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

Contract number: ICA4-CT-2002-10017

6-monthly activity report : 1/12/2005 - 31/05/2006

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

Editor: Julia Wilson

Coordinator's overview

As in previous years, delays in the receipt of payments have created serious cash-flow difficulties for some partners. Once payment has been received from the EU, CEH attempts to disburse the payments to partners as quickly as possible, after verifying the details of the partners' bank accounts and the payments due. Some bank transfers proceed very smoothly while others do not. Most payments from the CEH euro account to the bank accounts of partners have to be made through intermediary banks. These intermediary banks are determined by where the recipient bank holds its euro account. Much of the difficulty seems to arise because the recipient bank in the partner's country demands detailed information concerning the bank transfer from the project partner prior to the release of the money. CEH has to provide this information to the partner. Unfortunately, this information is not easily available to CEH, and it takes several weeks to obtain and pass on to the partner. In order to obtain the information CEH makes a special request to the bank holding CEH's euro account (the Bank of England) to provide the following information: the amount paid, the value date, beneficiary details, payment details etc. The Bank of England has to obtain this information from the recipient bank, via the intermediary bank and obtaining this information is a slow process. Unfortunately, some recipient banks do not seem to credit funds to the rightful account until the project recipient can provide all the information mentioned above, which of course is provided by the recipient's bank. This is a slow, frustrating and circular process for all parties concerned. The project leader has been in touch with the Bank of England to discuss alternatives, but there appear to be none offering suitable security.

In addition to the cash-flow problems, some partners are finding that the financial demands of maintaining the irrigation systems and externally commissioning soil and water analyses are causing strains on their budgets. Thus there is some need to re-evaluate priorities so that the most important project deliverables are met within budget, while meeting the overall objectives of the project. Nevertheless, irrigation systems are up and running in all 3 countries and considerable progress has been made in all areas.

Partner 1: CEH
UBENEFIT: Partner 1, CEH

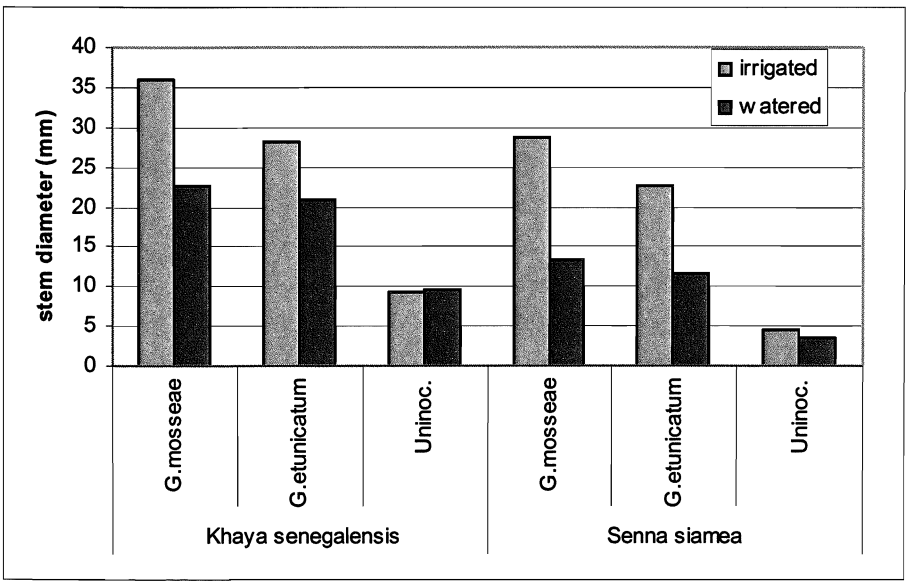
WP4: Summary of Progress

- The glasshouse experiment is continuing. Results show that uninoculated trees are not responding to the irrigation treatment, while inoculated trees differ in their growth response according to the fungal inoculant. The results suggest that *Glomus mosseae* is more effective than *Glomus etunicatum* in the uptake of nutrients from the irrigation water.
- Measurements of soil microbial activity and plant physiology are planned for this year.

The irrigation experiment (addition of simulated waste-water compared with tap water) has continued in the glasshouse during 2006. In January 2006, the fast-growing *Leucaena leucocephala* trees were removed from the experiment as they had already been pruned twice to restrict their vertical growth, and had far outgrown the 32 litre tubs. The experiment was thus reduced to 48 tubs (2 tree species x 3 inoculants x 2 irrigation treatments x 4 blocks) which allowed for better spacing of the trees in the glasshouse. The trees made little growth during the winter months, and feeding was reduced to 250 ml per week. From March 2006, feeding resumed at 500 ml per week and was increased to 1 litre per week in May 2006.

Although growth of the larger, inoculated trees has begun to slow as they have become increasingly pot-bound, measurements of stem diameter made in May 2006 continued to show significant treatment effects (Figure 1).

Figure 1. Effect of irrigation treatment on growth (stem diameter) of inoculated and uninoculated *Khaya senegalensis* and *Senna siamea* trees, 2 years after inoculation.



Inoculation has increased the growth of both tree species, with growth of those trees inoculated with *Glomus mosseae* better than those inoculated with *Glomus etunicatum* ($P<0.001$). Although irrigation with waste-water has also increased the overall growth of both tree species ($P<0.001$), a significant inoculation*irrigation interaction ($P<0.001$) showed that this effect was absent in uninoculated plants (Table 1). Growth responses of the inoculated trees to irrigation also differed according to the fungal inoculant: although overall growth of trees inoculated with *G. mosseae* was better than those inoculated with *G. etunicatum*, this was attributable to the better growth response of *G. mosseae* inoculated trees to irrigation.

Table 1. Growth response of *Glomus mosseae* and *Glomus etunicatum* inoculated trees to irrigation treatment (letters indicate LSD at $P<0.001$)

	G. mosseae	*G. etunicatum*	Uninoculated
Irrigated	32.3a	25.4b	6.9d
Watered	18.0c	16.3c	6.6d

As neither of these 2 tree species associate with N-fixing bacteria, the results suggest that *G. mosseae* is more effective than *G. etunicatum* in the uptake of N, and to a lesser extent P, from the irrigation water.

Progress against activities defined in technical annex

- WP4: Glasshouse experiment is continuing.
- WP4: isolates of AM fungi are being maintained in glasshouse.

Forward look

- WP3: training in measurement of sapflow in Burkina Faso, development of water-use model once data available from partners
- WP4: completion of glasshouse experiment; assessments of soil microbial activity and diversity, and stomatal conductance.

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

Work package 1: Water treatment and Irrigation

The irrigation system is functioning in Mali since April 2004. In fact the water used for irrigation is treated by the irrigation devices (drains which collect water through the soil pores and trees). The maintenance works of the system are done regularly (reinforcement of the second embankment with clayey soil).
According to the advise of the Canal province's expert (Francoise Bouroulet) (subcontractor), the drains have been dig deeper up to 50 cm and the water basin is divided in to 4 smaller basins. Since the purified water is not actually used for market gardening, Francoise Bouroulet suggested to practice fish farming in these water basins.

Partner 3 should assess the health aspects and quality of wastewater.

Work package 2: Tree growth and Management

The remaining irrigation space has been planted and the different tree parameters of these trials are measured regularly.

The coppicing of trees for fuelwood and fodder should start as soon as possible. But a good protocol should be agreed by all partners before starting the activities.

Experiment 1:
Objective: To compare the growth of tree species in different countries under irrigated field conditions in Burkina Faso, Niger and Mali.
Species used in Mali are: *Gliricidia sepium*, *Acacia angustissima*, *Leuceana leucocephala* and *Kaya senegalensis*.
The works are related to trees parameters measurement mainly plant height, basal diameter, diameter at 1m30 and the number of branches. These parameters are measured monthly and the data are available. Some of these data have been presented in the past annual report. The treatment of these data is going on and the technical report will be performed soon.

Experiment 2
Objective: to do a quick screening of the trees already produced, just to make sure that the selected species for experiment 1 are the best species
Species used in Mali are: *Acacia crassicarpa*, *Acacia mangium*, *Acacia auriculiformis*, *Leucaena leucocephala*, *Gliricidia sepium*, *Calliandra calothyrsus*, *Acacia angustissima*, *Acacia Senegal*, *Pterocarpus lucens* and *Khaya senegalensis*.
The same data concerning experiment1 have been also collected in this trial.

Work package 3: Tree Water-use and soil water status.
Many data such as sap flow, soil moisture and meteorological measurements have been collected in experiment 1 and 2. The measurement has been done in the treatments with and without mycorrhizas concerning each

species. Some of the data have been already sent the project coordinator Dr. Julia Wilson. We have experienced a period of interruption but now we started with the collection of sapflow data.

Work package 4: Mycrosymbionts and N-fixation:
Mycorrhizal infection data from the different treatments will be collected as soon as possible.
Spores extraction from the different treatments is going on. As reported by the coordinator of the project in a paper entitled 'Ubenefit: Progress of work and future plans' studies of inoculum potential of field sites will be performed in this reporting period.

Work package 5: Socio economic surveys have been done by Partner 3.

Work package 6: Soil and Plants nutrition,
Soil samples have been taken at the end of the rainy season in two horizons at 0-20 cm and 20-40 cm depth. Sampling is done according to the treatments. These soil samples will be analysed for chemical parameters.

Work package 7: planting stock qualities,
These data have been collected and analysed and reported in the previous annual report. Shoot root ratio, sturdiness quotient and Dickson's quality index of seedlings have been assessed before planting.

Work package 8: Pest monitoring has been done by Partner3.

Problem encountered:
The delay in the payment of our money causes a serious problem in performing our activities. The money has been available in our account there is only 2 weeks.

Partner 3: University of Bamako, Mali

This report emphasis on progress done on

- Survey of inoculation effect in field experiments
- analysis of soil, water and plants for their nutrient and heavy metal contents
- Pest and diseases
- economics studies
- training

WP4 Results of inoculation

Effect of inoculation was performed in experiment 1 and 2 by analysis of data collected in February and March 2006. Effect of inoculant was assessed using measurement of plant growth parameters.

Roots assessments for nodules were performed in February (6 months after planting). Roots nodules were collected for DNA extraction and analysis in the lab of soil microbiology at FAST Mali.

The presence of used strains/inoculant was investigated using RFLP as molecular markers techniques in the LCM at Dakar.

WP5 Economics

The surveys for economics studies were done. Activities planned for July 2005 were done, according to the methodology and questionnaire discussed in Burkina Faso during the last meeting. Relevant data on fuel and fodder were collected in 504 villages using investigation method (sample survey). Six (6) levels were concerned: Householders, wood and fodders providers and sellers, technical services (ON, Research Center for IER.), supporting Consul and NGO, Private Actors, Fields experiments in Minimana,

Data are being analysed, and are being compiled into a report.

In those villages several meetings and discussions were held with rural community and different groups concerned by fuel and fodder production,

A film and photographs were elaborated to document step by step this study.

WP6 Soil and plant nutrition

Soil, water and plants were sampled. Water was sampled and analysed chemical, heavy metal and pesticides residues during in February and May 2006 (six and nine months after planting).

Heavy metal were investigated using irrigated water and water collected after plant irrigation at the lab of LQE in Bamako, Mali. Presence of pesticides residues in both water was analysed for risk assessment in the LCV in Bamako, Mali.

Plant sheet were dried and send to the lab of LCM/ Laboratoire of biopédology at Dakar for analysis for the presence of heavy metal and main nutrients contents.

WP7 Pests and diseases

According to the last meeting in Burkina Faso, pest and diseases were investigated in the two experimental design, six and nine months after plantation

Soil and plant roots were sampled and analysed for nematodes investigation in the lab of IPR/IFRA. In each plot composite sample or main sample was performed using five sub- samples collected and mixed as defined by protocol adopted by different involved partners.
In each plot 4 plants were used for investigation of nematodes on roots.
Soil main properties C, C/N, N and K were determined.
Plant health was observed regularly.
Main attacks were observed by locust *(Micratauria microtaurides*). But no significant damage was caused because the problem was overcome by rapid intervention of local population and authorities, project technician and technical service agencies.

Problems:
Main attacks were done by locust (*Micratauria microtaurides)*.To solve this problem local populations have help to overcome this problem by involving technical services Thus chemical product Drusbans (1%, 1litre of Drusbans at 15ec in 100 litres of water) has been spread utilized by technical staff.
Availability of money: money transfer has been slow.

Training
Mr Fallaye KANTE registered for Ph. D degree at ISFRA in Mali, is now in Mali for collecting data from the site of Minimana Seribala. He will join the Lab of LCM for after collecting some data after copiccing.
Dr Inamoud YATTARA, Dr Fassé SAMAKE, Bakary SAMAKE and Hamed BATHILY were trained in wastewater treatments by Partner SCP. This project give opportunity to Youssouf CISSE registered at ISFRA to do a Ph. D

Workplan for remaining period (X three months)

	Year	
Wp and activities	**2006**	**2007**
Wp 4.		
Coppicing:	**June**	
assessment of plant growth parameters	**XX**	**XX**
assessment root nodules	**XX**	
Molecular microbial	**XX**	**XX**
Wp5 economic	**XX**	**XX**
Wp6 Soil and plant Analysis of Soil water, Plant Nutrition. Assessment of risks from heavy metals, pesticide residues	**XX**	**XX**
W7 pests and diseases Soil and plant analysis for pest	**XX**	**XXX**
Training and exchange	**XXXX**	**XXXX**
Reports	**X**	**X**

Partner 4: INERA Burkina

Mahamadi Dianda, Jules Bayala and Kadidia Sanon

WP 1. Wastewater treatment and irrigation

Wastewater purification system

The wastewater treatment equipment was totally installed and tested at the beginning of December 2005. This test coincided with the visit of SCP (represented by Mme Bouroulet) to INERA with the aim of assessing the functioning of the water treatment system and train local partners. According to her evaluation the purified wastewater presented appropriate characteristics. However, the system stopped functioning in late December because the sole pump that supplies the equipment with wastewater collapsed due to plastic materials carried in the wastewater. SCP and the local wastewater treatment specialists were informed of the problem and were asked for suggestions or solutions. It took us a long time to replace this component by a new pump that needed to be commissioned from Europe. At present the pump has been reinstalled and is being tested, along with the monitoring of the treated wastewater quality.

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Irrigation

This part of the system was completely installed in January 2006. The work was voluntary delayed waiting for running treated wastewater system in view to optimize the adjustment of irrigation system. However, because the treated wastewater was not available due to the difficulties outlined above, the irrigation system was installed without any water flow.
There were many criticisms by the SCP visitor about the functionality of the irrigation component which appeared not adapted to the field topography. Basically, a much steeper slope should have been realized to allow the purified wastewater to run downhill (gravity). Thus, there are many errors inherent to initial misconception of the system that further may account for the major difficulties in irrigation activities.

Currently, the irrigation activities are conducted manually using an independent motor pump (with fuel) to supply the treated wastewater to the plantation. However, for efficient irrigation it is suggested that an additional electric pump should be necessary to replace the actual motor pump, provided that financial resources are available to support additional costs.

WP 2. Tree growth and management

Preliminary Experiments

As repeatedly shown at the successive coordinating meetings of the project, preliminary irrigation experiments are necessary to address some essential scientific questions not explicitly detailed in WPs. For instance, it was agreed that irrigation trials to screen potential species and select candidate species for the main experiments were necessary. INERA carried out such irrigation experiments along with inoculation with microsymbionts on 20 local and introduced species. Although these experiments allowed the assessment of growth responses of species both to irrigation and inoculation, the result remained incomplete since data on mycorrhizal status of plants were lacking. Unfortunately, samples of fine roots that were taken to estimate the extent of root colonization by mycorrhizal fungi were accidentally lost.

Therefore, two small trials are being carried out as previously detailed (except that tap water is being used instead of well water) to generate more complete data on the mycorrhizal status of inoculated species in our environment. One experiment deals with the responses of 20 species to irrigation and inoculation with mycorrhizal inoculants (inoculated vs. uninoculated plants). There are two levels of irrigation, i.e. "permanently" wet and "temporarily" wet. In the former irrigation option, plants are grown in pots containing permanent levels of water delineated by holes made 4-5 cm below the soil surface in the pots, whilst in the later option treatments consist of common pots with holes made 2-3 cm above the base. The pots are watered twice daily with tap water in excess. Observations have shown that between the two water supplies, the soil surface tends to dry out only in pots with basal holes. The design was a split plot (with irrigation in main plots) with 3 blocks. The second trial is to evaluate the combined effect of inoculation with both rhizobia and mycorrhizas in *Acacia* sp, *Leucaena sp* and *Gliricidia sepium* and *Calliandra*. These species are being used because of the availability of their appropriate rhizobial inoculants. The plant species were inoculated each with the proper rhizobial strain following the recommendations of IRD. There were 4 blocks with a split plot design to reduce the risks of cross contamination between treatments. In both of the two trials, a single mycorrhizal strain (*Glomus* sp.) was used for inoculation. Seeds were pre-treated following the recommendations of the suppliers. After germination the seedlings were transplanted in pots containing 2 kg sand. Plant height and collar diameter will be monitored monthly. The experiments will be ended 2-3 months after inoculation for the assessment of growth and symbiotic characteristics.

Main experiment

The main field experiment has been set up with the four species retained by INERA according to the plan agreed by all partners (2 m and 1 m spacing

between and within lines, respectively). There are 4 blocks each comprising 4 plots of 4x4 plants.

Tree management

A second plantation similar to the main experiment (except that there are 3 blocks) was established to support tree management studies (coppicing trials).
Soil profiles were realized at randomized positions to describe the soil structure. From these profiles, soil samples were collected for chemical analyses before any irrigation activities.

WP 7. Planting stock quality

The parameters of planting stock quality (WP7) have been estimated using plants of the first screening experiments mentioned above at nursery stage. Some seedlings have been transplanted in the field for demonstration purposes, and their growth is being monitored frequently. Some of the transplanted trees will be removed to assess their biomass production (wood, fodder) as well as the stock quality parameters at the field level.

WP8. Pest monitoring and management

The monitoring of pests and diseases were done at seedling stage in the nursery, in bare field soils, and in the field again after the establishment of the plantations. Signs of disease were not noticed at any stage, although there was some dieback, which is being assessed. Details of the methods used for pest monitoring are not available, but emails have been exchanged between the specialists of Burkina and Mali for this topic.

Constraints

Apart from the technical problems outlined above, our activities are threatened by financial limitation. Most items that need to be monitored in the field including the quality of wastewater treatment, soil and plant analyses, etc., require the contribution of specialized labs and may bring about huge expenses. At present we fear to be unable to cover all topics listed. Furthermore, we have commissioned for a film on all activities of the project as a proper tool for dissemination. Even though up to two third of the scenario have been realized, we are forced to stop the process due to lack of money. Overall we are thinking of revising and managing the number of activities we have planned to do in a way to get the maximum out of them.

Partner 5: University Abdou Moumouni, Niger

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

During this first semester of the fourth year of the UBENEFIT project, the main activities were the measurements of plant growth, the sampling of soil, purified and non-purified water for irrigation, roots and nodules.

The trees were transferred to the field on August 13, 2005 and since then have been irrigated with waste water through a drip system. From august to February, trees were watered at two days interval with 6 litres of purified water/tree. But since March, with the high temperatures, the frequency of irrigation has increased, since then, each tree has received 6 litres/day.

Since transferred to the field, the following measurements for plant growth were carried out on trees at weekly intervals: the collar diameter, the plant height, the number of leaves.

Samples of water for irrigation have also been collected twice a week in order to determine it's quality. Therefore the following nutrients have been analyzed : total N, NH_4^+, NO_2^-, NO_3^-, total and available P, Al, Cd, Cr, Co, Cu, Mn, Mo, Ni, Na, Zn, SO_4^{2}, pH and conductivity. Some samples of waste water before purified have also been collected at weekly interval for analysis.
Roots and nodules samples were collected on the plant in order respectively to determine the mycorhization and the rhizobia strains.
In order to detect the annually changes in soil nutrient and organic matter status pre and post irrigation/plantation, samples of soil were also analyzed.

PLANNING OF ACTIVITIES

-The test of pruning will be carried out when tree will have sufficient growth ;
- The second experiment to make a quick screening of the trees produced in the current experiment.

Partner 6 IRD, France / Senegal

Tatiana Krasova-Wade and Marc Neyra

Work package 4 (Microsymbionts and Nitrogen-Fixation)

The principal task planned for IRD for this period was the analysis of the nodules collected by partners 3, 4 and 5 in field studies in Burkina-Faso, Mali and Niger. Unfortunately, due to the delays for establishing experimental trials, the nodules having been just collected and not yet sent in Dakar, we could not begin this analysis which will thus be carried out during the next period.

Falaye Kanté (partner 3, Univ. Mali) finished in December his six months stay (from July to December 2005) in LCM during which he was trained on DNA characterization of nodules.

Inamoud Yattara (Université of Bamako, Mali, Partner 3) and Alzouma Mayaki Zoubeirou (Université Abdou Moumouni, Niger, Partner 5) met together with Tatiana Krasova-Wade and Marc Neyra in Dakar on April 26 to plan the future actions.