ACACIAGUM

Innovative Management of *Acacia senegal* trees to improve land productivity and Gum Arabic production in Arid and Semi Arid Sub-Saharan Africa

NEWSLETTER No. 1/APRIL 2011

Dear All,

It has been a long time since the last issue of the ACACIAGUM's Newsletter. Significant progress was made by the project's consortium and this new issue is aiming to update you about the main results obtained in each Work Package. The Annual progress report for 2010 has been sent to the European Commission (Project Officer and Financial Officer) few days ago and we should be getting feedback from both of them in a couple of weeks. All our activities are almost in accordance with the time frame presented into the project document and the same comments could be done about deliveries and expected results.

We have started the last year of the project as the project has got in early January 2010 a one-year extension without any extra budget. The main argument to get such extension was the absence of activities carried out during the first year of the project because of administrative difficulties. This is giving us more time to finish the ongoing activities but also to publish papers and attend International Conferences where our results have to be presented. So far, ACIACIAGUM has generated a limited number of publications and significant efforts have to be made to achieve this objective. So you are all invited to attend International Conferences scheduled in 2011 such as the Rhizosphere 3 Conference in September 2011 in Perth-Australia or the 17th International Conference on BNF in Perth-Australia in November 2011.

Other upcoming issues of the Newsletter will be edited soon, a special one will be dedicated to Master and PhD students involved in the project. The consortium has made a significant effort on capacity building and this has to be raised because at the end of the project, more than 5 PhD students and 8 Master students will have taken advantage of ACACIAGUM to get graduated.

I hope that you will enjoy the Newsletter and as usual we look forward to hearing from you if you have comments and questions about its content.

Best regards

Didier Lesueur

Scientific Coordinator of the ACACIAGUM project

The **ACACIAGUM** Newsletter will be published twice a year. If you have any pictures or articles on project activities kindly email Info@ngara.org

For more information on ACACIAGUM contact:
Didier LESUEUR (PhD)
CIRAD, Dept PERSYST, UPR 80 "Ecosystems of Plantations"
Tropical Soil Biology and Fertility Institute of CIAT,
World Agroforestry Centre,
PO Box 30677, Nairobi, KENYA
Phone: +254 20 722 4777 Mobile: +254 723 916 767
Fax: +254 20 722 4763/64
Email: didier.lesueur@cirad.fr

WORK PACKAGE 1

General Objectives

To gather information on experience and constraints of local populations with *A. senegal* management in order to ascertain user priorities with respect to different activities (tree plantation, tapping, gum picking, fodder harvest, crop association, etc) and criteria of choice, including exogenous factors (economic situation, market situation, forest policy, exploitation rights, etc…) as a function of site conditions.

Specific Objectives

- To assess the current state of the art on A. senegal uses and gum production,
- To describe the commodity chains,
- To build a typology of the actors participating in the A. senegal resource management, gum production and marketing,
- To synthesize traditional agro-ecological knowledge applying to gum-arabic production, multi-purpose use of A. senegal and incorporation of gum trees into farming systems,
- To identify constraints and factors limiting gum production and utilization of Acacia trees

Highlights

- In all the participating countries, all the sites and the corresponding stakeholders involved in the gum arabic activity were described.
- In Kenya, Niger and Senegal the main stakeholders are the gum collectors in natural stands. In Senegal, some private companies are also strongly involved such as Asylia Gum Compagny and Valdafrique, who are dealing with International Trading Centers.
- The interest of local populations for *A. senegal* plantations is very different according to the country. In Senegal we have found large-scale private plantations, while in Cameroon many small plantations and no private plantation are existing in Niger and Kenya.
- Tapping is widely practiced in Senegal (in Ferlo but not really in the Goudiry area) and a little bit in Cameroon. In Kenya and Niger people do not tap *A. senegal* trees.
- The average amount of gum arabic produced per tree is around 275 g to 350 g per tree in Cameroon. In this country, a collectors can get around 500 kg of gum arabic in a year which represents an important source of financial revenues. In comparison in Kenya, this is estimated at around 185 kg of gum arabic in a year.

WORK PACKAGE 2

General Objectives

To understand the inter-linkages between the institutional organization of supply chain networks with the dynamics of innovation regimes in gum-arabic production, and their implications for rural livelihoods.

Specific Objectives

- Identify categories of farmers who are typically involved in particular market outlets
- Understand aspects that influence bargaining power and value added distribution along the chain
- Understand the influence of price and non-price aspects on primary production decisions (scale, technology choice, input intensity, labour use, quality performance)?
- Identify processing techniques and logistics regimes that offer best prospects for improving chain performance and tailoring gum production towards market requirements
- Explore how market segmentation systems based on (eco) labelling or certification could be helpful for enhancing process innovation and product upgrading?
- Understand the effect of insights regarding the functioning of the chain (including problems, opportunities and options for change) on the dynamics of cooperation among chain parties?
- Analyse the influence of interventions on learning and negotiation among chain parties, and understand the factors which stimulate or hinder progress in the chain innovation process?

Highlights

Cameroon

- Fieldwork and interviews with different categories of actors led to evaluation of their importance (number and presence) in the different study zones. The different categories of actors identified are interlinked in diverse ways
- Some of the actors supply seedlings to the farmers and other training on tree planting and tapping techniques. In recent years however, the activities of these institutions have reduced and are not regularly monitored (according to the farmers). The only active institution is SNV/FAO involved in the organisation of marketing, at least to some extent.
- The visited markets involve gum transactions from *A. senegal*, *A. seyal*, *A. polyacantha* and even other gum extracts. The quantity brought to the market varies from a quarter to 10 kora of gum. Producers regularly supply to the intermediaries and the regularity depends on loyalty to the intermediary. In each market 2 to 5 intermediaries were found.
- In the periodic markets of the Pays Toupouri, one collector can employ several intermediaries each with different stalls and at the end of the market day these purchases are assembled.
- In the markets of Sud-Bénoué, the quantities of gum arabic transacted are minimal, mainly used for crafts (washing caps, making ink for koranic schools…). In these markets few intermediaries are involved in gum arabic alone, but these traders retail other consumables.
- Gum trading is ongoing but the flows are reducing in quantity due to the Exporter's

monopoly and lack of commitment to purchasing.

- The embryonic organisation of the gum arabic chain remains the main factor discouraging the different actors who are not informed and are left at the margin when it comes to decision-making.

Kenya

Data was collected among the gum collectors and traders in the arid zone of Kenya. This was preceded by a pre-survey in Isiolo and Marsabit districts to test questionnaires and check possibilities for establishing a marketing monitoring system.
The targeted groups included collectors, traders, and other community actors. The questionnaires were consequently improved to reflect the distinctiveness of gum production and marketing in Kenya.

The survey targeted communities of gum arabic collectors; that is not only associated with occurrence of *Acacia senegal* but also with marketing of gum arabic. Hence some areas that were not surveyed even there was high occurrence of the Acacia species

Apart from collectors and traders, other people/institutions who are directly or indirectly involved in the sector were also visited such as Government officials/institutions, Community Based Organisations (CBO's): PANAPEL/Isiolo, Gum and resins associations and Non-governmental organisations

Results

On collection

Drought and insecurity were the biggest constraints.

- Insecurity: This region has been characterized by insecurity, especially in districts of Isiolo, Samburu and Turkana.

- Prolonged drought: During the drought people migrate in search of water and pastures. In addition the Government offers food relief; hence the people do not need to collect gum which fetches a small price, where as they already have some food. When they need money, they can always sell a portion of the food items they received from food relief.

On marketing chain

The reliability of market outlets/buyers is the main constraints in marketing which is perhaps another big problem constraining collection. This means that collectors are not interested in gum knowing there is no 'accessible market' for them or they will just get a 'low' price. This reluctance to collect gum without market assurance is associated with past disappointments for instance with the closure of SALTLICK (an NGO) in Turkana, collectors do not really know where to go with their gum since the buyers (duka owners in the village) do not also know where to profitably re-sell the gum.

Large traders confirmed that they are only interested in places where substantial quantities can be obtained because of the high cost of reaching the production areas.

This illustrates the need for a linkage between buyers and collectors, and highlights the need for information sharing; on this many respondents mentioned the need for a 'project' that could help in this linking role.

On monitoring

The monitoring exercise attempted during the pre-survey did not work out. At the time of survey when the notebooks were to be checked, the

traders said that there had not received any gum from the collector.

The survey was able to reach out to many people who seemed genuinely interested in gum arabic as shown by their participation and willingness to answer all the questions included in the questionnaire despite being a long and time-consuming one. However in some areas, respondents were not happy as they were expecting to be paid at the end of questioning.

Senegal

Data was collected among the chain agents in the gum production zones namely the **Sylvopastoral zone** covering the southern of the Senegal River and the **Eastern region (Tambacounda)** covering the region Tambacounda of Tambacounda.

Apart from the production zones, interviews were done with representatives of Valdafrique (Dr Madiagne Sakho) and Management Communication International (Pr Abdoulaye Sanokho) which are companies involved in the transformation or exporting of gum arabic.

The main issues discussed with these representatives include the organisation of gum supplies from the production zones (traditional chain or with EXPERNA), transformation operations (spray drying, manufacturing of pastilles) and exportation (sprayed gum powder or raw gum); and quality maintenance.

The approaches used for collecting information are surveys, interviews, semi-structured interviews and a literature study. The main instruments were questionnaires for gum harvesters, local boutiquiers, mobile traders and other traders. There were also interview guides for other key persons and leaders of government and non-government institutions involved in the gum sector.

With regard to gum marketing, the focus was on the physical transaction places: frequency of transactions, main buyers and respective market share in relation to the places.

The information also included the price determination and evolution, quantities transacted and revenues generated from gum sales. In addition, opinions were included in relation to the profitability of gum arabic harvesting and marketing in comparison with the other activities carried out in regions of study.

The analysis of the marketed quantities of gum arabic (declared at the Forestry Services) shows a progressive evolution of the quantities and the existence of several marketing points or zones. There are:

- **Collection or primary markets**: found in the gum collection zone. They include 3 categories of actors: the natives who are gum harvesters and immigrants who are the mobile collectors and permanent boutiquiers. In general we observe that there are no institutions involved in the management of gum harvesting. There is open access, there is no monopoly whatsoever and the marketing is only associated with private initiative. Prices are uncertain and the risk factor is quite important.

- **Assembly markets**: These are weekly and borehole markets. They constitute the first links from where gum is marketed.

In zones bordering other countries such as Mauritania, Gambia and Mali, a portion of the produce is exported however this is not accounted for the national production. Imports from Mali for

re-exportation to France were also observed. This informal flow is explained by the lack of control by the Forestry Service. The large economic operators with large finances obtain gum supplies from these markets. It is at this level that a tax is paid which allows these operators to take their goods to larger trading centres. This means that the losses and own-consumption shares found at the collection zones and even during assembly are not included in the statistics. It was observed that there are changes in the role and functions of some actors including middlemen and wholesalers who came to these markets for supplies.

Market dynamics

Small quantities collected by many harvesters who are not organised in a cooperative structure lead to low bargaining power of the producers.
The market chains of forest products are regulated by the forest legislation and related institutions. However, for the non-wood forest products, this legislation is not binding/rigorous. This does not mean that there are no constraints from implementing this legislation: open access is one of the biggest constraints in that it leads to thefts and abuse of the non-wood forest products and the tree resources.

All strategies aiming at improving the availability of resources and production conditions will also lead to reinforcing the producers' position. However, since the resource stock is not unlimited, the main issue to handle is the management of forest resources in terms of availability and sustainability.

The development strategy to adopt in this regard to forest resources in general and *Acacia senegal* trees in particular must be based upon:

- Creating a sense of responsibility within the local populations neighbouring forestry resources will lead to the creation of a management structure in the respective forestry sectors. This organisation which is indispensable for the development of the collection zones might also allow the creation of an effective system in terms of trainings for the techniques of harvesting and product preservation.
- Identifying and encouraging marketing opportunities for individuals or associations in the exploitation/harvesting and/or primary processing
- Access to appropriate credit programmes and installing equipments or other small scale processing technologies.

In short term, these strategies will enable the consideration of marketing gum of good quality which enables incentive prices.

WORK PACKAGE 3

General Objectives

The overall aim of this work package is to characterise the impact of the biophysical environment and tree management on gum yield and quality in multiple *A. senegal* based systems.

Specific Objectives

- To investigate the impact of rainfall and soil conditions on the growth, gum yield and quality at a range of sites with contrasting climate / soil conditions and to characterise water use through seasonal time series to analyse the impact of water availability, current and historic, on gum yield and quality.
- To analyse provenance differences in water-use and adaptation to edaphic conditions and to define selection criteria for *A. senegal* production systems.
- To investigate relationship between eco-physiological characteristics of *A. senegal* and both tapping management *A. senegal* management strategies, in order to make recommendations for optimising gum-arabic production.
- To study the outcome of a number of tree-crop systems incorporating *A. senegal*, including variable density, crop species selection and tree management strategies such as crown and root pruning, in order to evaluate approaches for the optimisation of gum yield, crop productivity and soil condition.
- To evaluate the potential to enhance gum yield with the use of a promising plant hormone (ethephon).

Highlights

CEH collaborated extensively with ISRA and UCAD in Senegal and with KEFRI in Kenya, made three field visits to Senegal. Additionally, CEH conducted further activities in its tropicalised glasshouses in the UK.

Leaf samples for analysis of natural abundance stable isotope ratios of C^{12}/ C^{13} (providing a measure of water use efficiency) were collected from 2 trials in Senegal (at Dahra and Bambey), which contain the same provenances growing under different rainfall conditions. Parallel samples were collected for N^{15}/N^{14} analysis for WP 5 (measuring nitrogen fixation), in collaboration with KEFRI. The analysis of all these samples is in progress.

In addition, root pruning to control tree-crop competition was demonstrated and is now being applied experimentally in trials at Dahra and on farm near Tambacounda where its effects on crop growth and gum yield are being evaluated. In glasshouses, morphological and physiological characters of provenances of *A. senegal* seedlings extending across its natural range are being assessed and linked with genetic analyses under WP4.

ISRA has examined the dynamics of soil water storage (**Wr**) and water potential in shoots of tree provenance in the trial provenance of Bambey and Dahra. Base level water potential and diurnal depression from the base level were measured in the beginning, full and the end of rainy season. This was measured just before dawn, when the water content of leaves and soil is presumed to be in equilibrium, should express the static water stress.

The phenology, gum production, leaf and seed samples were in progress. These measurements are made at the beginning of the rain season, the full rain season and the end of raining season.
At Dahra, Soil water status in the end of rainy season wasn't significantly different of those of beginning rainy season. Water status was higher in Bambey than in Dahra at the BRS and ERS.

Tapping was done in December 2008 and gum samples collected in January, February, April and July 2009 in Dahra. For local provenances, Daïba was the best provenance in the gum production in 2008 (Figure 1).

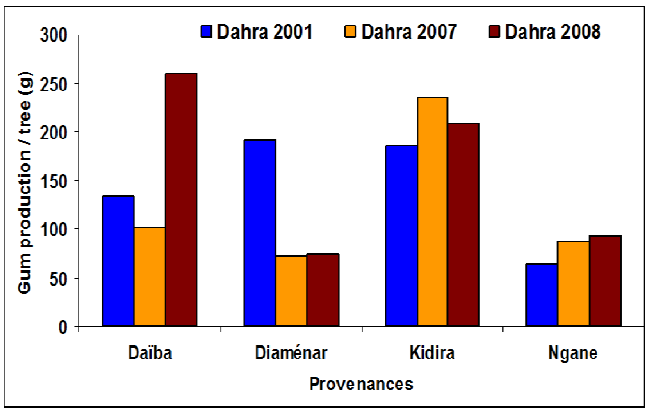

Figure 1: Variability of gum arabic production of local provenances in Dahra

In Dahra, gum production was increased at the first tapping (2001) to the thirty (2008) for 8 provenances (Bissiga, Daïba, Djigueri, Inde 60, Karofane, Kirane, Ngane and Somo). But highest gum production in 2008 was recorded for Karofane (260.3g), Daïba (259.6 g) and Somo (236.4 g). There is a low variation of annual gum production for tree provenances of Kidira, Tchad and Ngane in Dahra. Gum production is more important at Dahra than Bambey whatever the provenances except for India 50.

Regarding the work carried out by UCAD, the investigations were done in plantations of *Acacia senegal* twenty years old in two contrasted agroecological areas in Senegal, in order to assess the impacts of *A. senegal* trees management in gum yield and associated crops production.

Experimental designs were applied in the Sylvo-Pastoral area (Dahra) and South East area (Maleme Niani) to compare four tree pruning treatments (roots pruned trees, shoots pruned trees, root and shoots pruned trees, and not pruned control trees) effects on associated crops production and gum yield. Trees pruning was carried out during the dry season. For each treatment certified seeds of *Vigna unguiculata* (Cowpea, Var. melekh) were sowed during the rainy season.

Preliminary results showed that pruning had positive effect on cowpea cultivation in terms of fodder production and pods yield. Our results showed that even though any significant effect was recorded, the highest pods yield was obtained for cowpea associated with shoots and roots pruned trees. So, *A. senegal* trees might be associated to *Vigna unguiculata* without a significant negative effect on crop production. Trees were tapped and investigations on gum production are going on in order on to evaluate the effect of pruning on gum production

WORK PACKAGE 4

General Objectives

To characterize existing quantitative and neutral genetic variation and identify and understand the basis of variation in gum quality / yield.

Specific Objectives

- To sample existing provenance / progeny trials and natural populations to achieve range-wide coverage
- To optimize molecular methods for analysis of *A. senegal*
- To optimize chemical methods for analysis of *A. senegal* gum quality
- To characterize range-wide genetic variation and structure and patterns of variation in gum quality
- To synthesize quantitative data (provenance trials) with new data for genetic and gum quality variation

Highlights

- Significant advances have been made in analysis, based on method development and collections prepared during earlier periods. This has resulted in two new technical papers - Assoumane et al (2009) and Omondi et al (2010, accepted) - dealing with development of new and transfer of existing microsatellite markers. These tools have been applied to collections from Kenya (*A. senegal* var. *kerensis*, 220 trees) and Niger (A*. senegal* var. senegal, 470 trees) and analysed to assess genetic diversity and population structure, work which has so far resulted in one new publication, Omondi et al (2009).
- In addition, variation in the chloroplast genome has been surveyed in a large collection covering the entire species distribution from West Africa to India and South Africa. The data from this study is being synthesised with morphometric analysis of glasshouse-grown provenance material and will be submitted for publication during 2010. In both the rangewide collection and Niger collection, several candidate gene loci have been sequenced and are being assessed for variation; these variants will be used to investigate performance differences between provenances under trial conditions and stress testing.
- Finally, gum samples from a provenance trial in Senegal have been analysed using NIRS (near-infra red spectrscopy). A number of samples were characterised for chemistry and physical parameters using classical techniques, to provide calibration of the NIRS spectrum. Good predictive power was achieved using NIRS for, in particular, the key gum quality parameter of optical rotation, indicating that the method would be effective for high throughput screening of gum sample quality.

General Objectives

The general objective is to improve understanding of the relationship between soil microbial communities involved in the N cycle and the capacity of *A. senegal* trees to produce gum arabic in different environmental conditions and to rehabilitate degraded lands.

Specific Objectives

- Assess soil characteristics in association with *A. senegal* trees in plantations and natural populations of gum-producing *A. senegal* located in different climatic regions (*e.g*. rainfall gradient)
- To identify the natural diversity of symbiotic and heterotrophic communities associated with *A. senegal* occurring under various environmental conditions
- To measure the impacts of inoculation with selected symbiotic inoculum in terms of :
    - microbial activity, - seedling establishment and early growth, - N_2-fixation, and
    - arabic gum production in mature trees

Highlights

Senegal

UCAD/Senegal made a screening, and a selection of effective rhizobia associated to *A. senegal* was achieved. The genetic diversity of the selected strains was assessed.

Trapping, enumeration, and isolation of rhizobial strains: Forty eight (48) native rhizobia associated to *A. senegal* were trapped with different seeds and soils provenances. The seeds were collected from 3 sites (Dahra, Ngane, and Kidira) and soils from 2 sites with contrasted edaphic and climatic conditions: Dahra (arid zone) and Goudiry (subhumid zone). The MPN method was used to enumerate the rhizobia. The results indicated that the number of rhizobia nodulating *A senegal* is higher in the subhumid zone compared to arid one. Similarly, the nodulation rate and the nodules number were higher in the semi-humid zone (Goudiry), whatever the provenance tested.

Genetic diversity of the rhizobial strains: PCR/RFLP analysis of 16S-23S rDNA resolved the 48 strains in 14 electrophoretic clusters. The results indicated that two IGS types (types I and III) were both present in the two sites. Three ribotypes were identified by PCR/RFLP analysis of the 16S gene. All the IGS types from Dahra were present in the ribotype 1. The diversity estimated by Shannon diversity index indicated that the 16S-23S rDNA genetic diversity of the rhizobial isolates is higher in Goudiry site (H = 0.933) compared to Dahra (H = 0.638). The characteristics of the soils used as inoculum and seed provenances influenced the distribution and the genetic diversity of the rhizobial populations associated to *A. senegal* as estimated by Principal Component Analysis (PCA) and Simple correspondence analysis (SCA).

Selection of the best inoculum in relation to the soil characteristics and *A. senegal* provenances: An experiment is going on in greenhouse conditions to compare the efficiency, in terms of biomass production and nodulation of strains representatives of the 14 electrophoretic clusters identified on 9 provenances of *A. senegal* grown on two non-disinfected soils. The provenances tested came from Senegal (3), Kenya (3) and Niger (3). Investigations will be undertaken to assess the impact of rhizobial inoculation on soil bio-functioning for each factorial treatment design (provenance x microbial inoculation x soil).

AM fungi community diversity and spores density in the rhizospheric area of *A. senegal* trees: AMF were trapped on maize during 5 months and the spores were extracted to described the morphological characteristics. In Dahra, rhizospheric soils of *A. senegal* plantation and natural populations soils shared the same AMF species (*Scutellospora sp1*, Acaulospora *sp1*, *Glomus sp1 aff. Aggregatum*). Meanwhile, 6 species including the 3 found in *A. senegal* rhizospheric soil (*Scutellospora sp1, Acaulospora sp1, Glomus sp1 aff. Aggregatum, Scutellospora sp2 aff. verricosa, Gigaspora sp, and Glomus sp2)* were obtained in the soil without *A. senegal.* In *A. senegal* plantation at Bambey site, 3 AMF species were obtained (*Scutellospora sp1, Glomus sp2, and Glomus sp3)* with only one species common with the plantation soil at Dahra. In this site, the soil without *A. senegal* displayed 4 AMF species (*Scutellospora sp2 aff. verricosa, Scutellospora sp3 aff. gregaria, Glomus sp1, and Glomus sp2*) different from those obtained in the *A. senegal* rhizospheric soil. The results indicated that AMF spores density varied with the sampling areas (in *A. senegal* plantation, natural population or without *A. senegal*) and with the sites edaphic conditions (Dahra, Bambey, and Goudiry).

Microbial activity: Microbial activities of microbial communities associated with AM fungi present in the rhizospheric area of *A. senegal* trees were assessed using some enzymatic activities as Fluoresceine Di-Acetate, Dehydrogenase, Acid and alkaline phosphatases. All of the enzymatic activities measured were higher in rainy season than in dry season. During the dry season the soil enzymatic activities were higher in Goudiry soil than in Bambey and Dahra whereas in rainy season these activities were higher in Dahra compared to Goudiry.

Inoculation: The impact of inoculation with 6 AMF species on seedlings growth and mycorrhizal colonization by AMF was assessed. The results showed a positive response of *A. senegal* to mycorrhizal inoculation in the 3 different soils. The growth and root colonization of *A. senegal* are influenced by the species of AMF used as inoculum as well as by soil physico-chemical characteristics. *A. senegal* is highly dependent to AMF and the level of mycorrhizal dependency depends on the inoculated AMF species and the soil physico-chemical characteristics.

Regarding the work by IRD, in Bambey site, the impact of 17 *A. senegal* provenances from 9 countries (Burkina Faso, Ethiopia, Mali, Mauritanie, Niger, Pakistan, Sénégal, Sudan, Chad) on soil chemical properties (pH, C, N & P), microbial activities (C mineralization) and genetic structural diversity of total and functional bacterial communities were assessed.

The results indicated that *A. senegal* has increased the soil pH compared to the control soil without *A. senegal*. Soils under *A. senegal* trees from Sénégal (samples Ngane) and Burkina Faso (samples Bissiga and Burkina) have displayed the highest C, N and P contents. Meanwhile, soils under *A. senegal* trees from Mauritanie (samples Kankossa and Djigueri) and the control showed the lowest C, N and P contents.

The microbial activity has affected the Carbon mineralization. The results indicated that most of the soils with the "foreign" provenances displayed higher C mineralization meaning that higher microbial activity occured in those soils due to higher organic matter decomposition activity. The quality and the quantity of the leaf litter can explained the difference between soils.

The soil with the Sénégal provenance Ngane which has displayed higher C, N, P contents showed very low C mineralization probably because leaf litters content high lignin and polyphenols components which are known to inhibite the microbial activity.

These studies revealed that;

1. *A. senegal* tree provenance Ngane from Sénégal has enriched the soil C, N, P but those components were not fully transformed and then not available to the plants. Consequently, this result can have a negative impact on soil fertility and gum production.
2. Other provenances like those from Burkina Faso, Mali and Ethiopia has displayed high soil properties and high microbial activity and

therefore can impact positively on soil fertility and on gum yield.

A. *A. senegal* has enriched the diversity of microbial communities (compared to the HC) in relation to the provenance.

3. Each provenance has selected the total and functional bacterial community which in term will participate in a specific biogeochemical process in soil leading to soil fertility and yield improvement.

Another study was conducted in the rainy season to compare the impact of *A. senegal* on soil functioning and microbial communities in the 2 sites (Dahra and Goudiry). The results indicated that there is no significant different in soil chemical properties between the dry and rainy seasons.
In contrast, the seasons have impacted the genetic structure of the total and functional bacterial communities. The genetics structures are different between soils collected in the dry season and the one collected in the rainy season.

Kenya

In Kenya, soils were collected by KEFRI from 8 sites and used for rhizobia trapping with three *A. Senegal* varieties indigenous in Kenya: variety *kerensis*, variety *senegal* and variety *leiorachis*.
Using nodules recovered from an MPN experiment, 73 rhizobia isolates have been realized. The 73 isolates from *A. senegal* var *senegal* were analysed using PCR targeting 16S rDNA and 7 rhizobia groups were documented. More isolates are being characterized from other *A. senegal* varieties.

Trapping of AMF from all sites for inoculum production was carried out using sorghum. AMF species are yet to be identified.

For field trial for inoculation of mature trees of *A. senegal,* the following was done*:*

i. Identified an *Acacia senegal* field trial with mature trees for potential inoculation.
ii. Identified a site to establish *A. senegal* field trial.
iii. Raised seedlings to plant on the identified field site.

Still in Kenya, however of particular importance are the ontogenetic and edaphic effects in *A. senegal* populations on nutrient use and soil dynamics, a post doc student funded by the Canadian government was investigating age-related and site phosphorus conditions on

1. *A. senegal* nutrition, particularly the estimation of N_2-fixation rates, and
2. Adjacent soil status employing natural populations in the Rift Valley, Kenya.

Sites consisted of *A. senegal* seedlings (9 months) and mature *A. senegal* trees (7 years) along an edaphic gradient of soil P availability.

A single-tree neighborhood approach was employed using a two by two factorial design: site conditions [high and low soil P] and tree age class [juvenile and mature]. Soil and plant metrics (nutrient pools and fluxes) were quantified. A soil transfer experiment was also employed to confirm age and site effects on soil processes. On high soil P sites, *A. senegal* had significantly lower foliar $\delta^{15}N$ levels than neighbouring non-leguminous species (*Balanites* sp.), indicating that *A. senegal* trees fixed atmospheric N when soil P was not limiting in these natural populations.

However, N_2-fixation rates, as determined with ^{15}N natural abundance methodology, declined with age; higher %Ndfa (%N derived from atmosphere) was found in juvenile foliage. Although soil CO_2 efflux did not differ between sites or across ages, soils under mature *A. senegal* exhibited significantly greater total N (>42%) and total C (>72%) at high P sites as compared to the low P sites. Soil under mature *A. senegal* trees exhibited significantly greater potentially mineralizable N estimates as compared to under seedlings.
Soil transplants confirmed that soil biological processes and activity may be stimulated under mature trees as potentially mineralizable N estimates were 2 to 3 fold greater compared to under juvenile trees.

Our findings suggest that tree age and localized soil P levels are a dominant factor in the nitrogen budget of natural populations of *A. senegal*, stimulating N_2 fixation rates and influencing soil total N and C pools and soil mineral N.
This study provides information regarding the adaptation of *A. senegal* under differing edaphic conditions and provides further support for the promotion of *A. senegal* populations as agroforests.

Greenhouse experiments aiming to assess the growth and nitrogen dynamics of *Acacia senegal* seedlings under exponential phosphorus additions were set up. This consisted to come up with results about conflicting evidence on nitrogen fixation rates and plant adaptive strategies under P limitation, particularly for semi-arid species such as *Acacia senegal*. The objectives of the study were to
a) quantify plant performance along a P fertility gradient and
b) verify N acquisition strategies using isotopic techniques.

Acacia senegal var. *senegal* was cultivated in sand culture with three levels of exponentially supplied phosphorous [low (200 µmol of P seedling^{-1}), mid (400 µmol of P seedling^{-1}) and high (600 µmol of P seedling^{-1})] to achieve steady-state nutrition over a 12 week period. Plant growth and nutrition was evaluated. Seedlings exhibited significantly greater total biomass under high P supply as compared to low P supply. Both P and N content significantly increased with increasing P supply. Similarly, N derived from solution increased with elevated P availability, however, N derived from atmosphere, determined by ^{15}N natural abundance method, did not significantly respond to the P gradient. Phosphorus stimulated growth and increased mineral N uptake from solution without affecting the amount of N derived from atmosphere.

It is concluded that *A. senegal* N uptake strategies change with P and N supplies, and less reliance on N_2 fixation when the rhizosphere achieves a sufficient N uptake zone.

Niger

In Niger, the University of Niamey studied the potential of rhizobia in the soil of the natural gommeraies, an extraction of indigenous stocks of rhizobia was made on the soils of three sites: Tera, Dogona and Bader. The numerisation method showed a significant number of Rhizobia in the soil of Dogona (wet zone) and in the soil of Tera (semi arid zone) compared to the arid zone of Bader. Thus, 23 stocks were isolated from the soils of the three sites. The inoculation test at the laboratory concluded that these indigenous stocks are able to associate to all the sources of *Acacia* (Tera, Dogona and Bader) for the formation of the nodules. However, the greatest quantity of nodules (15 nodules/plant) was collected from the source of Dogona.

Additional studies were carried out to determine the effect of the inoculation on the growth of the plants. Seeds of *Acacia senegal* of 4 sources (Dogona, Téra, Bader and Kiki) were used. The plants were inoculated one week after the sowing;

- In the studied sources, the families responded differently to the inoculation
- The sources of Bader and Kiki gave the best results of nodule number and for the underground biomass

Eighty two (82) soil samples were collected from seven sites i.e. Azai, Bégorou, Bader goula, Kiki, Dagona, Kokoiyé and Tabé in Niger. The genetic structural diversity was analyzed using PCR-DGGE.

The results indicated that:

- The diversity studies carried out on these soil samples revealed significant difference within sites and tree species but not both factors combined.
- There were also significant differences in microbial diversity amongst the tree species in two sites Begorou and Bader Goula.
- There was also significant difference within *A. senegal* tree species alone.

WORK PACKAGE 6

General Objectives

To ensure that information generated is properly packaged and availed to different stake-holders in a form that is appropriate to each of them.

Specific Objectives

1. Evaluation and integration of results generated from different work packages into coherent outputs for
2. dissemination and technology transfer
3. Preparation of specific dissemination/technology transfer packages
4. Development of suitable dissemination/technology transfer pathways.

Highlights

Task 1: Evaluation and integration of results generated from different work packages into coherent outputs for dissemination and technology transfer

- During the reporting period Internal Meetings have been held at KEFRI to analyse the results achieved by WP1-5 and to review and prioritize information for different categories for stakeholders as follows;
  - Two papers are being prepared for journals from WP1 on ecological knowledge and marketing
  - Information from WP1 and WP2 being consolidated to develop policy briefs
  - Information from WP1 and WP2 being consolidated to develop pamphlets for community members
- An annual meeting was organized by KEFRI/NGARA in November 2008 at Isiolo in the Northern part of Kenya to share results among implementing scientists.

Task 2: Preparation of specific dissemination/technology transfer packages

- A Dissemination Plan was developed which outlines the strategy for information documentation and dissemination for different stakeholders. This document was shared with project members in Kenya and Niger during the reporting period and will be shared in Cameroon and Senegal in 2009.

Task 3: Development and implementation of suitable dissemination/technology transfer pathways

In the reporting period the following dissemination pathways have been used;

- Website and Emails
- Newsletter (produced biannually) Nov 2008
- Field Visit by KEFRI/NGARA to project sites in Kenya and Niger
  - Kenya 12^{th} – 18^{th} May 2008
  - Niger 19^{th}-24^{th} May 2008
  - Field Visit to Cameroon and Senegal planned for 2010
  - Field Visit to other project sites in Kenya planned for 2010
- Promotional information products produced in 2008, including Logo and Project Flier