Executive summary (year 3)

Context

Traditional cereals constitute the staple diet of many African populations and regions, especially in the most isolated rural areas, and play an essential role in providing food for the poorest populations. They are well suited to local conditions, being reasonably resistant to drought, and help to maintain the environment by providing a covering of vegetation on ground which is ecologically fragile, and considered of little value.

Among traditional cereals, fonio (*Digitaria exilis*), is considered as the most ancient indigenous West African cereal. Nowadays, fonio still grows in farmers' fields in a vast area extending from Senegal to Chad mainly on eroded lateritic soils. In West Africa, farmers cultivate mainly white fonio *(Digitaria exilis),* which is also called fundi, findi, acha or "hungry rice". The term 'hungry rice' well describes the role of this little plant in local population life. Fonio supplies to several million people food early in the growing season, when main crops are still too immature to be harvested and when other food resources are scarce. Fonio consumption varies between years and seems to be dependent on the availability of other cereals. When other cereals are not available, for example due to a failing harvest, fonio consumption is high, and thus fonio consumption could be considered as one of the coping strategies for increasing household food security.

The relative stagnation of production is partly explained by a lack of research and development devoted to this product. In order to ovoid the decline of this commodity, it is important to solve the many problems after the harvest, in particular by perfecting post-harvested techniques and by improving the quality and the follow-up of sales and distribution.
Today, fonio is produced by small enterprises and sold not only on local urban markets, but also to Africans emigrated in Europe and in United States. Indeed several small private enterprises, notably in Mali and Burkina, have been set up to cater for the export markets. There is strong consumer demand for fonio due to its nutritional qualities, and because it helps to satisfy the demand for a more varied cereal diet.

That is the reason why a research/development project named *FONIO - Upgrading quality and competitiveness of fonio for improved livelihoods in West Africa*- was elaborated to achieve the following objectives. The FONIO project started formally at January 1, 2006 per three years duration.

Objectives

FONIO's objective is to upgrade quality and competitiveness of fonio in West Africa by improving production (adapted varieties, appropriated production and farming systems, …), technology (innovation in post-harvest mechanisation and processing,…) and marketing systems for local and export markets. In Africa, the increasing interest for fonio, as well from consumers than from small enterprises, demonstrates the possibility for the development of good quality products based on fonio. For European consumers, the desirable criteria are nutritional quality, originality, healthier properties and environmental friendliness. The production of exportable value added fonio products is conceivable and must be promoted.

To achieve the overall objective, FONIO project promote an interdisciplinary and innovative approach involving scientists from various backgrounds: food technology, nutrition, process engineering, mechanization, social sciences, and agronomy. It support research/development actions with a participatory approach involving producers, processors, women's groups and small enterprises that will benefit directly and quickly from the research results.

The main research activities (workpackages) of the project are the following:
WP1 - Diversification of fonio products for niche export markets and local markets
WP2 - Nutritional aspects of fonio and fonio products
WP3 – Demand for new products and its effects on income generation and distribution
WP4 - Small scale enterprises and innovation in product and process
WP5 - Opportunities for diversification and multipurpose uses of fonio in crop-livestock systems
WP6 - Improving knowledge on fonio based cropping systems and ways for improving productivity

Participants

Research scientists are from three European countries and four West African developing countries (Mali, Guinea, Burkina Faso and Senegal). They belong to Research centres, Universities, National or International Research Systems.
Three from European countries:
Participant 1: Cirad (International Cooperation Centre in Agronomic Research for Development) France,
Participant 2: Wageningen University (Division of Human Nutrition) The Netherlands,
Participant 3: CRA-W (Walloon Center of Agricultural Research) Belgium.
Four participants from West African countries:
Participant 4: IER (Institut d'Économie Rurale) Mali.
Participant 5: IRAG (Institut de Recherche Agronomique de Guinée) Guinée.
Participant 6: CIRDES (Centre International de R&D sur l'Élevage en zone Subhumide) Burkina Faso.
Participant 7: ENDA-GRAF (Groupes Recherches Actions Formations) Sénégal.

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Work completed

Co-ordination and management

The second annual coordination meeting took place at CRAW Center (Walloon Center of Agricultural Research) in Libramont (Belgium) on 25-29 November 2007. This meeting was attended by the project Steering Committee with representatives of each partner. The 4 days meeting was dedicated to present and analyse the research results obtained during the second year, to prepare the activities for the last year of the project and to plan the submission of reports and deliverables.

During year 2008, the first 2 months were devoted to reports writing (second activity report and second management reports) with collaboration of WPs and team leaders. One specific mission was realised: in Mali (January 22-February 2/2008) to study fonio parboiling. Then a "Fonio conference"was organized in Mali on April 28/2008 during the SIAGRI (Salon International de l'Agriculture de Bamako) and a "Project meeting" took place in Bamako (April, 23-30/2008).

Lastly, the third annual coordination meeting took place in Dakar (Senegal) on 25-28 November 2008. Organized by the Cirad project coordination and ENDA Graf (local project partner I, Senegal) this meeting was attended by the project Steering Committee coming from France (Cirad), Belgium (CRAW), Netherlands (Wageningen University), Benin (Université Abomey Calavi), Mali (IER), Guinea (IRAG), Burkina Faso (Cirdes) and Senegal (ENDA Graf). The meeting was dedicated to present and analyse the research results obtained during the last year and to close the FONIO project (prepare the final scientific and management reports).

Research activities

Research Activities were conduced in the framework of the 6 thematic work packages. Activities of all workpackages were going on all along the first half of the year 2008 while WP5&6 still conducted operations (on-station trials, etc) during the agricultural season, from sowing (June-July) to harvesting (September-October). The main results of the FONIO project were presented to a large audience during the Fonio Conference organized in Bamako (Mali) on April 2008 during the SIAGRI (International Agricultural Show in Bamako).

WP1, coordinated by Cirad (France), concerns "Diversification of fonio products for niche export markets and local markets". During 2008, workpackage 1 focused on task 1.1. Sensory tests were conducted in IER Mali on 20 fonio ecotypes collected in villages from Mali, Guinea, Burkina Faso. A panel of 25 members was first trained through successive sessions where reliable descriptors were selected in consensus as well as the scale of intensity, the order of perception and the protocol to assess them. All the organoleptic properties perceived by the panel for each ecotype were related to its physicochemical, technological and cooking properties measured in the laboratory. Task 1.2 was completed this year by the development of a software to measure, through image analysis, several physical characteristics of fonio grain such as endosperm texture, thousand kernel weight, grain size, percentage of brokens present in the sample and grain colour L, a, b. This new technique was applied on all the fonio ecotypes analyzed in task 1.1 for their relation with sensory profiles and in task 1.4 for the study on multi-location trials. In addition, within the framework of task 1.2, fonio parboiling trials were implemented at IER/LTA level in Mali to test a small local manufactured parboiler and to draw up a diagram of fonio parboiling at SMEs level. Task 1.4 continued this third year with the analysis of 10 fonio ecotypes grown by WP6 in 2 locations: *N'Tarla* in Mali and *Bareng* in Guinea. These varieties were characterized at physical and biochemical level. Their dehulling, milling and cooking properties were determined. A Variance Analysis and a Principal Component Analysis run on all the quality traits showed an important location effect on most of the characteristics, specially the physical and technological characteristics.

Wageningen University is leading WP 2 "Nutritional aspects of fonio and fonio products". The activities of WP2 in 2008 were mainly focused on finalization of substudy 1 (nutrient value of fonio and fonio products), substudy 2 (food consumption and role of fonio in dietary patterns) and substudy 3 (contribution of fonio to nutrient intake and nutrition status), preparation and implementation of sub-study 4 and development of protocol for sub-study 5. Anthropometry data showed the existence of undernutrition (17% with BMI<18.5) and overweight/obesity (28% with BMI>25) among women in reproductive age, and a high prevalence of anemia (32%) and iron deficiency (20%).Food consumption studies among women of reproductive age in Bamako revealed that 73% of women did consumed fonio dishes, but the frequency and portion size of fonio, and hence the contribution to iron and zinc intake, was low. On average, women consumed from 7 different food groups and showed a probably of 54% (assuming a high bioavailability of 10%) or 7% (assuming a low bioavailability of 5%) of having an adequate iron intake. The molar ration of phytate to Fe was high, varying from 5.2 in mid wet fonio to 4.7 in cooked fonio. This refers to a low iron bioavailability also confirmed by the iron bioavailability of about 5% as determined by algorithms. Whether fonio could contribute to improving iron intake, is dependent on varietal differences in iron, effect of processing and possibility of increasing iron bioavailability. Samples of fonio varieties and fonio products were analysed for nutrient content and differences between varieties and effect of processing were analysed. Apparently, no significant differences in iron, zinc and phytate content were found between varieties; and processing reduced iron and zinc to low levels. A study was carried out to determine whether iron bioavailability in fonio porridge using natural phytase activity in whole wheat flour. First preliminary results indicate promising results and a protocol for a stable isotope study to measure improvement of iron bioavailability by using natural phytase activity has been developed.

WP3 led by Cirad concerns "demand for new products and its effects on income generation and distribution". During 2008, the processing of data collected in November 2007 by a survey focused on potential consumers of precooked fonio in Bamako was finalized within the framework of the task 3.1. (demand for new products in Africa). It was shown that new products (precooked and *djouka)* are well known by the consumers and a lot of them discovered these products on the shelves of the stores, and

others got to known them by word of mouth. The fonio products are available in many places in Bamako. The number of new buyers has increased sharply between 2000 and 2005. Taking into account that the products are quite well known, quite well geographically distributed in the city, this result may reveal a possible stagnation of the expansion of this market. Almost all potential customers may have been convinced by the products. Concerning task 3.2 (demand for new products in Europe), a new statistical analysis (Analysis of Variance) has been realised using data collected about the preferences of French consumers (in addition to the "logit" model done in 2007). A new bibliographic research has been done in order to write a paper. Concerning the impact of the development of new product on added value, income generation and employment, a synthesis of information collected during the project by the different WP (3, 4 and 5) showed first the consolidation of the new market in Bamako and second, the rapid emergence of new market chains from different origins (urban or rural) to fair trade and organic stores in France. New activities are thus created both in farms and all along the market and processing chain. It is difficult to assess the quantitative impact of these new markets since data are scattered but also because it is changing very rapidly, but it is obvious that several hundreds of jobs have been created, mainly concerning women in urban areas.

WP4 is led by ENDA Graf (Senegal) and concerns "small firms and innovation in terms of products and processes". Despite their modest size, fonio companies are developing growth and survival strategies essentially premised on their capacities and ingenuity to take advantage of the various relations that they establish with strategic partners. Among those, suppliers and distributors are in the forefront. Connection of fonio SMEs with them is often a business relation. Here the notion of trust is paramount; it is even decisive. It is at the centre of the sustainability of the links and guides them. Processing SMEs are maintaining a "congenital" link with their fonio suppliers. Risks can be defined in terms of availability, quality steadiness, variation of prices along seasons, adjustment or capacity to resist the various internal or external crises... In the three countries, fonio MSEs have developed many strategies to adequately ensure their supplies: stock constitution right after the harvest, own production, funding production, imports from neighbouring countries, etc. Distribution is done at two levels: local level and international level. At local level MSEs are sometimes unsatisfied with the selling mode of the product to distributors because management of profit dominates over social considerations. At export level, the client-distributor-exporter constitutes a screen between MSEs and final clients. Thus, MSEs have necessity to maintain and boost links with distributors but also to develop their fame throughout the product and their label.

WP5, directed by CIRDES (Burkina Faso) is named "Opportunities of diversification and multiple uses of fonio in production systems". In 2008, the technical itinerary of fonio as well as the major yield variation factors have been specified by farm-based agronomic monitoring of land plots. For each stage of the itinerary the technical modalities, the intervention years, the duration of work and the expenditure were collected according to the agro-ecological zones. Grain paddy yields range between 600 and 750 kg/ha. Fonio remains basically a crop used for family consumption (particularly between September and November) but it can be an occasionally-marketed crop. In order to meet local demand, the price of husked fonio should be lowered through mechanization. To meet the demand of the « organic » export market, fonio cultivation should be intensified ecologically through the following techniques: organic manuring, early mechanical weeding, selected local varieties. The demand for support services in fonio production is essentially for threshing and husking. The supply of support services is often lacking. Therefore, two ways could be explored for organizational innovations: i) the creation of private husking units to reduce the production cost of husked fonio; ii) organizational support to cooperatives Concerning the technical innovations, organic manure and straw composting gave interesting results. The input of organic manure on fonio, at 5tMS/ha and suitably buried in the soil during plowing increases paddy yield to about 100 kg/ha. The technical use of the results of WP5 will be described in technical fact sheets (effect of organic manure on fonio, composting of fonio straw, urea treatment of the fonio straw meant for ruminant feed). The results of WP5 will also be published in an article (« Fonio, a diversification crop for production systems in West Africa»), and summarized on 3 posters (multiple functions of fonio in cropping systems, factors for farm-based fonio yield variation, utilization of fonio straw in ruminant feed).

WP6 is led by CRAW (Belgium) and involves IRAG, IER, CIRAD and CIRDES. The aim of WP6 is to find out more about fonio-based cropping systems and look at ways of improving productivity, in line with the production chain's expectations. In 2008, the partners focussed on the analysis and the interpretation of the results obtained in 2007 and on the definition of valorisation and dissemination plans for the main findings of the project. Variety trials highlighted the large variation existing amongst the different cultivars tested. The interaction (variety * experimental site) proved to be highly significant as expected under the hypothesis of an adaptation of fonio varieties to soils and climatic conditions. Nevertheless, it was observed, during two cropping seasons (2006 and 2007) that varieties with longest cycle, collected in Guinea, did not exceed the varieties with a shorter cycle length in Bareng (Guinea), where conditions are optimal for the expression of their potential. Hypotheses were proposed to explain this phenomenon. The fertilisation trials also underlined the interaction existing between the experimental site and fonio response to NPK fertilisation. So fonio response to nitrogen was observed on the different sites but was dependant from P and K fertilisation in IRAG Bordo Centre (Guinea). These observations underlined the necessity, to allow the expression of the nitrogen fertiliser, to have enough P and K in the soil and *vice versa.* In terms of fertilisation strategy, for a same cost level, it seems better to bring a low or moderate amount of N, P and K macro-nutrients than to bring a high level of N. Aside from yield performances, fonio paddy grains quality was also characterised in 2008. To do so, the corresponding Near Infrared Spectrometry calibrations were developed and applied to the samples obtained in variety and one of the fertilisation trials. In the fertilisation range applied (0 to 30 unit for each of the N, P and K nutrients), grain protein content was only lightly (+ 4 %), even if significantly, impacted by the N supply while 1000-grains weight lightly increased with P and K fertilisation. Based on these results, WP6 defined and implemented, in collaboration with WP5, the different demonstration trials in the villages followed up by WP5 in order to debate around the proposed innovations in terms of fonio cropping systems and varieties. The results of these demonstrations trials must yet be compiled and will be a support for further discussions with the farmers.

Dissemination of knowledge

Fonio producers and processors are the final target of the FONIO project and need to be informed about the different tasks. Within the framework of WP1, some processors and IER partners, have participated to fonio parboiling trials conducted by Cirad in Mali in January 2008. Then, consumers and local IER partners have directly taken part to sensorial and hedonic tests carried out by IER and Cirad in Mali in February 2008.

For WP4&3, specific information exchanges took place between fonio processors and traders during the activities organized jointly by ENDA Graf and IRAG, in Guinea in October 2008

WP5 specific meetings with fonio producers all over the year in Labé and Kankan regions (Guinea) and in Kénédougou and Kossi provinces (Burkina) and participation to the Fonio Festival in Bondorokuy in Burkina Faso to disseminate information.

In the WP6 framework, discussion of innovation through radio support was also performed in Mali. Indeed, radio diffusions on the topic developed and the results obtained in Fonio project were done on radio of Tominian and radio of Parana de San (Tominian area) and on Garalo's radio and radio 'arc en ciel' (Bougouni area). The topics developed during these diffusions focussed on : cultural practices, variety diversity, the development of adapted strategies for knowledge sharing between peasants, the new opportunities in terms of fonio valorisation, processing (Garalo) and commercialisation

The main results of the FONIO project were presented to a large audience during the Fonio Conference organized in Bamako (Mali) during the SIAGRI (International Agricultural Show in Bamako) and under the presidency of APCAM (Assemblée Permanente des Chambres d'Agriculture du Mali)**.** This Fonio Conference took place on Monday, April 28, 2008 and was attended by a hundred of people (processors, professionals, scientists, NGOs, decisions makers,…..) from West Africa and Europe. Eight topics were presented and a specific posters session was organised (more than 20 posters). A specific CD-Rom of that conference was edited by Cirad. In parallel, a stand representing the FONIO project had been especially built to present various varieties of fonio, fonio products and fonio dishes (dégué, biscuits,..) and

machines (GMBF fonio huller). During the week of SIAGRI, the stand had several hundreds of visitors and the official visit of the Prime Minister and the Minister for the Agriculture of Mali who especially congratulated the coordination and the staff of FONIO project.

Lastly, in November 14, 15, 16 – 2008, the FONIO project was part of the Cirad stand: "The Field of Tropical Cereals". The aims of Cirad's participation in the European City of Science, organized at the Grand Palais in Paris, are to show how involved Europe is in guaranteeing global food security and to demonstrate the role of scientific research in promoting local food products.
(http://www.villeeuropeennedessciences.fr/projet_FR_189.htm). During these 3 days, the stand presented tropical crops and particularly fonio (for that purpose, fonio plants were specially grown under greenhouse in Cirad Montpellier) and had several thousands of visitors. Hundreds of leaflets about fonio were distributed to the large public very interested by this unknown cereal.

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Figure 1. FONIO project stand in the Grand Palais during exhibition "Paris- European City of Science"

For larger public information, the FONIO project Website continued to be developed (http://inco-fonio.cirad.fr) and, since the beginning of the project, several web pages have also been produced on the European FONIO project:

"Cirad" or Agropolis pages
http://www.cirad.fr/en/actualite/communique.php?id=501
http://umr-qualisud.cirad.fr/projet_de_recherche/axe_1_theme_1_1/amelioration_de_la_qualite_de_la_filiere_fonio
www.agropolis-international.net/pdf/lettre/lettre_122.pdf
http://www.cirad.bf/fr/anx/fonio01.php

"CRAW" pages
http://www.cra.wallonie.be/module/newsletter/index.php?ID=76&Action=view
www.cra.wallonie.be/module/craw_info/craw_info_pdf/craw-info-16-2007.pdf

"European Union" pages
http://ec.europa.eu/research/headlines/news/article_06_09_22_en.html
http://cordis.europa.eu/fetch?CALLER=EN_NEWS&ACTION=D&SESSION=&RCN=26409

Other Web pages
http://www.underutilized-species.org/record_details.asp?id=701
http://www.underutilized-species.org/MasksSearch/SearchProjectDetail.aspx?id=227
http://www.seedquest.com/News/releases/2006/august/16742.htm