
3. Autres ?

13 Sur laquelle de ces sources reposent les dépenses familiales ?

13.1 revenu de l'époux

13.2 revenu des enfants

13.3 autres sources

14. Quel pourcentage des dépenses de la famille est couvert par les revenus de la vente de bois?

Contract number: ICA4-CT-2002-10017	Year 3 2004-2005

Data sheet
For annual report

(to be completed by the co-ordinator at 12-monthly intervals from start of contract. Figures to be up-dated cumulatively throughout project lifetime)

	Totals (cumulative)	
1. *Dissemination activities*		
Number of communications in conferences (published)		
Numbers of communications in other media (internet, video)		
Number of publications in refereed journals (published)		
Number of articles/books (published)		
Number of other publications	1	
2. *Training*		
Number of PhDs	2	
Number of MScs	1	
Number of visiting scientists	6	
Number of exchanges of scientists (stays longer than 3 months)	7	
3. *Achieved results*		
Number of patent applications		
Number of patents granted		
Number of companies created		
Number of new prototypes/products developed		
Nubmer of new tests/methods developed		
Number of new norms/standards developed		
Number of new softwares/codes developed		
Number of production processes		
4. *Industrial aspects*		
Industrial contacts	Yes	No ✓
Financial contribution by industry	Yes	No ✓
Industrial partners:- Large	Yes	No ✓
SME[1]	Yes ✓	No
5. *Comments*		
Other achievements (use separate page if necessary)		

[1] Less than 500 employees