Project D

Promoting food security and income generation through sustainable production and commercialization of starchy and grain staples in Eastern and Southern Africa

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Contents

Preface

IITA's research-for-development agenda is divided into six project themes, around which these project annual reports are prepared. These projects themes address different aspects of attaining sustainable increases in productivity of dominant farming systems and utilization practices in the various agroecologies of sub-Saharan Africa (SSA). Research and training activities carried out in the six projects are being implemented together with national program partners in order to increase the well-being of resource-poor people in SSA through higher levels of food production, better income, nutritional status, and reduced drudgery particularly for women.

Project D

Promoting food security and income generation through sustainable production and commercialization of starchy and grain staples in Eastern and Southern Africa

by

Adebayo Abass, Steffen Abele, Maria Andrade, Piet van Asten, Danny Coyne, Carine Dochez, Thomas Dubois, Morag Ferguson, Anneke Fermont, Shaun Ferris, Cliff Gold, Rachid Hanna, Bill Khizzah, Edward Kanju, Sicco Kolijn, James Legg, Nzola Mahungu, Victor Manyong, Chiedza Muchopa, Caroline Nankinga, Bjoern Niere, Pheneas Ntawuruhunga, Suleman Okech, Michael Pillay, Phillip Ragama, Abdou Tenkouano, Muaka Toko, John Wendt (Project Coordinator), and Jim Whyte

Project goal

Enhanced food security, improved livelihoods, and socioeconomic development in Eastern and Southern Africa.

Project purpose

Develop and promote, in collaboration with public and private sector stakeholders, the adoption of improved technologies and market support services for sustainable increases in production, utilization, and commercialization of starchy and grain staples.

Outputs

1 Market opportunities identified for setting R&D agenda and formulating policy options

1.1 Opportunities for soybean processing and marketing in Rwanda

by S. Abele and S. Ferris, in collaboration with J. Magnay (Uganda Grain Traders) and A. Turner (Chemonics)

Given the critical situation of income and food security in Rwanda, ADAR seeks to improve rural income and food security by fostering the agribusiness sector. The project goal was to determine the market potential for soybeans and its derivatives and to design a processing industry that could profitably supply the quantity of soybean products needed on the domestic and possible external markets. Consequently, the objectives of the study were:

- To determine the market potential for soybean products in Rwanda and the subregion. Products envisaged at the beginning of the study were mainly soybean oil and soybean flour. Further areas of interest that came up during the study were mixed food products based on soybeans and cereals. Market potentials were evaluated by assessing prices of the products studied and their substitutes, i.e., their competitors.

- To design a competitive processing plant for soybeans in the potential project area of Kibuye. This design was done on the basis of an initial business plan provided by the client. Criteria for the design of the plant were the products to be identified as having the best market potential in the first stage of the study. The second task in designing the plant was to choose an optimal location between Kibuye and Kigali.
- To determine the feasibility of improving soybean primary production in Kibuye. The initial outline of the project included a development component for an outgrowers' scheme of soybean producers in Kibuye. The major issue in this decision was whether it was more profitable for the project to make the raw product within a vertical integration or to buy it from the market.

Activities, methodologies, and database. The field study was conducted during a visit of the team from 24 to 29 March 2003. During this study, data on prices for soybean products and substitutes were collected in the study region as well as in Gitarama and Kigali. A group interview with farmers in the envisaged production region near Kibuye was conducted to gather information on their production schemes and on soybean production in particular. Further information was gained through statistical publications from the Ministry of Plan, the Ministry of Agriculture, the Customs office, and the National Bank of Rwanda. Additionally, data were taken from the Food and Agriculture Organization, and from secondary literature.

Based on the data, the market size of soybeans and soybean products was estimated by setting up commodity balances. Primary production schemes were assessed by running scenarios on gross margins. The business plan was set up with respect to investment and operating costs, and figures for return on investment and cash flow were estimated under different market and finance scenarios.

Findings on soybean demand. An analysis of Rwandan household expenditure data with respect to soybean consumption revealed the relationship between income and private households' soybean consumption in Rwanda. As consumption is scattered and unevenly distributed, precise econometric estimations of the income elasticity could not be made. By defining income classes and calculating the average consumption within these classes, at least a rough idea on income elasticity and future demand could be gained.

The data show that soybean consumption is increasing with increasing income. Yet, there seem to be two different sections of income and consumption relationships. In the upper income class section (from 500 000 Frw onwards), consumption seems to have different development paths and elasticity. This could indicate that in the sections below and above 500 000 Frw of income, different types of soybean products are consumed. However, in both sections, initial income elasticity is relatively high, but then decreasing very rapidly. Elasticity in the lower income section is on the average 1.7, in the upper section it can be estimated as one. This means that at given income growth rates, in the lower section, it would take 12 years to double the expenditure for soybeans—from less than one kg per household per year to about two, in the upper section it would take 20 years to double soybean product consumption from now about two kg per year to four. The statistical data also show that soybean oil, currently consumed at a level of 7000 L a year, does not constitute a significant market for a commercial enterprise.

Apart from the private market for soybean products, there is also an institutional market created by international organizations like the World Food Program (WFP), UNICEF, and the Government. WFP distribute about 2500 t of Corn-Soya-Blend (CSB) and Unimix, a blend of extruded whole maize and whole soybeans on the Rwandan market. This equals about 700 t of soybeans per annum. UNICEF supplements milk which could be replaced by about 200 t of UNIMIX which is an equivalent of 60 t of soybean raw material. Contrary to the previous market discussion, forecasts of future developments cannot be easily made as this market is not dependent on income and preference development, but on political situations and the will of donors. Further, market transactions are rather based on negotiations than on the "invisible hand" which is supposed to arrange prices on a free market. This makes it difficult to estimate price and quantity developments. It can be said that the WFP will continue their work in East Africa and thus the market will be sustained. Concerning price developments, the costs will surely be affected by inflation. However, it depends on the negotiating power of the supplier to what extent the inflated costs can be covered by higher prices on the output side. It should also be emphasized that revenues especially are heavily dependent on regional competition, and price margins are rather due to logistical differences (e.g., transport costs of the finished products) than to overall inflation, so that Rwandan inflation (except for raw material prices) is a minor issue.

From the above conclusions, the following observations can be made:

- Present soybean demand traded on private commercial markets is rather weak.
- Prospects for the future are also not very promising, as income elasticity of demand is not enough to assure high (absolute) growth rates of soybean products on the private commercial markets.
- The only stronger, stable demand for processed and soybean-based food products comes from the institutional markets.

Rwandan soybean production. Rwanda produces about 17 000 tonnes a year of soybeans, but production is unevenly distributed within the country. The highest production is found in Gitarama, about 50 km from Kigali, with slightly more than 9000 t per year, most of which is home consumed and only a small part traded. Data show that production is highest in Gitarama, both in terms of quantities produced and in terms of households producing soybean. This implies that the region of Gitarama has a comparative advantage in soybeans, while Gitarama's advantage is probably due to the consumption preferences in Gitarama itself (which has the second largest population density in Rwanda) and its proximity to Kigali, so that we could call the production in Gitarama "demand-driven". The study site, Kibuye, does not have a significant comparative advantage, neither in terms of consumption nor in terms of production.

Primary production at the study site. Primary production of soybean in Kibuye is done on smallholder farms, mainly own less than 1 ha, if not less than 0.5 ha of land. Besides soybean, other crops planted are coffee, which is the only cash crop, banana, sweetpotato, manioc, and others. The production, including soybean, is mainly subsistence oriented with only the surplus sold off at times of good harvest. Chemical input use is restricted to coffee production, for which farmers buy the inputs on credit and repay when selling their harvest to the same traders. Inputs used on other crops are own produced like animal manure. Seeds are also own produced so that one could assume that they are of low quality. The data obtained from the field study give an overview of the current soybean production system and outlines the possible improvements when using improved seeds and fertilizing techniques. Data show that there is a potential to increase both soybean production and profitability through intensification. It also shows that the calculation is quite sensitive to output price changes and to different assumptions on yields. A decline in output prices of less than 20 percent could lead to a situation where gross margins are cut back to the state of traditional production. This price decline could occur when institutionally driven intensification leads to a sharp increase of production without a sufficient absorption capacity of the local market. The size of the possible decline is quite probable, as price data show *volatilities up to 32%. The same holds for yield deviations.* The *Ministry of Agriculture* gives a range of 1200 to 1500 kg yield per hectare. Going to the lower edge of the yield scale, the returns would again be only 80 percent of the initial prospects as in the low price scenario. This throws up the question why the farmers should invest in a technology that would yield only a 20 percent increase of gross margins under favorable conditions. However, other studies show that Rwandan farmers tend to renounce up to 40 percent of their yield potential for hedging against risks. In other words, risk adverse farmers might tend to not apply highly intensive technologies.

It thus seems that there a high effort is required to obtain the desired results of a functioning outgrowers' scheme:

- Farmers have to be trained to intensify production.
- Extension has to be conducted with special care on farm and household economics and objectives of farmers.
- Inputs have to be provided at reasonable prices, mostly to remote areas.
- Contracts have to be made to link farmers to soybean production.
- The scope of production has to be planned to assure inputs for the processor at profitable prices and to maintain profitable output prices for the farmers to sustain their production.

It is doubtful if this can be done efficiently by the processor. It was thus recommended to use the market signals given by the demand of the processor and other buyers to set the incentives for the farmers.

Plant design. The selection criteria for the processing site as chosen in the study were:
- Proximity to markets capable of absorbing the product at profitable prices.
- Proximity to resources like energy, maintenance facilities etc.
- Proximity to institutional buyers like public institutions, and to development and aid programs like world food program. This was a result of the market observations made.
- Good institutional background and support from the community (availability of land titles and production permits).

Given these criteria, it was concluded that the best site would be Kigali for the following reasons:

- In Kigali, the prices for soybean products are generally higher than elsewhere, except for Gitarama, but the latter does not have Kigali's advantages.
- Proximity to institutional buyers is closest. This implies not only proximity to the outlets, but also low transaction costs in negotiating with buyers and assuring proper interaction in quality management.

- Provision of resources is best, especially in terms of stability of water and electricity supply, as well as availability of maintenance and repair services.
- Institutional background and support from the community is best in Kigali. It is probably lowest in Kibuye, where the community seems to encourage tourist activities rather than industrial investments.

Profits and cash flow assessment of the plant. Following the market and site assessment, the study evaluated the profitability of the proposed firm. Criteria for assessment were (a) profitability, (b) liquidity or cash flow, (c) returns on owned capital, d) the net present value over periods of five and ten years, and e) the internal rate of return. All of them were calculated under different finance scenarios that are given by the abovementioned banking conditions, as well as different market scenarios and the consequent coverage of the plant's potential.

The analysis showed that, when designed for producing blended soybean products, the plant can operate profitably already with a low market share or potential coverage. For finance, the best option with respect to cash flow and profitability is to obtain a loan from the Rural Development Bank. However, this requires higher own capital than loans from private creditors, so that in this option, initial returns on investments are lower.

1.2 Market opportunities identification study in southern Sudan

by S. Abele and S. Ferris, in collaboration with CRS/USAID

The aim of this market opportunity study is to identify and describe the current and expected market potential and demand for a broad range of commodities and items that will be addressed by the six training centers under the recently initiated Southern Sudanese Agricultural Rehabilitation Program (S-SARP).

The study is being undertaken in three parts. Phase I, is focused on gathering secondary information on six selected sectors, crops, agroprocessing, livestock, forestry, fish, and wildlife; and conducting a rapid market opportunities identification (MOI) analysis to evaluate and prioritize products with the most promising marketing options in each subsector. The results of this first analysis will be discussed extensively with the partners and stakeholders of the SSARP consortium, as these results will be used to direct the next phase of the study.

Phase II of the study will conduct a more detailed market chain analysis of those products which were identified as having highest market potential, for small, medium, and potentially large-scale intervention. The aim of this second level of analysis is to gain a more comprehensive understanding of the critical constraints to marketing and to find the most promising areas of investment in specific supply chains. The information from Phase II will be used by the S-SARP consortium to develop business/agroenterprise plans. Phase III of the process will be to work with the SSARP consortium to use the findings from the marketing studies to develop specific training plans for the six S-SARP agribusiness centers to exploit the prioritized market opportunities.

Methodology of analysis. Due to the very specific nature of the situation in Sudan and the scale of the territory, the process of analyzing market opportunities was unlike most marketing studies. In most cases secondary data is easily sourced, markets and financial structures are functioning, infrastructure is in place, and key informants can be located and interviewed with ease in their normal place of work. Due to the ongoing insecurity, none of these conditions are found in Sudan and therefore the study team was required to develop a more complicated analytical framework. The analysis was also further complicated by the scale of operation being reviewed and the potential for investment at local, national, regional, and international levels.

To accommodate these conditions, the analysis was conducted with information and analysis from several perspectives and included an analysis which compared current conditions and scenarios of "what might be" when peace and economic functionality returns.

To undertake this type of analysis, several types of analysis were combined including:

- Analysis of secondary data.
- Development of economic filters and use of secondary data to model potential trade scenarios.
- Survey work of current market conditions in S-Sudan.
- Analysis from commodity traders.
- Analysis from expert practioners on markets and current import/export opportunities.

A "triangulation process" of the data was then used as a basis to prioritize commodities within subsectors in regard to market opportunities and to formulate the basic ideas for the way forward, i.e., the next stage in the analysis. The starting point of the MOI analysis is to draw up a "Long List" of products and commodity options which are already or could be produced and marketed from the territory, i.e., S-Sudan. The MOI analysis then attempts to use market demand as the key filter in prioritizing commodities and products such that the initial "long list" is distilled down to a manageable "short list" of products, which have strong market demand and can be studied in more detail. The results from the MOI analysis of commodities, products, and sectors were drawn up as a basic long list and a short list after being analyzed through market filters. The prioritized grain crops are maize and rice; oil crops, palm oil, sesame, sunflower, and groundnuts; root crops, cassava; stimulants, tea and tobacco. SSARP should focus on making gains in food security and once marketable surpluses are available, should work with local farmers' groups to find the best market channels. As indicated in the livestock section, SSARP could accelerate the process of market support by developing a reliable market information service to facilitate the marketing process. As also indicated in the Trader's analysis, export options for hides and skins could be a major source of income, particularly if the products are of high quality. For all the markets, a critical constraint is lack of market information and this is an aspect that could be addressed by SSARP relatively quickly.

The forest reserves in southern Sudan, particularly in the Equatorial region, are known to be one of the most lucrative assets that the region can immediately exploit for the domestic, regional, and international markets. In Eastern Africa, the stocks of tropical hardwoods are rapidly being exhausted and this is effectively raising the value of the Sudanese forest reserves. In regard to the exploitation of the tropical hardwoods into the regional and international markets, all efforts should be made to increase the level of value addition that is carried out in Sudan. The domestic markets are based on the opportunities for substituting what is already being imported. The listings of goods for the international market are based on strengthening existing operations. The potential for all of these markets is, however, much dependent upon exporting goods only of the very highest quality and this means that considerable investment should be made in highly professional operations, such that quality is strictly controlled and that the operators focus on niche, high end market supply chains.

Way forward: areas for Phase II marketing and training possibilities

Summary of "Results from the market opportunities identification survey: options and commodities to consider for the phase II marketing study" are as follows:

- Undertake subsector analyses for crops with highest market demand/potential within the country and for regional markets. These crops are sorghum, maize, rice, sesame, and cassava, with a view to developing these sectors on a large scale.
- Develop business plans for larger scale, plantation operations, possibly linked to out-grower schemes including the production and processing of oil palm, sunflower, rice, sugar, cotton, coffee, tea, gum Arabic, and tobacco, as well as livestock and fish. These business plans should be developed in partnership with interested and/or existing investors.
- Development of investment plans for niche products and markets including Arabica coffee, lulu, spices, dried fruit, to be done in collaboration with NGOs that have agro-enterprise skills and plans/funds to organize community-based production systems.

1.3 Survey on banana–coffee systems: economics of farming and marketing systems

by S. Abele, S. Okech, C. Gold, and C. Nankinga, in collaboration with A. Nabuye (Coffee Research Institute (CORI), Uganda) A. Karugaba (Mbarara District Agricultural Extension Department, Uganda), and W. Tushemereirwe (Kawanda Agricultural Research Station, Uganda)

The purpose of the study is to provide first insights into the yet underresearched farming systems in Western Uganda that are based on banana and coffee. These two crops are the economic bases for most of the people living in the rural areas of Western Uganda. They provide both cash (coffee and banana) and, for the case of banana, food and by-products. Yet, the system faces decline in various ways: Both banana and coffee are affected by pests and diseases that threaten the whole system and the livelihood of the rural communities. Moreover, price declines, especially on global coffee markets, have a negative impact on the systems. It is thus of vital interest to generate knowledge about the banana–coffee system, on the interaction of these crops in agronomic and economic terms, and on how theses systems can be stabilized and further developed. This prestudy aims at gaining information to built up the hypotheses of a following detailed diagnostic survey and analysis. It also attempts, as far as this part of the study is concerned, to determine first assumptions on the economic behavior and decision-making patterns of small-scale farmers within this system.

The study assesses the economics of three sections of the farming and marketing system. The first section deals with the farming system, throwing specific emphasis on the banana and the coffee production systems and their interactions, both in terms of competition and complementarities. The farming section further includes other on-farm activities of cropping and livestock, off-farm activities, characteristics of farms especially in land and labor organization, constraints and management, farm sizes, decision-making, market orientation, and on-farm constraints such as liquidity and risk. The marketing section deals with patterns and problems of marketing and farmers' organizations. The third section on postharvest processing addresses the status quo of postharvest technologies in the region as perceived during the survey.

The methodology used to obtain the information was the conducting of group interviews on three sites in Mbarara during April/May 2003. Group interviews were held during meetings with 15–40 farmers. Further, single farmers were visited on their fields and interviewed in a nonstandardized way.

Farm and household economics. Farm sizes are rather small in all the sites, usually averaging about 0.8 ha (2 acres), but ranging from 0.1 to 47 ha and from 0.1 to 1.6 ha across sites. While in the first area, land is mainly consolidated, in other sites, land holdings are dispersed due to the heritage system. Also in some sites, large size farms or landholdings exist that are assigned to their owners by the state. On these holdings, farmers can settle but have to pay rent. About ten percent of the population on the sites is landless. It was mentioned throughout the sites that land is scarce and that this scarcity is one of the main reasons for intercropping.

As far as labor organization is concerned, hired labor is used on all sites, mainly for weedng and pruning, but also for soil preparation. On one site, labor is scarce during the high cropping season, in Ndaija, mainly during the coffee-picking season, while in other sites, labor scarcity does not seem to be much of a problem, probably due to the remoteness that makes off-farm alternatives scarce. Labor is mostly hired for working on cash crops (banana and coffee), for food crops, and for soil preparation. Contracts may be per piece of labor, per land area, daily, monthly, or, rather rarely, permanently. Payment is mainly made in cash, but sometimes also in kind, especially in times of food scarcity. The other major constraint apart from land is liquidity that imposes a bottleneck to input use (including labor, so that management of coffee and banana is affected) and investments.

Cropping patterns are quite similar across sites. The most prevalent system is intercropping, with a few exceptions in banana and coffee that are discussed further below. The main reason for intercropping is land scarcity, and it appears that land-use management in terms of complementary intercrops (e.g., legumes to fix nitrogen) is hardly known amongst farmers; at least it was never explicitly mentioned during the survey. Sole cropping mainly occurs in banana and in coffee systems. Although they were predominantly intercropped in the first two sites, coffee was mainly planted sole in the third site.

Crops differ only slightly from site to site. Apart from banana and coffee, millet, maize, groundnut, beans, and horticultural products like avocado, orange, pineapple, mango, passion fruit, and guava are grown. In all the sites, one has to discriminate cash and food crops. Coffee and banana are major cash crops on all the sites. Food crops are banana, cassava, millet and the horticultural products, whereas cash crops are (according to the farmers' ranking) banana, beans, coffee, livestock products (especially milk), millet, and groundnut. As stated above, most of these crops are intercropped with at least one other crop. Although the main reason mentioned for this is land scarcity, intercropping systems can be quite complex, as the following example shows. By visiting one farmer, we found beans are grown in a banana plantation. But the beans are not grown by the owner of the plantation, but by the day laborers, mostly women. The day laborers take the grains quasi a salary, while the banana plantation benefits through the application of labor and from the nitrogen fixing effect of the beans as the residues are used as mulch. The same complexity can be shown for banana–coffee interactions. To start with some (yet) separate aspects; we look at the economic functions of banana and coffee as mentioned by the farmers.

Most bananas grown at all sites are of the matooke (cooking banana) type, followed by brewing banana (mbiri), large desert bananas (bogoya) and, on a smaller scale, small desert or apple bananas (ndizi). Yet, the shares shift across sites. In the first site, about 75% of the bananas grown is matooke, about 11% are mbiri, the same share is held by bogoya, and the remaining 3%, is held by ndizi. In the second site, matooke holds about 80% of production, the rest is mainly dedicated to bogoya. The other types are not considered as profitable by the farmers at this site. In the third site, between 40 and 60% of the bananas grown are matooke, followed by mbiri (20–30%), which is seen as very profitable at this site, bogoya (10–20%), and ndizi (10%). The main agronomic constraint to banana production is banana weevil, followed by wilts, nematodes, droughts, and windbreaks.

As for coffee, the dominant variety is robusta; the higher quality yielding arabica is very rarely found. An improved variety of robusta, colono, is also found on the sites, but to a lesser extent than robusta, as colono requires high management (which is not available due to liquidity constraints and the consequent labor shortage), and is susceptible to all kinds of agroclimatic risks, especially drought. The biggest problem, apart from management, seems to be coffee-wilt. One of the agronomic advantages of coffee is that it can be grown on marginal soils.

Banana and coffee are, beside beans, the two most important cash crops in the region. But this is not the only feature they have in common. These crops interact in many ways, be it in economic terms or in agronomic terms as intercrops.

Concerning the agronomic interaction, we have to first look at the banana–coffee-intercropping systems. Again, sites differ in the scope of banana–coffee intercropped from 70% of the farmers having coffee and banana intercropped, to about 30% of farmers who intercrop banana and coffee. The rest of the farmers grow them on pure stands. These figures depict well the controversy of opinions and perceptions about agronomic banana–coffee interactions. There appear to be many agronomic factors affecting the relationship between banana and coffee, both positive and negative, both applying to intercropping and sole cropping relationships.

First, there seems to be a certain competition between the crops on intercropped stands. They obviously compete for soil fertility, while coffee is often believed to deplete soils and eventually kill intercropped bananas. Banana seems to throw shade on coffee, which is advantageous for the younger plants or for colono—as colono is trained to have lower bushes—but disadvantageous for older and higher coffee plants. Bananas are also seen to retain moisture and thus provide a certain shelter for coffee in times of drought. Further, both banana and coffee provide mulch for each other, bananas in terms of leaves and cut stems, coffee in terms of coffee-husks (which cannot be spread on coffee due to the consequent spreading of coffee wilt).

The most important economic relationship between the two crops is that they provide seasonal liquidity (especially coffee) for their mutual benefit on management. During the whole year, banana sales provide liquidity for hiring labor for banana and coffee management, coffee provides liquidity for banana management during the coffee-harvest season. The same controversy as for agronomic interactions is found when it comes to the discussion of economic features of the two crops and their profitability.

Comparing the mere cash revenues of banana and coffee, coffee generally seems to be the slightly more profitable crop. Here, it can be seen that coffee yields, according to site, between 600 000 and 1 400 000 Ush/acre/year in cash, while banana yields between 400 000 and 1 000 000 in cash on the same area. But if the additional amount of food is calculated and valued that banana gives, the picture changes rapidly. Assuming that 15 to 50% of the harvest is home consumed, we can add a value of about 150 000 to 320 000 Ush to the economic yields of banana, which makes banana almost as profitable as coffee. It can thus be assumed that farmers renounce possible coffee profits for the sake of liquidity and food security, although this renunciation is at current prices rather small.

This leads to a summary of economic functions that comprise but go beyond profitability for both crops. While coffee provides cash even from marginal sites, it is also seen as a saving device and a source of funds for investments that have to be made once a year. Banana gives cash, but also provides food security. Another major economic function of bananas is that they can be harvested throughout the year and thus provide a continuous flow of liquidity. Finally, banana provides by-products like leaves that can be used as mulch, animal feed, and fibers. This underlines the preference for banana versus coffee of most farmers. Even if coffee prices rose, so most of the farmers stated, banana would still be cultivated to cover permanent liquidity needs and to assure food security.

Marketing, postharvest, and processing of banana and coffee. In this section, the farmers were asked about the products marketed, the organization of banana and coffee marketing, problems with this organization, price developments, and seasonality of the two products. Further, problems of farmers' organizations were discussed. Another topic was postharvest and processing.

In general, the farming systems on the survey sites can be considered as both market and subsistence oriented. Apart from coffee, of which the marketed share is naturally 100%, be it fresh or dried, of other crops like beans, 50% of the harvest is marketed. In the case of banana, 50–85% of the harvest is sold, depending on the site and, of course, on the relationship between land endowment, land productivity, and the nutrition requirements of the owner and his or her family.

The way the farm produce is harvested is quite homogeneous across the sites, with a slight difference in coffee marketing at the first site. Generally, products are sold at the farm gate, without having a market place. Brokers go around the farms and negotiate the price on behalf of the traders. As soon as there is agreement on the price, the crops are cut (in the case of the banana) and then sold on the spot. The system is the same for all other crops in two of the sites, while there is a slight difference on the third site, where coffee is taken to the trading post, gathered, and stored before selling to traders. This is the only exception to the rule of farm gate selling.

Farmers encounter many problems in this system. Above all, there is a huge asymmetry in information, as banana prices in Kampala are only known by the brokers or traders, not by the farmers. The farmers have to take what they are offered by the brokers, the latter having at least a temporal monopoly at the farm gate. This depresses the prices the farmers earn for their product, as "the buyer determines the price". Other problems encountered by the farmers are renegotiation of prices when bunches are already cut (e.g., at collection centers), that they have to pay brokers in-kind (i.e., with bunches), as well as theft during the high price season, failure of payment, and losses of cut bunches while waiting for brokers to come. The problems encountered in coffee marketing are mainly similar concerning the weak marketing position of the farmers.

Banana, especially matooke, prices show significant seasonality. From September to March, prices range from 2000 to 3000 Ush per bunch (depending on size and quality of the bunch). They go down to 50–250 Ush per bunc, during the season when large quantities are harvested, i.e., April to August, yet price fluctuations slightly differ across sites. Moreover, additional price deductions of up to 25% during the rainy seasons are reported due to poor accessibility through roads.

Other banana types, e.g., bogoya, show lower seasonal price variability. Coffee has only one main harvesting season in the region, so there is no seasonal variation. However, through the harvesting season, price fluctuations are reported, astonishingly of two different kinds. While at one of the sites, prices at the beginning of the season are lower (at about 200 Ush/kg) and rise towards the end of the season to about 300 Ush/kg, in other sites prices fall during the season from 300 to 150 Ush/kg. The explanations for this difference have to be sought in the liquidity pressure at the beginning of the season, which seems to be high in the first case: farmers have no cash reserves and are thus forced to sell off at almost any price. Later in the season, liquidity pressure is no longer so high; small quantities of coffee are available, while during the season, quantities rise and thus prices decline. It would be interesting to see why these different price developments in adjacent regions are not balanced by interregional trade.

Besides these seasonal price volatilities, one has to consider long-term price developments of both banana and coffee. Also here, perceptions differ across sites. While at one site, both banana and coffee prices are considered to have declined through the last decade and thus negatively affected profitability of both crops, at the other two sites, banana, particularly matooke, is considered as getting higher prices as ten years ago. This is said to be due to better infrastructures and higher demand in the urban regions. During the same period coffee seems to have experienced a sharp decline in price. It was mentioned that matooke prices have risen from 500 to 2500 Ush per bunch. Coffee prices were reported to have declined from 800 to 300 Ush/kg.

Organizations and marketing boards, e.g., a cooperative, that could counterbalance these negative developments, especially in coffee prices, and increase the market power in other products' trade do not exist in any of the three sites. Cooperatives seem to have disintegrated during the early nineties, mostly due to corruption and mismanagement. While at one site farmers are about to revitalize the cooperative system, and hope for more market power and better prices, farmers in other sites refrain from doing so. They argue that during high price seasons, there is no need for collective action, and during the low price seasons, collective action would be pointless due to the overall surplus and price depression throughout the region. In economic terms, these farmers see themselves as price takers in a highly atomized market.

As far as postharvest activities and processing are concerned, these are considerably low at all sites. Coffee is partly dried, partly sold fresh. There does not seem to be many problems in storing coffee, especially when dried. Banana is processed into beer in case of the mbiri variety, which seems to be a quite profitable business. Future requirements mentioned by the farmers were mainly for processing matooke to improve storage capability and reduce postharvest losses, so that low price seasons can be overcome by adding value or storing until the higher price season.

In conclusion, it can be said that systems, both farming and marketing, are complex and diverse and a lot of research is required to provide optimal support for the development of these systems. It seems that both the economic and agronomic potential especially of intercropping systems is not yet fully exploited. Banana and coffee play a major economic role as cash crops (both) and food crop (banana) on all the sites. Whether they are grown intercropped with each other or cultivated on pure stands, banana and coffee have many economic and agronomic relationships, both positive and negative. These relationships have to be further developed and improved. As for the economic part, the following assumption can be made:

Behavior patterns of the farmers are not only for profit orientation, but liquidity and food security also play an important role in economic decision-making. The major constraints to production are land scarcity and poor marketing options and therefore a lack of liquidity, which leads to poor crop management and poor exploitation of the economic potential.

Economic hypotheses to be tested during further research are the following:

- Improved crop management could increase land productivity and thus remove the bottleneck of land scarcity.
- Improved marketing and organization would increase cash income and thus remove the bottleneck of liquidity and add resources (esp. labor) to improve management and input utilization.

1.4 Cassava market studies

by N. Mahungu

Market surveys to quantify demand and product type are being conducted in Malawi, Tanzania, and Zambia. This will complement the findings of the cassava and sweetpotato subsector analysis conducted in these countries in 2002 whose final reports have been distributed to stakeholders and important libraries in these countries.

To improve on marketing of cassava products, SARRNET is also working with the Malawi Bureau of Standards to formulate grades and standards for cassava flour and cassava starch. The grades and standards for edible flour have been published which gives specifications on safety levels, packaging, transportation, storage, and labeling requirements. In Zambia work is also done in close collaboration with the Zambia Bureau of Standards (ZBS).

1.5 Research on harmonized policies for increased commercialization and trade among the SADC countries

by V. Manyong, C. Muchopa, T. Takavarasha (FANRPAN), and FANRPAN country nodes of five SADC countries

Countries such as Angola, Malawi, Mozambique, and Zambia have suffered from a series of natural disasters that have also been compounded by poor short-term policy decision-making in the past decade. Often policies are country specific while the effects of climate, pests, or trade span borders. In periods of severe crisis, such as the most recent drought, specific trade policies appear to be inappropriate to address issues of a regional dimension. It is therefore important to better understand both country level agricultural policies and regional policies and their contribution to the mitigation of the food crisis that has emerged.

This study is targeting five countries of the SADC region (Botswana, Malawi, Mozambique, Tanzania, and Zambia). The beneficiaries of this study are the smallholders who can diversify their rural economy in order to become less vulnerable to natural disasters. The goal is to provide critical policy analysis leading to dialog and enhancement of policies within selected SADC countries.

Methodology/implementation strategy. The study involves the GIS mapping of the countries in development domains and identification of commodities with a comparative advantage in the target countries and the region. Many policy consultations will be organized at the country level and for the region as a whole. The study will include policy analysis, policy technology formulation, communication to national governments, a regional Ministerial conference, and follow up (with SADC) of Ministerial decisions with national governments.

Expected results/deliverables in 2004. Three intermediate results are expected: (1) Policy constraints evaluation and prioritization, (ii) Effective policy dialog initiated and strengthened in and across the target countries, and (iii) Mechanism established for monitoring and evaluation of policy technologies.

Milestones for coming year. Organization of a regional methodology workshop, country technical reports followed by country policy workshops, synthesis in a regional report and organization of a Ministerial conference, and development of a database for agricultural statistics in the four pilot countries.

Key findings to date in 2003. The workplan for the implementation module was developed and discussed during the inaugural meeting of the project, which took place at Lilongwe on November 2003. Representatives of FARNPAN nodes from five countries endorsed the workplan: Botswana, Malawi, Mozambique, Tanzania, and Zambia.

Georeferenced data were collected from various sources in the websites. Preliminary GIS analysis was conducted for five potential countries using those secondary data. Results indicated that Botswana falls outside of potential development domains for this project. Therefore, this country was not retained for the first year of this project while four countries were selected: Malawi, Mozambique, Tanzania, and Zambia.

2 Commercially viable small- and medium-scale agroenterprises that expand trade of the starchy and grain staples enhanced

2.1 Rural agroprocessing of cassava flour

by S. Kolijn, V. Rweyendella, and national research partners (Root Crops team SRI-Kibaha and TFNC)

Based on the successful establishment of a cassava chip-processing group in Bungu Village, Rufiji District, 140 km south of Dar es Salaam, three additional processing groups were established in Bungu ward. The three new groups started processing dried cassava chips in February–March 2003 and were successfully linked with the identified flour millers in Dar es Salaam for selling into urban supermarkets and food stores.

Two SUA students studied and documented the performances and operations of the four groups and a report was developed in April/May 2003.

Key findings and development of events. Making chips has raised the farmer's income significantly from around 280 USD/ha (in case of selling the fresh roots to local traders) to above 800 USD/ha when processing and marketing of dried cassava chips to urban flour millers. The vertical integration through value adding has created additional local rural labor (harvesting, peeling, and processing) and has resulted in expansion of the total production of cassava among the members (all farmers intended to double or triple their area under cassava production), less dependency of local traders, ability to process older stocks of cassava fields into chips (traders in fresh cassava don't like to buy cassava > 12 months). The four groups organized themselves into a processing association to oversee and coordinate the transportation and marketing of chips to Dar es Salaam, and coordinate the communication with SARRNET, government authorities, and traders. The Rufiji District Council backed the initiative further by providing microloans to the four groups as a kind of operations capital fund.

Despite the fact that the four groups have only 50 members, many more additional non-member villagers have benefited from the presence of local chipping processing facilities as the group buy cassava roots from nonmembers and/or nonmembers can get their roots processed there for a fee or can get employed as casual workers (peeling, harvesting, etc.). By the end of 2003 the four groups had produced around 60 t of dried chips.

In May/June 2003 SARRNET started exploring further market outlets in Dar es Salaam in an effort to expand urban demand (especially among the lower income groups) but, due the much lower maize prices, this effort remained largely without much impact/success. (Maize prices retail remains under 0.30 USD/kg). Mid-2003, farmers hesitated to process more chips due to higher prices of fresh cassava roots due to lower stocks in their fields.

Despite the fact that cassava flour is only available at a relatively high retail price (0.40–0.55 USD/Kg) and has only been bought by the middle-income consumers who are more quality concerned; the full market potential of high quality cassava flour still needs to be explored and developed for the much larger lower income consumer group who are looking for an affordable starch food (to be consumed in ugali form like maize).

This requires more efficient production and marketing of cassava chips/flour (right now the two flour millers take more than 200 USD/t for their milling and marketing operations while the larger scale maize and wheat flour normally take up to 20%).

Intermech Engineering in Morogoro further developed its expertise and capacity with regular technical backstopping by me, manufacturing the various cassava processing equipment. The fruitful collaboration was further strengthened through the joint visits to farmer groups, postharvest meetings, and agroequipment/agricultural shows/exhibitions. SARRNET facilitated further in the importation of petrol engines at an affordable price.

Many visitors paid a visit to Bungu during 2003 to get first hand experience about the project approach and implementation, and the experience of the four farmers' groups. The following NGOs and individuals visited Bungu: Norwegians People Aid Program—Dodoma team, Concern, Action Aid, 12 farmers from The Initiative for Development and Equity in African Agriculture (IDEAA) Project Malawi, representatives of the Ministry of Agriculture, Rockefeller Foundation, IMPACT/USAID team, commercial flour millers, and Peter Chisawillo (Intermech Engineering). The general outcome of these visits is that several NGOs are currently implementing this pilot-processing project in other areas of Tanzania and Malawi.

In May and July 2003 the team visited Mtwara Region (southern Tanzania) to assess the cassava sector in Southern Tanzania, and sensitize Provincial and District Governors and agricultural staff on what could be done with the introduction of a market-oriented processing strategy to their regions. The CFC funded project on small-scale cassava flour processing is building further on these initial meetings.

In January 2004, David and Marlene Mowbray documented the work of two of the four groups in Bungu. (The lead story in the IITA Annual report 2003 will cover this).

2.2 Development of a large-scale cassava starch industry in Tanzania

by S. Kolijn, E. Kanju, V. Rweyendella, Root Crops team SRI-Kibaha, and Dr Subbiah (METL)

During 2003 the partnership with METL in developing a larger scale, commercial cassava starch industry was further strengthened by the ongoing agronomy, selection of most suitable varieties, and long-term, soil-fertility trials.

This work has been developed in close collaboration with the Root and Tuber program at SRI-Kibaha. The fertility trials, using MOP, NPK, and a combination of the two, were harvested during November 2003 and despite the extreme low rainfall throughout 2003 (less than 260 mm!) the yields were above expectations (maximum 35 t of fresh roots). Further new, detailed soil fertility-production trials, with the help and input of Anneke Fermont, had to be postponed due to the lack of rain in March 2003.

This unique and new partnership has attracted the interest of many collaborators and donors and hopefully will lead to additional donor funding (e.g., RF). IITA could provide technical backstopping in the development of an outgrowers scheme to supply the 20 000 t native starch capacity.

Technical inputs by Anneke Fermont, John Wendt, Edward Kanju (IITA), and local staff: Mr Vianey Rweyendella, and SRI-Kibaha).

2.3 Introduction of food extrusion technology in Tanzania

by S. Kolijn and S. Ferris

One of the approved FoodNet projects was an extrusion project developed for and with Powerfoods Ltd; a medium-scale flour miller in Dar es Salaam. Food extrusion technology is aimed at improving the food quality of flours by a quick and intensive heat treatment (based on shear and compaction). The extruder and cleaner unit were imported from UK and the equipment was commissioned in March 2003. In May the DG visited the site and met Mrs Anna Temu, the General Manager of the company. By June, just after the official inauguration of the equipment, Powerfoods got its first contracts to supply UNHCF and WFP as it now could meet the UN food standards for UNIMIX and other fortified flour blends. All standard flours retailed by Powerfoods now undergo the extrusion process. This technology has boosted the business of Powerfoods, as the company is now able to compete with imported foodstuffs like weaning food, high quality flour porridges, and refugee flour blends. In addition to the FoodNet extrusion project in Dar es Salaam two local agroprocessing manufactures developed a strong interest in food extrusion after the FoodNet sponsored study tour to Vietnam (November 2002) and, in 2003, several small units were constructed and tested by Pemba Engineering (Mwanza) and Intermech (Morogoro).

2.4 Inaugural stakeholders' workshop of the Common Fund for Commodities (CFC)-funded regional project on "Small-scale cassava processing and vertical integration of the cassava subsector in Eastern and Southern Africa"

by A. Abass, R. Ranaivoson, A. Zacarias, N. Mlingi, A. Agona, M. Zulu, and J. Whyte

The Small-scale cassava processing and vertical integration of the cassava subsector in Eastern and Southern African countries (ESAC) of Madagascar, Mozambique, Tanzania, Uganda, and Zambia is a cassava commercialization project within the R4D agenda of IITA. The project seeks to develop the income generating potential of cassava as a cash crop in these countries. The strategy to achieve this is to be tested in pilot operations by making simple market-oriented processing technologies and appropriate marketing strategies available to smallholder farmers, processors, and farmer cooperatives. It is expected that participating smallholder farmers and processors will be able to transform highly perishable fresh cassava roots into shelf-stable, market-grade, intermediate products like chips, starch, or flour and be able to access both the national and the regional markets. Phase I of the project, is being executed in collaboration with five national institutions; Centre National de Recherches Appliquées au Développement (FOFIFA) in Madagascar, Instituto Nacional de Investigacao Agropecuaria in Mozambique, Tanzania Food and Nutrition Centre (TFNC), Kawanda Agricultural Research Institute (KARI) in Uganda, and Department of Research and Specialist Services, Food Conservation Unit in Zambia. The inaugural stakeholders' workshop of the project was held in Dar es Salaam, Tanzania from 24 to 25 November 2003. The meeting brought together a coalition of stakeholders from the five participating countries, the International Institute of Tropical Agriculture (IITA-Malawi, Tanzania, Uganda), the Common Fund for Commodities (CFC-Netherlands), Food and Agriculture Organization (FAO-Ghana), the Natural Resources Institute (UK), regional cassava networks (i.e., Southern Africa Root Crops Research Network—SARRNET and Eastern Africa Root Crops Research Network—EARRNET), UNIDO, other national and international organizations. The meeting discussed the work plan for Project Year 1 (PY1) and appointed the Steering Committee (SC) members. Some activities approved for PY1 include mobilization and formation of farmers, processors, and end-users into groups, training sessions for farmers and processors, introduction of technologies and machinery for production of high quality cassava flour (Madagascar, Tanzania, Zambia), rali (Mozambique) and chips (Uganda), and market creation for the products. The 12 member SC was elected in a manner that gave the SC a wide representation of the entire stakeholder' categories. The CFC, FAO, NRI, IITA, EARRNET, SARRNET, private sector, public sector, research/universities, farmers/processors, and NGOs were all represented in the SC charged with the responsibility to oversee the project activities for the three-year period of Phase I.

2.5 Training on cassava processing, market expansion for cassava products, and development of a combined cassava grater and dewatering device

by A. Abass in collaboration with V. Rweyendela and P. Chisawilo

Most farmers in Eastern and Southern African countries (ESAC) have very little knowledge of cassava processing and are therefore unable to take advantage of the huge latent market opportunities for processed cassava in the industrial sector. Where processing is done, the quality and safety of the products are extremely poor. This is responsible for the rebuff of cassava in the industry and prevalence of diseases associated with consumption of improperly processed cassava foods. The situation is made worse by lack of appropriate processing machinery such as graters and dewatering devices.

By third quarter of 2003, IITA conducted training of trainers for staff of Tanzania-NARS and some farmers' groups on the grating technique for production of high quality cassava flour (HQCF), starch and *gari*. Prior to this, the chipping technique that was popularized during the SARRNET project phase was already in commercial use but the grating technique was not. Seven extension and research staff of Tanzania-NARS were trained on production of industrial cassava starch while three farmers' groups in Msongola area of the Coast region of Tanzania were trained and assisted to set up HQCF and *gari* processing enterprises. The Root and Tuber group, farmers, and processors have commenced test marketing of these cassava products to textile mills (starch); supermarkets, biscuit factories (HQCF), and consumers (*gari*). The textile factories are at the moment demanding for more starch to conduct larger tests.

Rapid dewatering is one of the key operations in the production of HQCF and certainly the most tedious. It is the second most important rate-determining factor after drying in the production of HQCF. With IITA backstopping, Intermech Engineering Ltd based in Morogoro, Tanzania embarked on a project to design and fabricate a "combined grating-dewatering device" which would make it possible to carryout both grating and dewatering operations in a single, rapid, and continuous operation. The device comprises of a transport system, which also squeezes the cassava mash through a series of screens thereby enabling the water to be removed (Fig. 1).

About 50% dewatering efficiency was achieved with the first design but further improvements on the device are continuing. It is hoped that the technology, when perfected, will be transferred/disseminated to other parts of SSA where cassava processing and consumption are being promoted.

Figure 1. The new cassava-dewatering device by Intermech Engineering Ltd, Tanzania.

2.6 Cassava pilot production and processing facilities

by N. Mahungu

Four pilot production and processing sites for processing high quality cassava flour and chips for industrial use have been formed. These are Kapili, Mthiramanja, Mbawa, and Mpamba in Malawi. In Tanzania, in addition to the Ubungu farmers associations, pilot processing centers have been established in Kigoma and Tanga regions, as well as Mansa town. In Zambia, the sites are in Western (Kaoma), Northwestern, and Luapula provinces.

In Malawi, two levels of pilot processing sites have been established. The first level is the one described above where individual farmers are organized into associations and are using improved production and processing technologies and making high quality chips. The second level is referred to as a secondary pilot-processing center, which will involve promotion of mid-entrepreneurs. The secondary pilot processing center will be buying cassava processed products from the primary pilot processing center to further process into flour, package, and display/sell in various markets including supermarkets.

Improved processing machines such as graters, chippers, and leaf choppers are being promoted in these pilot-processing centers. Training of local fabricators for these machines is still ongoing.

SARRNET is promoting cassava-based products such as cassava silage for livestock feed with dairy farmers in Malawi in five sites: Doroba, Chimbiya, Chigumula, Chileka, and Mpemba. Twelve farmers are involved including one large-scale commercial dairy farm—Katete Farm—where 5 ha have been planted with cassava for cassava silage.

SARRNET is promoting both sweet and bitter cassava varieties including yellow cassava varieties, which have Beta-carotene. The sweet varieties such as *Mbundumali* are being promoted for the fresh market but also for the bakery and biscuit industries. The bitter varieties *Sauti*, *Yizaso*, and *Mkondezi* in Malawi are being promoted for industrial application (chips and flour) such as in the plywood industry. One variety, *Mkondezi*, has been found to have a better binding effect in the plywood industry compared to other cassava varieties. The bitter varieties are also used in processing fermented flours.

3 Broad-based and special trait genotypes and populations targeting the major production systems and market opportunities developed and disseminated

3.1 Identification of sources of resistance to *Radopholus similis* in *Musa* germplasm

by C. Dochez, M. Pillay, J. Dusabe and J. Whyte, in collaboration with D. De Waele (KU Leuven, Belgium)

The East African highland banana is the most important staple crop in the East African Great Lakes Region. However, nematodes are a serious constraint to sustainable banana production. *Radopholus similis is* commonly known as the most damaging nematode species, causing severe yield losses. The use of host-plant resistance provides promising prospects as a basis towards sustainable nematode management and improved banana production. Using a rapid and reliable screening method based on the inoculation of individual roots, screening of available germplasm for resistance to nematodes has been markedly improved and efficiency increased. This screening method was used to evaluate available germplasm and newly developed hybrids for resistance to *R. similis*. All five clone sets of the East African highland bananas, including cooking and beer types, are susceptible to *R. similis*. Crosses between East African highland bananas and Calcutta 4, a diploid wild banana with resistance to *R. similis*, have resulted in resistant tetraploid hybrids. Resistance was also identified in several diploid hybrids, which were used to further improve the tetraploid hybrids. To date, five secondary triploids with resistance and seven with partial resistance to *R. similis* have been identified. In addition, new sources of resistance have been identified, mainly among germplasm from Papua New Guinea. An overview of the host responses of the evaluated germplasm is summarized in Table 1.

Table 1. Overview of host responses of landraces, wild bananas and IITA's breeding materials to *Radopholus similis* based on the individual root inoculation method.

Resistant	Partially resistant	Susceptible
Reference cultivars		
Yangambi km5 (AAA) Gros Michel (AAA) Calcutta 4 (AA)		Valery (AAA)
East African highland bananas (AAA)		
		Endirira, Enzirabahima, Kazirakwe, Mbwazirume, Nakawere, Nfuuka, Nakitembe, Nakabululu, Musakala, Kabula, Tereza, Kabucuragye, Enyeru, Kibuzi, Nakyetengu, Kisansa, Namwezi, Nakayonga
Tetraploid hybrids		
TMHx 917K-2 TMHx 660K-1 TMHx 4349S-2 TMHx 1977K-1	TMHx 222K-1 TMHx 1438K-1	TMHx 401K-1, TMHx 246K-1 TMHx 1201K-1, TMHx 376K-7 TMHx 365K-1, TMHx 199K-4 TMHx 2048K-2
Diploids		
TMP2x 1549-7, TMB2x 3107S-4 TMB2x 1968-2, TMB2x 2582S-1 TMB2x 5265S-1, TMB2x 2537S-1 TMB2x 8075-7, TMB2x 4443S-1 SH 3142, TMB2x 2569S-1 TMB2x 9128-3, TMB2x 2569S-2	TMB2x 1297-3 TMP2x 1518-4	TMB2x 7197-2 TMB2x 8848-1 TMB2x 9839-1 TMP2x 9722-1
Secondary triploids		
7269S-15, 7604S-4 8386S-5, 8386S-22 1201OPP79	1201OPP30 2156K-41, 2409K-3 8386S-15, 9494S-10 8386S-19, 8386S-50	8386S-4, 8386S-27 1201OPP81, 1201OPP85 7798S-2
Wild bananas and landraces		
Marau, Pora Pora, Kokopo, Pisang Mas, Saba, Gia Hiu, M.a.ssp. burmanica, Galeo, M.a.ssp. malacencis, Vudu papua	Pitu, Yalim, *M. balbisiana*, Cachaco, Yanin Yefan	Gunih, Mshale, Pama, Dumingi, Kikundi, Wambo, Merik, M.a.ssp. truncata, Pagatau, Garunga, Ambiri

3.2 Identification of mechanisms of resistance to nematodes in *Musa*

by C. Dochez, M. Pillay, J. Dusabe, A. Tenkouano, and J. Whyte, in collaboration with D. De Waele (KULeuven, Belgium) and Makerere University Kampala, Uganda

Studies on the mechanisms of resistance will help the breeding program to select for a desired feature. Lignin might form a physical barrier for nematode penetration, i.e., pre-infectional resistance. Formation of phenolic compounds might refer to induced resistance as a response to nematode penetration. In a first set of experiments, the attraction and penetration ability of *R. similis* was compared among resistant and susceptible cultivars. No significant differences in attraction and penetration of *R. similis* were observed between resistant and susceptible cultivars. Similar invasion rates of *R. similis* on resistant and susceptible cultivars, suggests that the resistance is not due to physical or mechanical barriers. Histochemical experiments were carried out to detect differences in lignin and phenolic compounds between susceptible and resistant cultivars. At different times after inoculation with *R. similis* of resistant and susceptible cultivars, root sections were taken from near the corm, in the middle of the root, and at the root tip. Detection of lignin was done using safranine with counter stain fast green. Phenolic cells were detected using ferric chloride. An increased number of phenolic cells were observed after nematode inoculation in resistant cultivars. The highest number of phenolic compounds was observed in the resistant diploid hybrid TMB2x 9128-3 and the reference cultivar Yangambi Km5, both showing resistance to four *R. similis* populations from Uganda. No lignified cells were observed in the cortex of the root. Lignification was only observed in the endodermis, especially in susceptible cultivars.

3.3 Genetic analysis of nematode resistance in a segregating population of *Musa*

by C. Dochez, A. Tenkouano, M. Pillay, and J. Whyte, in collaboration with Dirk De Waele (KU Leuven, Belgium)

A diploid banana population (TMB2x 6142-1 x TMB2x 8075-7) with 81 progeny was screened for resistance/susceptibility to *R. similis* to find out if the gene(s) for nematode resistance/ susceptibility may be segregating in this population. Screening of this population and determination of segregation ratios will provide information on the inheritance and number of alleles controlling this trait in banana. Eighty-one progeny have been tested with the individual root inoculation method, and the reproduction ratio of *R. similis* on each progeny was compared with the reproduction ratio of *R. similis* on the resistant reference cultivar Yangambi km5 and the susceptible reference cultivar Valery. The female parent TMB2x 6142-1 is a cross between Nyamwihogora (EAHB) and Long Tavoy and is susceptible to *R. similis*. The male parent TMB2x 8075-7 is resistant to *R. similis* and derived from the cross between SH 3362 (PJB pedigree) and Calcutta 4, which are both resistant to *R. similis*. Of the 81 hybrids evaluated, 37 were resistant, 13 were partially resistant, and 31 were susceptible to *R. similis*. After chi-square analysis, these results indicate that resistance to *R. similis* is controlled by two dominant genes, A and B, both with additive and interactive effects, whereby recessive bb suppresses dominant A (either A- or B- required for partial resistance, both A- and B- confer full resistance, but bb suppresses A-).

3.4 Identification of sources of resistance to *Pratylenchus goodeyi* in *Musa* germplasm in Rwanda

by C. Dochez, J. Dusabe, M. Pillay, and J. Whyte, in collaboration with Dirk De Waele (KU Leuven, Belgium) and Sveta Gaidashova (ISAR, Rwanda)

A yield loss trial in a farmer's field was established at Kibuye, Rwanda, in September 2003. This area showed the highest densities of *Pratylenchus goodeyi* during a survey carried out in 2001. No other important nematode species (as *Radopholus similis* and *Helicotylenchus multicinctus*) were present in this area. Three varieties of the East African highland bananas (Mbwazirume, Ingaji, and Intuntu) were planted in a nematode infested plot and in a noninfested plot. Nemacur is used to control nematodes in the noninfested plot at a rate of 15 g active ingredient (phenamiphos) twice a year. Six plants per variety were planted in three replications. Within the infested and noninfested plots, subplots with mulch and no mulch were established. Data will be taken at nine months after planting, at flowering, and at harvest of the motherplant and first ratoon.

A screening method is being developed for evaluating *Musa* germplasm for resistance to *P. goodeyi.*

3.5 Studies on expression of host plant resistance

by C. Gold, in collaboration with G. Night and A. Powers

Antibiosis has been advanced as the most important pathway in the resistance of banana-to-banana weevil. Treatment of eggs with sap (latex) from resistant cultivars has been reported to reduce hatchability. However, it is not clear whether the negative effects of sap are due to its physical properties, chemical elements, or both. Furthermore, an antibiotic mechanism in some cultivars was suggested based on high performance liquid chromatography (HPLC) analysis of extracts from various cultivars. Increased developmental time, reduced vigor, and increased mortality of larvae were observed when larvae were reared on corm tissue of resistant cultivars. Antibiosis may be expressed either as a chemical toxin or antifeedant.

In addition to chemical composition of plants, physical factors such as corm hardness may confer antibiotic resistance to banana weevil. Increased corm hardness may lead to failure of larvae to tunnel and feed. Tissue toughness may lead to wearing of larval mandibles and reduced feeding.

In banana, patterns of corm damage by weevils suggest uneven distribution of plant defenses. Distribution of damage in the plant may also influence yield loss. Additionally, differences in oviposition and larval performance on different phenological stages have been reported. By evaluating resistance at different growth stages, useful patterns can be identified that have applications for breeding programs. Understanding of these phonological patterns is also important for purposes of pest management and timing of control measures.

Expression of resistance is a result of interplay between genetic traits and environmental factors. One of the environmental factors that may influence resistance of banana plants to the weevil is plant nutrition. Given a limited set of resources, plants might change their allocation pattern in response to such factors as herbivore attack.

The objectives of this ongoing student research activity are: (1) to characterize the chemical and physical factors responsible for banana resistance to weevil; (2) to study the distribution of resistance factors within the plant and variation of resistance with plant phenology for selected cultivars; and (3) to determine the influence of plant nutrition on expression of resistance.

Observations were made on characteristics of sap: color, quantity, viscosity and speed of coagulation, and dispersion. The study was carried out in the dry season between September and October 2002. The more weevil resistant cultivars tended to have a higher number of drops per unit area compared to the more susceptible cultivars. Also, sap of resistant cultivars thickened on wounding of the corm. Atwalira, a susceptible cultivar, did not produce sap. These observations will be repeated in the first rainy season of 2003. The effect of sap on egg hatchability was also studied. It was hypothesized that if sap effects were chemical, embryo development would fail. If, however, the effects were physical, embryo development would occur but eclosion might be reduced. As of yet, no conclusive results have been obtained, in part, because the controls did not perform well (hatchability was only 70%). This experiment will be repeated. Eclosion rates will also be determined for eggs treated with methanol and water-based extracts from the pseudostems and corms of different cultivars.

Feeding deterrence is one way in which antibiosis may be manifested. An experiment was set up to observe settling and tunneling time of newly hatched larvae offered corms of different cultivars (Atwalira, Kabula, Mbwazirume, Calcutta, Kauai, Keying, and Yangambi Km 5). Settling time was increased on resistant cultivars. While on susceptible cultivars (Atwalira, Kabula, Mbwazirume) all larvae penetrated the corm completely in 1–1.5 hours, up to 40% of the larvae had not penetrated the corms of resistant cultivars (Kauai, Keying, and Yangambi Km 5) in the same time interval.

Antibiotic effects of resistance are being tested further in larval feeding bioassays. An experiment is underway to study survivorship and development rate of larvae raised on corms of different cultivars. Additionally, the influence on adult weight of feeding larvae on different cultivars will be determined.

The objectives of an ongoing study are to study mechanisms of resistance to banana weevil, to determine the distribution of resistance in different parts of the plant and in different plant phenological stages, and to determine the influence of plant nutrition on resistance expression.

.The distribution of resistance factors within the plant and in different plant phenological stages will be determined using egg and larval bioassays described above. HPLC analysis are also being carried out on different parts of the plant and different plant phonological stages.

Larval bioassays on corm tissue indicate that larvae feeding on resistant cultivars generally have longer developmental periods. For instance, larval developmental period on Kauai was 37 days while that on Atwalira was 25 days. Adult weights were similar. Survivorship data was not consistent with resistance patterns observed in the field. A pot experiment is being conducted to further study resistance in different cultivars.

Larvae feeding on pseudostem had longer developmental periods (59 days) than those feeding on the corm (31 days). Also, survivorship of individuals feeding on pseudostem was low (59% for early instars; 29% at adult stage) compared to that of larvae feeding on corm tissue (77% for early instars; 53% at adult stage). Adult weight of weevils raised on corm tissue was 0.054 g compared to 0.033 g for those on pseudostem tissue. Studies on variation of resistance with plant phenology are underway both in the laboratory and in the field.

In another study, egg hatchability (eclosion rates) was influenced by cultivar and tissue type. For cortex tissue, the lowest hatchability was in Calcutta 4 (68%) and highest in Atwalira (83%). For the pseudostem, Calcutta 4 again gave the lowest hatchability (84%) and Atwalira and FHIA 03 the highest (88%). High mortality and delayed larval development was observed on resistant cultivars (Keying, Kauai, and Calcutta 4) compared to a susceptible cultivar (Atwalira). While the larval stage lasted 27 days in Atwalira, it ranged from 30 to 37 days among the resistant cultivars. Adult weights were similar on the different cultivars.

A study on the influence of plant nutrition on expression of resistance to banana weevil will be carried out in a field experiment planted in December 2002 at the Kawanda Agricultural

Research Institute, Uganda. The cultivars planted are Atwalira, Nsowe, FHIA 03, Cavendish, Keying, and Yangambi Km 5. The nutrition levels are low and optimum nutrients.

3.6 The identification of candidate genes for developing transgenic resistance to banana weevil in East African Highland banana

by M. Pillay and C.S. Gold, in collaboration with A. Kiggundu, A. Viljoen, and K. Kunnert*

This project is being addressed through an ongoing PhD study under the lead of the University of Pretoria and in collaboration with IPGRI. The primary objective is to explore the feasibility of developing transgenic plants with resistance to banana weevil.

The use of proteinase inhibitors to engineer plants for resistance to a wide range of insect pests has recently gained much attention. Several studies have demonstrated effectiveness in the use of such inhibitor genes for transgenic control of various pests including insects and nematodes. Proteinase inhibitors which operate by inhibiting the gut enzymes that break down proteins in the insect's diet, have been isolated in several plant species and are believed to function as defense compounds against insect and pathogen attack. Exploring plants own defense mechanisms, by engineering and the introduction of insect defense proteins from other plants, is seen as a more natural strategy. Several genes encoding various proteinase inhibitors have been introduced into crop plants with successful improvement in resistance to pests and these plants are now at various stages of field-testing worldwide.

The general objectives of this project are to (1) evaluate a strategy for the use of cysteine proteinase inhibitors as a first target gene for genetic engineering of banana for resistance to banana weevil; and (2) to optimize inhibition activity of plant cystatins to obtain novel inhibitors with increased activity and thus acquire intellectual property rights. Specifically, we wish to: (a) identify the major class of proteolytic enzyme activity in the mid-gut of banana weevil and thus potential proteinase inhibitors of plant origin; (b) develop in-vivo and in-vitro bioassays for testing purified proteinase inhibitors against gut proteinase activity, and on larval growth and development; (c) engineer through site directed mutagenesis, two plant cystatins with improved and specific inhibition of banana weevil gut proteinase enzymes, both in-vivo and in-vitro; and (d) design gene constructs for engineering bananas with novel proteinase inhibitor genes.

A system for the dissection of adult and larval banana weevil mid guts and subsequent extraction of their active proteinases has been developed. This was followed by the development of a fluorimetric in-vivo assay to evaluate proteinase activity, optimum pH, and inhibition of the gut extracts. The assay uses a synthetic peptide which releases a highly fluorescent compound on breakdown by proteolytic enzymes present in the gut extracts. Activity is measured by a fluorescence spectrophotometer or can be scored visually under UV light.

The major proteinase enzyme class in both adult and larval banana weevils was established to be of the cysteine type as has been reported in many other Coleopteran insects. Cysteine proteolytic activity in weevil gut extracts was highly inhibited, in-vitro, by synthetic cysteine specific inhibitor E-64 and two plant cystatins; Oryzacystatin I (OC-I) from seeds of rice (*Oryza sativa*) and Papaya cystatin from leaves of paw paw (*Carica papaya*). The two phytocystatins were obtained in large amounts by cloning, and expression in *E. coli* bacteria before purification as fusion proteins.

An in-vivo bioassay system based on vacuum infiltration of banana stems with cystatin solutions and subsequent rearing of weevil larvae on the stems was developed. Preliminary experiments with this system have shown that larvae reared on cystatin infiltrated stems experienced up to 76% reduction in early larval growth and development. This assay system is a significant achievement since there is no known artificial diet for banana weevil.

3.7 Micropropagation of planting material in *Musa*

by M. Pillay, in collaboration with W. Tushemereirwe

Routine micropropagation of introduced germplasm from the *Musa* Transit Center, Belgium and other planting material was carried out. The genotypes used for micropropagation and the number of propagules derived from them are presented in Table 2.

Table 2. List of banana genotypes propagated during 2003.

Genotypes	Source	# propagules	Purpose
Mpologoma, Kisansa, Nakitembe, Namaliga, Mbwazirume, Mudwale, Atwalira, William, KM-5, FHIA-17, 18, 23, 25	Local	38 100	Field trials for the National Banana Research Program
P.Nangka, Cultivar Rose, PA03-22, PA03-44, GCTCV-215, GCTCV-119, PV42, PV-53, Robusta, Malaccensis, Ruyondo, Truncata, Who-o-gu, P. awak, *M. balbisiana* Cameroon, Toowoolee, P.Tongat, P. raja, Nzizi, Foulah 4, Too.	ITC	190	Breeding
TMBx 5295-1, FHIA-1, FHIA-23, FHIA-25, SH 3436-9	ITC	In progress	For distribution in Malawi and Zambia
Nine secondary triploids plus a landrace	EET	In progress	Preliminary yield trial
Twelve PNG accessions plus two *Musa acuminata banksii*, Calcutta 4 and *M. balbisiana*	ITC	In progress	Screening for banana bacterial wilt

3.8 Germplasm propagation, exchange, and conservation

by M. Pillay, in collaboration with W. Tushemereirwe (NARO)

The tissue culture laboratory in Kawanda is responsible for embryo rescue and micropropagation for NARO and IITA. A total of 25 643 hybrid seeds from the various crosses made at Sendusu and Kawanda were dissected for embryo culture. The characteristics of the seeds and their embryo germination rate are shown in Table 3. In addition, 2095 Gamma irradiated seeds of Calcutta 4 were cultured to observe their rate of germination.

During this period, 2927 hybrids from various crosses were weaned and hardened for field trials.

3.9 Evaluation of seed fertility in *Musa*

by M. Pillay and A. Tenkouano

FHIA 23 and FHIA 25 were used as female parents and crossed with male fertile triploid East African banana landraces Tereza, Nakasabira, and Namwezi. No seeds were obtained from these crosses. However, FHIA 23 produced seeds when crossed with Calcutta 4 suggesting that it is female fertile. The FHIA hybrids are now being crossed with the diploid male parents including 8075-7, 9128-3, and 7197-2. The cross 1438K-1 × FHIA 23 produced 170 seeds, while 1201K-1 × FHIA 25 produced a single seed. The female fertility of the triploid 1968-2 is being ascertained by crossing it with Calcutta 4.

Table 3. Characteristics of hybrid seeds for embryo rescue at Kawanda (January-November 2003).

Female*	Male*	Seeds	Embryos	Germination	Embryo recovery (%)	Embryo germination (%)
Matooke landraces	Improved 2x	293	199	24	67.9	12.1
Matooke landraces	Calcutta-4	10	4	0	40.0	0
TMHx	Improved 2x	11 595	7121	717	61.4	10.1
TMHx	Calcutta-4	4566	3263	164	71.5	5.0
TMHx	Kokopo	25	6	2	24.0	33.3
TMHx	FHIA-23	140	112	24	80.0	21.4
TMHx	TMHx	523	334	30	63.9	9.0
TMBx 22788-4	*Balbisiana*	367	64	20	17.4	31.3
Improved 2x	Improved 2x	250	73	17	29.2	23.3
Calcutta-4	*P. lilin*	606	346	80	57.1	23.1
Total		18 375	11 522	1078	62.7	9.4

*Matooke landraces: Entukura, Enzirabahima, IITA-Nakyetengu, Kabucuragye, Nakasabira, Nakayonga, Namwezi, Nfuuka and Tereza.
*Improved diploids (2x): TMB2x 6142-1, 7197-2, 8075-7, 9128-3, 9719-7, SH 3142, 3217, 3362.
*TMHx: 199K-4, 222K-1, 365K-1, 376K-7, 401K-1, 660K-1, 917K-2, 1201K-1, 1438K-1.

3.10 *Musa* improvement at diploid level

by M. Pillay and A. Tenkouano

Eight diploids were identified by flow cytometry and selected for further improvement. These diploids, their parents, and some of their characteristics are listed in Table 4.

Table 4. List of diploid hybrids with 'matooke' characteristics selected for further improvement.

Genotype	Parentage	Remarks
5610S-1	Kabucuragye × TMB2x 7197-2	Big bunch, being crossed with tetraploids, produced 41 seeds with TMHx 660K-1
861S-1	Namwezi × Calcutta 4	Nonparthenocarpic, little pollen, female fertile
1537K-1	Kabucuragye × Calcutta 4	Nonparthenocarpic, being crossed with tetraploids
8817S-1	Kazirakwe × 8075-7	Being pollinated on tetraploids
7927S-1	Nakyetengu × 7197-2	Being propagated
12187S-12	376K-7 × 5105-1	Ploidy determined by chromosome counting
12495S-3	917 K-2 × 9719-2	Ploidy determined by chromosome counting
10969S-1	376K-7 × 5105-1	Ploidy determined by chromosome counting

3.11 Evaluation of *Fusarium* wilt resistance in *Musa*

by M. Pillay

Panama disease (*Fusarium* wilt) is the one of major constraints affecting Pisang Awak (ABB) and Sukali Ndizi (AAB) in eastern and southern Africa. Nine genotypes comprising Pisang lilin, Fougamou, Pisang Awak, SH3217, SH3142, SH3362, Yangambi Km5, and Kikundi were tested for resistance in a *Fusarium*-infested field. Of the nine genotypes, Pisang Awak and Fougamou showed typical symptoms of *Fusarium* wilt including leaf discoloration and wilting, pseudostem splitting, and browning of the vascular tissue. The seven other genotypes have not showed symptoms of *Fusarium* wilt after being in the infested field for 20 months. A new trial with 42 new genotypes is being screened for *Fusarium* resistance in the infested field.

3.12 *Musa* improvement at the polyploid level

by M. Pillay and A. Tenkouano

Sixteen secondary triploids (Table 5) were selected for preliminary yield testing and evaluation by farmers. Bunch weights of these hybrids ranged from 13 to 25 kg. Some hybrids were resistant to black Sigatoka while others were classified as tolerant.

Table 5. Secondary triploids selected for preliminary yield trial (PYT).

Hybrid	Parentage	BWT	DFF	NSL
1. Opp30 1201K-1	1201K-1 (Opp)	13	132	3
2. Opp79 1201K-1	1201K-1 (Opp)	19	170	3
3. Opp81 1201K-1	1201K-1 (Opp)	18	-	3
4. Opp85 1201K-1	1201K-1 (Opp)	14	152	4
5. 2159K-5	660K-1 × 8075-7	16	170	3
6. 2156K-41	1438K-1 × 9128-3	22	122	3
7. 7689S-20	1201K-1 × 9128-3	12	164	2
8. 7798S-2	917K-2 × 9128-3	21	151	3
9. 8386S-15	917K-2 × SH 3217	19	134	2
10. 8386S-22	917K-2 × SH 3217	20		2
11. 8386S-50	917K-2 × SH 3217	24	139	3
12. 8386S-19	917K-2 × SH 3217	19	139	4
13. 9187S-8	660K-1 × 9128-3	20	131	4
14. 9494S-10	917K-2 × SH 3362	25	137	4
15. 9750S-13	401K-1 × 9128-3	19	139	5
16. 2409K-3	222K-1 × 8075-7	17	150	4

NSL = number of standing leaves at harvest; DFF = days to fruit filling; BWT = Bunch weight

3.13 Evaluation of banana bacterial wilt resistance in *Musa*

by M. Pillay, R. Bandyopadhyay, and W. Tushemereirwe

Bacterial wilt, caused by *Xanthomonas campestris* pv. musacearum has been identified in Uganda. A task force was set up to evaluate the disease epidemiology and make recommendations to the National Agricultural Research Organization. To enable screening of genotypes for bacterial wilt resistance, 41 genotypes (Table 6) were multiplied by micro- and macropropagation. These genotypes have been established in the "hot spot" area in the Mukono district.

Table 6. Genotypes used for banana bacterial wilt screening in Mukono, Uganda.

PNG accessions	TMP/B 2x hybrids	FHIA Hybrids	TMHx Hybrids	TMH3x Hybrids	ITC accessions	Introduced landraces
Ambiri	8075-7	SH 3217	660 K-1	8386S-19	*M. acuminata* ssp. Banksii	Yangambi Km 5
Dumingii	9128-3	SH 3362	917 K-2	9187S-8	*M. acuminta* ssp. mallaccensis	Pisang lilin
Kokopo	7197-2	SH 3142	1201 K-1	9494S-10	*M. acuminata* cv. Pahang	Mshale
Merik	1968-2	FHIA 23	1348 K-1	9750S-13		
Pama			376K-7	2409K-3		
Pagatau			222K-1	7798S-2		
Pora pora			365K-1	8386S-15		
Yalim			401K-1	8386S-22		
				8386S-50		

3.14 Open Quarantine Facility (OQF)

by E. Kanju, M. Hermes (ARI Kibaha, Tanzania), J. Whyte, and B. Khizzah

The restricted movement of germplasm has been a major drawback in the expansion of production and utilization of cassava. It has not been possible for varieties or advanced genotypes developed in one country to benefit other countries in the region, which has impeded the spill over effects of cassava improvement activities in the region. The open quarantine system was established by plant quarantine services in the region to permit the transfer of a number of genotypes (in the form of cuttings) from the regional midaltitude germplasm enhancement program in eastern Uganda to western Kenya, Tanzania, and Rwanda specifically to combat the CMD pandemic. With the increasing devastation of cassava from cassava brown streak virus disease in the coastal lowlands of eastern and southern Africa, the open quarantine system was adopted to enable the exchange of tolerant/resistant materials in the region.

In order to increase the number of resistant cultivars available to farmers, about 457 clones were introduced into the OQF established at Kibaha, Tanzania in March 2003, from the East African Root crops Research Network (EARRNET) breeding program at KARI Mtwapa, near Mombasa, Kenya. Mtwapa is a CBSD hot spot. Only clones, which did not show any CMD and CBSD symptoms, were introduced. The clones were also selected on the basis of their high yielding ability and high dry matter content. One stem per clone was taken. At Kibaha, each stem was cut into four cuttings and planted in the OQF. Planting was done on 4 May 2003. The spacing of 0.5 m × 0.5 m was used. After sprouting, the plants were closely inspected (weekly) for any disease symptoms. Plants showing any symptoms were recorded and then rouged and buried. After every two months, inspectors from the postentry quarantine station based at Arusha inspected the plants to make sure that only apparently disease free plants will be multiplied after the one-year compulsory confinement in the OQF. The OQF is located in isolation (at least 200 m from the nearest cassava crop) and fenced and guarded.

Plant establishment in the OQF was excellent due to watering. By the end of October 2003 (5 MAP), 169 (37%) clones out of the 457 introduced into the OQF had all their plants rouged. Out of the 288 (63%) clones remaining, only 97 (21%) had all established plants free of disease symptoms. The use of the OQF has facilitated the quick and efficient introduction of improved germplasm.

4.15 Cassava Crossing Block

by E. Kanju, M. Hermes (ARI Kibaha, Tanzania), J. Whyte, and B. Khizzah

In order to generate new genotypes, which combine resistance to both CMD and CBSD, a crossing block was established at ARI Kibaha, Tanzania. The following cultivars were used: Kiroba, Amani 46106/27, NDL 90/34, Namikonga, Kigoma Red, Kitumbua (CBSD tolerant/resistant); Kibaha, and TMS 4(2) 1425 (CMD resistant). Planting was done in April 2003. A randomized complete block design was used, with four replications. One row of ten plants constituted a plot. The spacing of 1.5m × 1.5 m was used. A full diallel mating system was used to generate F1 seeds for genetic studies.

Due to severe drought experienced during the season (only 100 mm were received compared to the normal expected amount of 900 mm), plant growth was adversely affected to the extent that no seeds were collected. Kibaha is not an ideal site for the establishment of crossing blocks due to poor soils and poor flowering of clones. Drought is not a common phenomenon at the site. In order to avoid the risk of poor seed set, two new sites (ARI Maruku, Bukoba and ARI Naliendele, Mtwara) were selected for the establishment of crossing blocks during the next planting season.

3.16 Cassava Clonal Evaluation Trial (CET)

by E. Kanju, M. Hermes (ARI Kibaha, Tanzania), H. Saleh. (ARI Kizimbani, Zanzibar), J. Whyte, and B. Khizzah

In December 2002 a team of cassava breeders from eastern and southern Africa jointly met at ARI Kibaha, Tanzania for the harvesting of a cassava seedling trial. Their efforts resulted in the selection of about 513 seedlings that showed promising resistance to both cassava mosaic disease (CMD) and cassava brown streak disease (CBSD). The selected seedlings were cloned and planted in a clonal evaluation trial (CET) at three sites to evaluate their yielding potential and other quality attributes, and also to confirm their disease and pest reaction.

Seedlings selected from the seedling trial were cloned and planted at three sites: Kibaha, a hot spot for both CMD and CBSD but poor soils (520 clones); Alavi estate, 10 km from Kibaha, where an entrepreneur (Mohamed Enterprises–MeTL) intends to establish a large cassava starch factory (480), and Zanzibar (170 clones). Planting was done in December 2002. Three cuttings per clone were planted. A check plot design was used where a local check was planted after every ten clones. The spacing of 1.0 m × 1.0 m was used. Plant height and pest and disease scores were taken at three-month intervals up to harvesting. Diseases and pests were subjectively scored on a scale of 1–5, where class 1 indicated no symptoms and class 5 very severe symptoms. At harvest yield and yield component data were taken. The roots were also carefully observed for brown streak root necrosis.

Table 7. Some characteristics of 41 cassava clones selected from the CET for advanced evaluation at Kibaha, Tanzania during the 2004/2005 season.

Clone no.	Root weight kg/plant	No. of roots/ plant	Average root size (kg)	Pedigree
1. KBH 2000/010	1.27	3.0	0.42	71673-OP
2. KBH 2000/016	4.47	6.0	0.74	71673-OP
3. KBH 2000/017	1.90	5.5	0.34	71673-OP
4. KBH 2000/018	2.40	6.7	0.36	71673-OP
5. KBH 2000/023	5.50	8.0	0.69	71673-OP
7. KBH 2000/025	3.35	6.0	0.56	4(2)1425-OP
8. KBH 2000/038	1.40	4.7	0.30	TME 146-OP
9. KBH 2000/049	1.83	3.3	0.55	88/00279-OP
10. KBH 2000/057	1.73	5.0	0.35	91/00459-OP
11. KBH 2000/062	2.47	7.0	0.35	92/0325-OP
12. KBH 2000/063	2.85	7.5	0.38	92/0325-OP
13. KBH 2000/066	1.90	6.3	0.30	96/1613-OP
14. KBH 2000/068	2.60	3.7	0.71	96/1613-OP
15. KBH 2000/069	2.10	5.0	0.42	96/1613-OP
16. KBH 2000/073	1.90	3.7	0.52	96/1613-OP
17. KBH 2000/100	3.55	5.5	0.64	88/00188-OP
18. KBH 2000/111	1.73	6.7	0.26	88/00188-OP
19. KBH 2000/129	1.70	5.0	0.34	TME 139-OP
20. KBH 2000/164	1.50	3.7	0.41	61677-OP-OP
21. KBH 2000/169	1.80	3.7	0.49	91/02316-OP
22. KBH 2000/175	2.10	7.3	0.29	TME 629-OP
23. KBH 2000/190	1.73	4.3	0.40	71762-OP
24. KBH 2000/213	1.30	3.7	0.35	71762-OP
25. KBH 2000/248	1.53	5.0	0.31	71762-OP
26. KBH 2000/257	1.87	4.0	0.47	88/00593-OP
27. KBH 2000/264	2.95	7.5	0.39	88/00593-OP
28. KBH 2000/280	2.50	6.0	0.42	88/01043-OP
29. KBH 2000/283	1.93	7.0	0.28	88/02122-OP
30. KBH 2000/288	1.70	5.0	0.34	88/00417-OP
31. KBH 2000/289	1.60	6.0	0.27	88/00417-OP
32. KBH 2000/306	1.83	5.0	0.37	88/02334-OP
33.KBH 2000/336	2.83	10.3	0.27	88/00022-OP
34. KBH 2000/344	1.57	3.7	0.43	91/00424-OP
35. KBH 2000/376	2.93	7.0	0.42	84563-OP
36. KBH 2000/417	2.40	4.7	0.51	84776-OP
37. KBH 2000/418	3.07	7.7	0.40	84776-OP
38. KBH 2000/453	1.77	4.3	0.41	Mkondezi-OP
39. KBH 2000/464	2.33	4.3	0.54	Mkondezi-OP
40. KBH 2000/505	2.17	5.0	0.43	Kiroba-OP
41. KBH 2000/513	1.63	4.3	0.38	Kiroba-OP
Local check	0.55	2.0	0.27	

Plant establishment at all three sites was excellent. However, Kibaha and Alavi estate experienced unusual severe drought. The short rains expected in October–December also did not arrive, therefore, harvesting at these sites was postponed until the beginning of the 2003/2004 rains (March 2004). Harvesting of the trial at Zanzibar was done in December 2003. The number of clones selected for further evaluation and their characteristics are summarized in Tables 7, 8, and 9.

A high genotype by environment interaction was observed. Different clones were selected at the three sites (only seven clones were common between Kibaha and Alavi estate, only one clone was common between Kibaha and Zanzibar, and only two clones were common between Alavi estate and Zanzibar). This highlights the importance of adopting breeding for specific adaptation approaches. Family performance in terms of both root yield and number of clones selected, seem to have also depended on the environment. Under poor soil and low moisture conditions (Kibaha environment) the following families seem to have performed well: 71673 and 96/1613; under good soil and low moisture conditions (Alavi estate) the following families seem to have performed well: 71762 and 88/00188 whereas, under good soils and good moisture conditions (Zanzibar), the following families seem to have performed well: 71762, 96/1632, 91/00424, and Kiroba.

Table 8. Some characteristics of 39 cassava clones selected from the CET for advanced evaluation at Alavi estate, near Kibaha, Tanzania during the 2004/2005 season.

Clone no.	Root weight kg/plant	No. of roots/ plant	Average root size (kg)	Pedigree
1. KBH 2000/001	2.60	6.3	0.41	96/1431-OP
2. KBH 2000/020	1.47	4.3	0.34	71673-OP
3. KBH 2000/023	1.67	5.3	0.31	71673-OP
4. KBH 2000/043	0.47	4.0	0.12	88/00623-OP
5. KBH 2000/055	0.87	3.0	0.29	88/00279-OP
7. KBH 2000/063	1.97	5.7	0.35	92/0325-OP
8. KBH 2000/066	3.60	8.5	0.42	96/1613-OP
9. KBH 2000/069	2.20	4.5	0.49	96/16138-OP
10. KBH 2000/111	5.20	6.5	0.80	88/00188-OP
11. KBH 2000/119	0.40	0.7	0.60	88/00188-OP
12. KBH 2000/122	5.35	11.0	0.49	88/00188-OP
13. KBH 2000/123	4.50	8.0	0.56	TME 130-OP
14. KBH 2000/135	1.50	2.7	0.56	TME 200-OP
15. KBH 2000/139	3.25	8.5	0.38	91/00438-OP
16. KBH 2000/141	4.15	9.0	0.46	95/0947-OP
17. KBH 2000/145	1.93	2.3	0.83	TME 168-OP
18. KBH 2000/150	1.37	5.0	0.27	91/00174-OP
19. KBH 2000/170	2.30	3.0	0.77	91/02316-OP
20. KBH 2000/180	1.13	3.7	0.31	71762-OP
21. KBH 2000/182	4.40	9.5	0.46	71762-OP
22. KBH 2000/188	3.00	7.0	0.43	71762-OP
23. KBH 2000/197	2.10	4.7	0.45	71762-OP
24. KBH 2000/202	1.57	5.0	0.31	71762-OP
25. KBH 2000/208	1.65	7.0	0.24	71762-OP
26. KBH 2000/213	0.87	1.7	0.52	71762-OP
27. KBH 2000/228	5.85	7.5	0.78	71762-OP
28. KBH 2000/232	5.20	10.0	0.52	71762-OP
29. KBH 2000/283	2.23	4.0	0.56	88/02122-OP
30. KBH 2000/301	1.47	3.0	0.49	88/02334-OP
31. KBH 2000/363	3.00	2.7	1.13	96/1632-OP
32. KBH 2000/378	1.60	6.3	0.25	84563-OP
33.KBH 2000/379	2.70	5.0	0.54	84563-OP
34. KBH 2000/382	3.10	7.0	0.44	84563-OP
35. KBH 2000/405	1.50	6.7	0.23	88/02363-OP
36. KBH 2000/407	1.57	3.3	0.47	30211-OP
37. KBH 2000/416	1.50	5.0	0.30	84776-OP
38. KBH 2000/425	0.93	2.3	0.40	96/0867-OP
39. KBH 2000/488	1.57	5.3	0.29	Kiroba-OP
Local check	0.77	2.3	0.33	

Table 9. Some characteristics of 26 cassava clones selected from the CET for advanced evaluation in Zanzibar during the 2004/2005 season.

Clone no.	Root weight kg/plant	No. of roots/ plant	Average root size (kg)	Pedigree
1. KBH 2000/64	2.67	5.0	0.53	92/0325-OP
2. KBH 2000/152	1.67	3.0	0.56	TME 117-OP
3. KBH 2000/191	2.67	5.0	0.53	71762-OP
4. KBH 2000/200	2.67	4.3	0.62	71762-OP
5. KBH 2000/228	3.50	6.5	0.54	71762-OP
6. KBH 2000/239	2.33	5.3	0.44	71762-OP
7. KBH 2000/251	4.00	6.3	0.63	71762-OP
8. KBH 2000/341	3.00	4.5	0.67	91/00424-OP
9. KBH 2000/344	3.33	6.7	0.50	91/00424-OP
10. KBH 2000/352	4.67	5.3	0.88	91/00424-OP
11. KBH 2000/365	2.50	4.5	0.56	96/1632-OP
12. KBH 2000/367	2.50	3.5	0.71	96/1632-OP
13. KBH 2000/368	3.33	6.0	0.56	96/1632-OP
14. KBH 2000/383	1.17	4.7	0.25	84563-OP
15. KBH 2000/397	1.33	2.7	0.50	71173-OP
16. KBH 2000/462	1.83	5.3	0.34	Mkondezi-OP
17. KBH 2000/471	2.50	6.0	0.42	Kiroba-OP
18. KBH 2000/477	1.00	3.0	0.33	Kiroba-OP
19. KBH 2000/480	1.50	3.0	0.50	Kiroba-OP
20. KBH 2000/482	2.00	10.0	0.20	Kiroba-OP
21. KBH 2000/488	1.33	4.0	0.33	Kiroba-OP
22. KBH 2000/494	1.17	4.0	0.29	Kiroba-OP
23. KBH 2000/500	1.73	4.0	0.43	Kiroba-OP
24. KBH 2000/506	0.83	3.7	0.23	Kiroba-OP
25. KBH 2000/513	1.25	5.5	0.23	Kiroba-OP
26. KBH 2000/517	1.50	5.0	0.30	Kiroba-OP
Local Check	0.56	2.7	0.22	

3.17 Genotype by environment interaction for native cassava (*Manihot esculenta* Crantz) starch quality and its use in the commercial sector

by I.R.M. Benesi[1], M.T. Labuschagne[2], A.G.O. Dixon[3], and N.M. Mahungu[4] [1]Chitedze Research Station, PO Box 158, Lilongwe, Malawi; [2]Department of Plant Sciences, University of the Free State, PO Box 339, Bloemfontein 9300, Republic of South Africa; [3]International Institute of Tropical Agriculture (IITA), Oyo Road, PMB 5320, Ibadan, Nigeria; [4]Southern Africa Root Crops Research Network (SARRNET), PO Box 30258, Lilongwe 3, Malawi

Genotype by environment study on interaction for native cassava was also initiated. Cassava starch is used directly in different ways or as a raw material for further processing like food, textile, paper, adhesives, chemicals, glucose, soap, detergent, laundry, ethanol, cosmetic powders, sausage making, pharmaceuticals, and insecticides. Dry matter content is closely related to starch content in cassava. This makes dry matter an important trait to cassava producers since it is a crop grown largely for its carbohydrate content. Dry matter varies very widely in cassava over years and environments.

This study therefore was initiated to look into native cassava starch qualities from different Malawi cassava genotypes, determine the appropriate stability parameter to deal with G × E for starch quality traits, and also find out the possibility of use of cassava starch by the main industries in Malawi. Apart from starch quality parameters, root dry mater and starch extraction evaluation were also included. Various stability measures were used to deal with the problem of genotype by environment interaction. The results show that all the cassava genotypes produced starch with no protein just like the one used in the pharmaceutical industry. The moisture and ash content were much lower than the recommended allowable maximum (Table 10).

Table 10. Whiteness, pH, moisture content and ash content for starch evaluated in 2000/2001 season.

Genotype	Whiteness of starch (L) Chitedze	Makoka	Mean	pH of starch Chit-edze	Makoka	Mean	Starch moisture content (%) Chit-edze	Makoka	Mean	Starch ash content (%) Chit-edze	Makoka	Mean
Silira	94.75	94.75	94.75	5.5	5.5	5.5	13.10	14.20	13.65	0.13	0.11	0.12
Sauti	96.02	96.02	96.02	5.2	5.1	5.2	12.60	13.70	13.15	0.09	0.11	0.10
CH92/082	94.94	94.94	94.94	5.4	5.5	5.5	12.20	14.30	13.25	0.09	0.15	0.12
TMS4(2)1425	95.36	95.36	95.36	5.0	5.3	5.2	11.20	14.20	12.70	0.22	0.13	0.17
CH92/112	93.49	93.49	93.49	5.1	5.5	5.3	10.30	13.70	12.00	0.15	0.13	0.14
CH92/105	94.56	94.56	94.56	4.8	5.5	5.2	11.40	12.30	11.85	0.13	0.13	0.13
LCN8010	94.63	94.63	94.63	5.1	5.7	5.4	11.80	13.40	12.60	0.20	0.14	0.15
30786	94.94	94.94	94.94	5.2	5.6	5.4	11.80	13.50	12.45	0.10	0.16	0.13
83350	96.11	96.11	96.11	5.2	5.1	5.2	12.50	12.90	12.70	0.25	0.15	0.20
TME1	94.51	94.51	94.51	5.3	5.3	5.3	11.60	13.70	12.65	0.20	0.11	0.15
81/00015	94.84	94.84	94.84	5.1	5.6	5.4	11.80	14.00	12.90	0.13	0.11	0.12
CH92/108	95.42	95.42	95.42	5.5	6.2	5.9	12.20	14.00	13.10	0.22	0.13	0.17
MK95/054	93.77	93.77	93.77	5.0	6.0	5.5	12.70	12.90	12.80	0.11	0.16	0.13
Mbundumali	96.28	96.28	96.28	4.8	5.7	5.3	12.60	13.10	12.85	0.12	0.19	0.15
Gomani	96.33	96.33	96.33	5.1	5.9	5.5	12.80	12.60	12.70	0.09	0.19	0.14
Mkondezi	94.81	94.81	94.81	4.9	5.7	5.3	12.60	13.20	12.90	0.12	0.09	0.11
TMS60121	95.38	95.38	95.38	5.0	5.8	5.4	12.00	13.70	12.85	0.18	0.09	0.13
TMS84563	95.22	95.22	95.22	4.7	5.8	5.3	12.10	12.00	12.05	0.12	0.13	0.12
Maunjili	95.48	95.48	95.48	4.9	5.1	5.0	12.80	13.90	13.35	0.13	0.10	0.11
TMS60142A	95.64	95.64	95.64	4.9	5.7	5.3	14.00	12.70	13.35	0.14	0.09	0.11
Nzeru corn starch	95.20	95.20	95.20	4.7	4.7	4.7	11.20	11.20	11.20	0.15	0.14	0.14
PIM corn starch	96.46	96.46	96.46	5.1	5.0	5.0	11.80	11.80	11.80	0.18	0.13	0.15
MPL corn starch	97.28	97.28	97.28	4.1	4.1	4.1	9.90	9.90	9.90	0.11	0.14	0.12
Corn flour	94.20	94.20	94.20	3.4	3.4	3.4	10.60	10.60	10.60	0.86	0.70	0.78
Mean	95.33	95.33	95.33	5.0	5.4	5.2	11.97	12.98	12.47	0.17	0.15	0.16
CV (%)	0.83	0.83	0.83	0.19	0.15	0.17	5.96	4.54	5.25	11.40	9.36	12.04
LSD for G	1.97	1.97	1.97	0.02	0.02	0.02	1.78	1.47	1.12	0.05	0.04	0.03
LSD for L	-	-	-	-	-	0.01	-	-	0.32	-	-	0.01

G = genotype; L = location; MPL = Malawi Pharmacies Limited; PIM = Packaging Industries Malawi Limited; Nzeru = Nzeru Radio Comp

The pH for cassava starch was within the recommended range. Additive main effects and multiplicative interaction (AMMI) was strongly correlated with other stability parameters like Wi-ecovalence and stability variance–no covariate. AMMI is therefore recommended for use in the stability analysis of starch quality parameters since it provides additional information on appropriate environments for unstable genotypes. This study suggests that genotype has a greater influence on root dry matter (hence on the starch) than the environment.

3.18 CSA Rural livelihoods project, biotechnology module

by M. Ferguson

A project entitled "Improving rural livelihoods in Southern Africa" was funded by USAID-Regional Center for Southern Africa (RCSA), with a biotechnology component. Implementation of the biotechnology component began in October 2003 with the recruitment of a biotechnology coordinator, based at the NEPAD Biosciences Center in Nairobi, located at ILRI. The overall goal of the project is to improve the livelihoods of the rural poor in Southern Africa through an integrated approach to marketing and competitive production that links farmers and processors to growth, value-added markets. Countries participating within the project are Angola, Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe. With the lack of a strong regional biotechnology forum in southern Africa the biotechnology component proposes to build a regional platform, as part of a longer term strategy, for priority setting and technical capacity development in Southern Africa. This will evolve in close association with activities coordinated by the Program for Biosafety Systems Consortium (PBS) aimed at strengthening biosafety policies and decision-making processes in the region. A stakeholders meeting was held in Malawi from 5–7 November 2003, to develop a workplan. Key elements of the strategy that evolved, that form the basis of this plan of work are (1) collating and disseminating baseline information for use as decision-making tools, (2) establishing a regional working group to initially define agricultural priorities and within these, biotechnology priorities (3) identify and facilitate opportunities for strategic private sector/public sector research partnerships with advanced (international) research institutions to transfer skills and develop policy and regulations to facilitate technology access, and (4) enhancing adaptation, application, and dissemination of biotechnology tools and products that address food and income needs.

In this first year of the project, these key elements will be addressed in the following way:

- Compile an inventory of ongoing and planned plant breeding and biotechnology activities in the region, with an indication of capacities.
- Compile an inventory of biotechnology applications appropriate to Southern Africa.
- Coordinate a regional biotechnology introductory and planning workshop to share baseline information and define the way forward; followed by a regional priority setting workshop. The above two documents will provide valuable baseline information and facilitate the building of strategic partnerships.
- Address constraints to cassava: a regionally important commodity particularly for agriculturally vulnerable households:
  - Establish a tissue culture facility in Maputo, Mozambique to produce disease-free cassava planting material of disease resistant varieties.
  - Support ARI-Tanzania at Mikocheni to assess the regional diversity of cassava brown streak resistant germplasm.

- Facilitate a strategic partnership between national institutes in Malawi and the Danforth Center, St. Louis, USA, where a transgenic cassava mosaic disease (CMD) resistant cassava has been developed.

3.19 CSA Rural livelihoods project, legumes module

by John Wendt, in collaboration with H. Soko (Malawi Agricultural Research), K. Kanenga (Zambia Agricultural Research), M. Amane, INEA-Mozambique, B. Mtonga and J. Hoopper (World Vision Zambia), D. Kanyerere (World Vision Malawi)

Following a stakeholders meeting in Malawi in November 2003, the above stakeholders agreed to implement a program of soybean and cowpea selection. Best soybean and cowpea varieties were selected regionally from Malawi, Zambia, and Mozambique and were tested on-farm against two IITA soybean and one IITA cowpea variety. This activity was implemented by World Vision at over 70 farmer sites in Malawi and Zambia, and five in Mozambique. IITA soybean and cowpea germplasm sets were planted in Malawi, Zambia, and Mozambique through their respective national programs in December 2003 through March 2004. Best varieties from these germplasm sets will be multiplied if found superior to already certified varieties for further testing.

3.20 CSA Rural livelihoods project, banana module

by M. Pillay and C. Nankinga, in collaboration with B. Mwenebanda, J. Hoopper (World Vision), J. Heermans (CLUSA), and M. Mataa (University of Zambia)

Stakeholders meetings were held in Malawi and project partners were identified for Malawi and Zambia.

Weaning and hardening sheds were constructed in Malawi. The first phase of planting material was delivered to Malawi for weaning and hardening. A rapid appraisal of tissue culture facilities in Malawi was completed.

3.21 Marker-assisted breeding in cassava

by M. Ferguson

Total funding of US$518 000 was received from The Rockefeller Foundation for a collaborative project between CIAT, IITA, and The Agricultural Research Institute, Mikocheni, Tanzania entitled "Molecular marker-assisted and farmer participatory improvement of cassava germplasm for farmer/market preferred traits in Tanzania". The project will cross farmer-preferred germplasm by agroecology to improved introductions that have resistance to cassava mosaic disease (CMD), cassava green mite (CGM), and cassava bacterial blight (CBB). Molecular markers associated with pest and disease resistance will be employed to reduce, in a logical manner, the number of progeny to a manageable number. The progeny selected by MAS will be evaluated in a single season in the corresponding agroecology and then evaluated over two cycles in collaboration with end-users (rural communities and other cassava producers). The project will be carried out in a total of six years divided into two three-year phases. A principal objective of the project is also the development of capacity for participatory plant breeding and marker-assisted breeding. This would be achieved by training two national program breeders at the MSc and PhD levels, and through two training workshops on participatory plant breeding and marker-assisted breeding. Activities, including molecular marker analysis, would be conducted at national program facilities, while CIAT and IITA that work on cassava will provide backstopping in conventional and modern methods of cassava breeding. A first work planning meeting was held in October 2003.

4 Environmentally safe integrated plant protection technologies that reduce pre- and postharvest losses due to pests and diseases developed and applied

4.1 Monitoring the CMD pandemic

by J. Legg, in collaboration with S. Bigirimana, A. Jorge, G. Okao-Okuja, R. Obonyo, F. Ndjelassili, P. Ntawuruhunga, H. Obiero, S. Ajanga, I. Ndyetabula, S. Jeremiah, L. Traoure, T. Hangy, J. Mabanza, and M. Toko

In partnership with national research teams, an extensive monitoring and diagnostics program was implemented, covering more than 500 sites across East and Central Africa including Kenya, Tanzania, the Democratic Republic of Congo (DRC), the Republic of Congo (ROC), Gabon, Cameroon, and Burundi. CMD surveys were also conducted in Senegal and Guinea-Conakry. These wide ranging surveys demonstrated the expansion of the pandemic into three new districts of Tanzania (Mwanza, Kahama, and Kasulu), the occurrence of severe CMD throughout ROC, and new pandemic spread into eastern Gabon, northeastern Burundi, and North Kivu Province in eastern DRC. CMD in both Senegal and Guinea was relatively mild and there was no evidence of the rapid spread characterizing the pandemic in East/Central Africa. Similarly, there was no evidence for the occurrence of EACMV-UG and severe CMD in southern or southeastern Cameroon. This suggests that the western limit of the pandemic lies in eastern Gabon and has yet to reach Cameroon. GIS techniques were used to analyze epidemiological factors contributing to CMD epidemics and the region currently most threatened by continued epidemic expansion is the eastern part of the Great Lakes region encompassing Rwanda, Burundi, northwestern Tanzania, and eastern DRC.

A follow-up countrywide survey of cassava pests and diseases was completed in the Republic of Congo (ROC) and virus and virus-disease assessments were also made within a comprehensive pest and disease survey implemented in Mozambique. In ROC, CMD incidence was greater than 85%, an increase on the value of the previous year, and CMD continued to represent the most important biotic constraint to cassava in that country. In Mozambique, CBSD was confirmed as being the main constraint, although it was largely restricted to the northern provinces of Cabo del Gado, Nampula, and Zambezia.

4.2 Characterization of cassava mosaic geminiviruses

by J. Legg, in collaboration with G. Okao-Okuja, R. Obonyo, B. Owor, P. Sseruwagi, J. Ndunguru, P. Ntawuruhunga, H. Obiero, S. Ajanga, I. Ndyetabula, S. Jeremiah, T. Hangy, and J. Mabanza

More than 2000 CMG diagnoses were completed during the year in the IITA-ESARC laboratory with the primary aim of mapping the spread of the pandemic associated EACMV-UG (the Uganda variant).

A survey of more than 100 sites in Uganda revealed the occurrence of EACMV-UG in 73% of severely and 54% of mildly diseased plants. ACMV was less frequent and occurred primarily in mildly diseased plants. Three RFLP variants of EACMV-UG and two of ACMV were identified and their distributions mapped. An important finding from this study was that mixed EACMV-UG + ACMV infections occurred in both plants with mild and severe symptoms. During the epidemic period in Uganda, mixed infections had been uniquely associated with very severe symptoms arising from a synergistic interaction between the two viruses. The incongruence of these results suggests that different variants of the same virus may interact in different ways. Further investigation will be required to characterize these interactions and identify what triggers synergism.

A survey in Tanzania which provided more than 500 virus-infected samples from all cassava growing regions of the country revealed a unique level of cassava mosaic geminivirus diversity. In addition to the previously characterized EACMV- [Tanzania] (EACMV- [TZ]), eleven EACMV-like virus types, designated as EACMV- [TZ1] to- [TZ11] were identified following restriction analysis of PCR products using EcoRV and MluI endonucleases. The Uganda variant was recorded from throughout the Lake Zone, in addition to the northern coastal zone in the Tanga area. ACMV was not detected in the coast region. Important differences in symtomatology were associated with the different virus types, highlighting the importance of further characterization studies. Fifteen virus isolates were cloned to produce partial and full length sequences of DNA A and B. Significantly, East African cassava mosaic Cameroon virus was shown to occur in parts of Tanzania. This is a recombinant EACMV which has now been shown to occur throughout West Africa and now for the first time in a part of East Africa.

4.3 Identification of novel satellite molecules associated with CMD in East Africa

by J. Legg, in collaboration with J. Ndunguru and C. Fauquet

Two previously undescribed single-stranded DNA satellite molecules have been found in association with CMD in both Tanzania and Kenya. This represents the first record of such components in association with a bipartite begomovirus infection and may have significant implications for the epidemiology of CMD. The first satellite, SatDNA II (approx. 1030 bp in length), when co-inoculated with EACMV-UG in the CMD resistant variety TME3 seems to break the resistance, and SatDNA III (approx. 1209 bp long) enhances symptoms of EACMCV in the test plant, *Nicotiana benthamiana*. The satellites also appear to be associated with unusual CMD symptoms in the field, including a strap-like symptom in which cassava leaflets are sharply narrowed. The molecules occur widely in the pandemic affected areas of western Kenya and northwestern Tanzania, but also occur, albeit less frequently, in coastal Tanzania. Tests have yet to be carried out on CMD-diseased material from other geographical locations in the cassava belt of sub-Saharan Africa to verify whether or not the occurrence of satellites is a more general phenomenon or particularly associated with the pandemic affected zone. The ultimate, but as yet unachieved goal of this research is to develop a molecular marker that will facilitate the monitoring and tracking of the putative epidemic-associated genotype.

4.4 Molecular markers to track CMD epidemic associated *Bemisia tabaci* biotypes in East and Central Africa

by J. Legg, in collaboration with P. Sseruwagi and J. Brown

Bemisia tabaci whiteflies collected in Uganda were characterized through sequencing a c. 850 bp portion of the mitochondrial cytochrome oxidase gene, in collaboration with the University of Arizona. Previous studies of whitefly populations collected at the time of the passage through Uganda of the CMD epidemic had shown the occurrence of two *B. tabaci* genotype clusters: one, designated the "invader", had been shown to occur at and behind the epidemic "front", whilst the other, the "local", occurred almost entirely ahead of the epidemic front. The 2003 analysis of whiteflies collected more widely through Uganda revealed the co-occurrence of the two genotypes in all regions surveyed, although the "local" was more frequent (83%) and widely distributed than the "invader" (17%). This apparently anomalous result could be explained by the fact that the two populations freely interbreed, and either the local haplotype confers a selective advantage on progeny or cytoplasmic incompatibility resulting from activity of endosymbiotic enterobacteria means that mating is unidirectional. Additional molecular characterization using sequences of the "kdr" gene is currently underway to test the hypothesis that "ocal" by "invader" hybrids occur. In addition to whitefly material from Uganda, samples are also being examined from other CMD pandemic affected countries, including Kenya, Tanzania, Rwanda, Burundi, DRC, and ROC.

4.5 Interactions between cassava mosaic geminiviruses, effects on yield and putative cross protection

by J. Legg, in collaboration with B. Owor, M. Latigo, S. Kyamanywa, and D. Osiru

Previous studies have shown that cassava plants of CMD-susceptible varieties infected with mild strains of EACMV-UG have some protection against superinfection by severe strains of the same virus, and in the field situation perform better than initially CMD-free plants. Studies conducted to assess the sustainability of the benefit of this protection revealed that replanted cuttings from the initially mildly diseased treatment yielded almost 50% more than those from the initially CMD-free treatment. Similarly, mean severity of plants in the initially mildly affected treatment remained significantly lower than that of the initially CMD-free treatment. These results suggest that there are sustainable benefits accruing from the selection of plants with mild CMD symptoms under high inoculum conditions in Uganda. A proposal was developed for a PhD study which will examine the molecular mechanisms underlying these phenotypic effects.

Molecular approaches have been used to examine the interactions between cassava mosaic geminiviruses occurring in Tanzania. A truncated DNA A component of EACMV has been identified from some CMD-affected plants in the Lake Victoria zone of northwest Tanzania. This appears to have a beneficial effect through modulating symptoms. The component is cotransmitted with the intact helper EACMV DNA A. Subgenomic satellites have been shown to have the converse effect, through enhancing symptoms of EACMCV in *Nicotiana benthamiana* and appearing to break resistance to EACMV-UG in the normally CMD-resistant cassava variety, TME 3. Further interactions between Tanzania virus isolates are being studied following the production of infectious clones. These studies are of vital importance given both the complexity of the existing virus fauna in Tanzania and the epidemic-associated gross geographical displacements of some species, such as the Uganda variant, EACMV-UG.

4.6 Evaluating the efficiency of aphelinid parasitoids as biocontrol agents of whitefly vectors of cassava mosaic geminiviruses

by J. Legg, in collaboration with M. Otim, P. Asiimwe, S. Kyamanywa, and D. Osiru

Surveys of parasitoids of *B. tabaci* on sweetpotato in Uganda have been initiated and revealed the occurrence of two principal species, *Eretmocerus mundus* and *Encarsia sophia. E. mundus* was the more abundant of the two species. The level of parasitism was greatest at the site at which whitefly populations were least. This mirrors the pattern recorded for parasitoids (the same two principal species) of *B. tabaci* on cassava and suggests that a negative density dependent relationship exists between the parasitoids and their host. Detailed assessments of the stratification of whitefly and whitefly parasitoid populations on sweetpotato were conducted to determine the optimal approach for sampling parasitoids on this crop. Fourth instar nymphs were most abundant on leaves 9–16 (counting from the growing tip) and parasitoid mummies on more mature leaves. Intercropping sweetpotato with cassava was shown to reduce the abundance of whitefly populations on cassava, and there was a concomitant reduction in CMD spread in the intercropped treatment. However, parasitism levels did not differ between the intercropped and sole crop treatments, and it is speculated that an augmentation of predator activity may have been responsible for the reduced whitefly populations on the intercropped cassava.

4.7 Baseline survey of pests and diseases associated with cassava in the DRC

by J. Legg, R. Hanna, M. Toko, D. Coyne, and A. Dixon in collaboration with SECID

Further assessment of the Eastern region of the country has shown higher levels of root galling damage by *Meloidogyne* spp. are being observed than in most other parts of the country. Samples taken during the survey are currently being used for identification of species associated with cassava.

4.8 Baseline survey of pests and diseases associated with cassava and sweetpotato in Mozambique

by J. Legg, R. Hanna, M. Toko, D. Coyne, and A. Dixon collaboration with INERA

Root-knot nematodes (*Meloidogyne* spp.) were present throughout the cassava belt of Mozambique. The severity of galling damage based on a 1 to 5 scale was slight, however, throughout most areas within about 90% of fields and moderate in about 10% of the fields sampled. Although the mean number of galls per 50 cm of feeder roots was low in most sampled fields, the results indicate a consistent presence of root-knot nematodes throughout the cassava production areas. Results, however, from the soil and root samples collected during the survey, suggest that while *Meloidogyne* spp. consistently occur, *Pratylenchus* spp. (most likely *P. brachyurus*) are more prevalent and occur in greater abundance than *Meloidogyne* spp. Identification of samples are continuing. Few other nematode species have so far been observed. Details from the sweetpotato have yet to be assessed. However, observations of roots in the field suggest widespread damage to roots by nematodes.

4.9 Importance of root-knot nematodes on cassava in yield loss assessed

by D. Coyne, in collaboration with J. Whyte, A. Dixon, T. Munga, KARI, Kenya; and M. Ogunlolu, University of Ibadan, Nigeria

Trials established in both West and East Africa to assess the yield difference of cassava between nematicide treated or not treated in *Meloidogyne* spp. infested soils continue to provide limited insight into the relationship between the nematodes and crop production. A major factor appears to be the high levels of variability in crop growth within treatments, but also the erratic occurrence of nematodes and lack of differences in nematode densities between treatments as the cropping season progresses. Regression of root galling damage against yield parameters shows negative relationships however. In more controlled inoculation studies conducted in the field at ESARC-Uganda, cassava production yield was on average, 30% lower ($P \leq 0.05$) in all inoculated treatments (100, 1000, and 10000 nematodes per plant) than uninoculated for cv. Migyera (TMS30572) and 25% fewer small (unmarketable) tubers. There were no differences observed between inoculated treatments. Yield was 20% less for inoculated treatments compared with uninoculated for cv. SS4, but not significant ($P \leq 0.05$).

4.10 Maintain and further develop plant parasitic nematode cultures and collections

by D. Coyne, C. Dochez, and G. Georgen

Plant parasitic nematode cultures are continuously being cultured and maintained in vitro and in vivo for use in nematode pathogenicity and biology studies at IITA and also for access by national programms. A reference collection of plant parasitic nematode microscope slides continues to be gathered and stored for training purposes from samples from diagnostic surveys. Photographic images of nematodes on microscope slides are being additionally taken for storage electronically at the Biodiversity Museum in Cotonou, and elsewhere.

4.11 Country-wide survey of cassava pests and diseases in Mozambique

by M. Toko[1], R. Hanna[1], M. Andrade[1], J. Legg[1], and D. Coyne[1], in collaboration with M. Otema[1], B. Agbonton[1], G. Okao-Okuja, R. Obonyo, A. Jone [2], E/Mambo[2], and A. Sitole[2] [1] IITA; [2] Department of Sanidade Vegetal, Mozambique

Upon request by IITA-PROAGRI (The National Programme for Agricultural Development) Project in Mozambique and with financial support by PROAGRI and the IITA Africa-wide Cassava Green Mite (CGM) Project, a comprehensive survey was conducted in two stages in April–May 2003 to assess the importance of cassava pests and diseases throughout the cassava belt of Mozambique and in September–October 2003 to determine the impact of the most important pests and diseases on cassava production. Earlier surveys conducted in Mozambique were scanty and hence did not give an overall picture of the status of pests and diseases of cassava in the country. This activity reports on the survey done in April–May 2003.

Through discussions with The National Institute for Agronomic Research INIA and SARRNET-Mozambique and CGM Project, the itineraries of the survey were decided based on previous surveys conducted on cassava green mite in Mozambique. Eight provinces—Maputo, Gaza, Inhambane, Sofala, Manica, Zambezia, Nampula, and Cabo Delgado—were retained for the survey.

Frequency. The frequency was recorded to determine the importance of cassava in each of the provinces. It was determined by recording the presence/absence of cassava fields on the right and left side of the roads while driving. The distance covered per day was determined from the difference between the mileage recorded at the beginning of the day and the mileage at the stopping point of the day. The frequency per km was equal to the total number of cassava fields recorded on the left and right sides of the road, divided by the total mileage covered for the day. With this formula, one can calculate the frequency per district and per province as needed.

Field sampling. Young cassava fields (> 3 months and <10–12-months-old) were sampled at every 15–20 km interval along the itinerary of the day. Although most fields were selected along the main roads, others were selected from secondary roads when there were not enough fields along the main roads. Fields with less than 50 plants were not sampled as 30 plants were the minimum for sampling. In addition, only fields near homes were sampled to obtain authorization from the owner of the field/farmer. When a field was identified at a given interval and the farmer was present, the provincial technician who accompanied the team explained to the farmer the purpose of the survey and asked him further questions such as the names of the location, district, varieties cultivated, age of the field etc. This information was recorded on a datasheet agreed upon by all scientists involved in the survey. Other relevant information recorded on the datasheet included the geographic position of the location (GPS), the cropping systems (monocrop vs intercrop), weed coverage (based on 1–5 scale where 1 = no weeds, 2 = < 25% of the field is weedy, 3 = 50% of the field weedy, 4 = 75% of the field is weedy, and 5 = 100% of the field is weedy), the soil type (classified as sandy, loamy, or clay), and the vegetation (classified as savanna, secondary forest, and primary forest). Thirty plants were then randomly selected in each field and were used to assess the abundance and damage severity of the pests and diseases. The most common pests evaluated included the cassava green mite (CGM), red mites (RM), cassava mealybug (CM), whiteflies (WF), and nematodes while the main diseases were the cassava mosaic disease (CMD), cassava brown streak disease (CBSD), cassava bacterial blight (CBB), and cassava anthracnose disease (CAD).

Pests. The damage severity of CGM, CM, and RM was evaluated using a rating scale from 1 to 5, where 1 represented plants with no visible damage symptoms and 5 represented plants with very severe symptoms or death of the plant. The abundance of CGM was determined by directly counting the number of actives encountered on the first fully developed leaf while the abundance of CM was estimated by counting the number of actives in the shoot tips. The number of whiteflies was counted on the 5th leaf from the top of the plant. The presence/absence of the predatory mite, *Typhlodromalus aripo* was determined by examining the shoot tip of each sample plant. Nematodes were sampled on 10 of the 30 plants randomly selected above, i.e., every other 3rd plant. A trowel and a knife were used to dig and loosen the soil around the selected plant to get access to the feeder roots without uprooting the plant. A 50-cm length of feeder roots was collected to count the number of galls to determine galling intensity. When less than 50 cm of feeder roots, the number of galls was counted on whatever length obtained. The root system was also scored for galling damage on a scale of 1–5 (where 1 + no galling, 5 = severe galling damage). All feeder roots collected from the plant with approximately 100 ml of soil dug around each sample plant were placed in a plastic bag and bulked for each field. These samples were stored in a cooler to prevent adverse heating and were later processed in the laboratory/hotel room. Nematodes were extracted within 24–48 hours from 100 ml soil and 5 g root fresh weight subsamples from each field, using a modified sieve system with plastic sieves and plates. Nematode suspensions were then reduced with a 38 micron sieve, killed with hot water, and fixed with formalin for later nematode identification and counting.

Diseases. The severity of cassava mosaic disease (CMD), cassava brown streak disease (CBSD), cassava bacterial blight (CBB), and cassava anthracnose (CA) was evaluated using a similar rating scale from 1 to 5 as for the pests. Leaf samples from severely CMD infested plants were harvested and placed in vials with alcohol for DNA determination later in the hotel room.

Frequency results. The highest frequency of cassava was found in Zambezia (8.1 fields/km), followed by Gaza and Inhambane with, respectively, 5.95 and 5.65 fields/km. Nampula occupied the fourth place with 4.24 fields/km and Cabo Delgado occupied the fifth place with 2.45 fields/km, or about half of the frequency of Nampula. The lowest cassava frequencies were recorded in Sofala (0.56 field/km), Manica (0.52 field/km), and Maputo (0.49 field/km).

Pest results. Five pests were encountered during the survey. These were the cassava green mite (CGM), red mites (RM), cassava mealybug (CM), whiteflies (WF), and nematodes. However, only CGM infestations were severe in much of the fields sampled across the country (Figs 2a and b). The distribution and incidence of the predatory mite *T. aripo* coincided with that of CGM (Fig. 2c). Whitefly population densities were abundant particularly in Zambezia where surprisingly CMD severity was rather low, suggesting that WF may not only be vector of CMD virus but can also be an independent pest. Indeed, the leaves of the plants with high WF populations were black sooty which could seriously affect photosynthesis. Others pests such as CM and RM were considered minor pests. Nematodes were present throughout the country. The most commonly observed plant parasitic nematodes associated with surveyed fields are root-knot nematodes (*Meloidogyne* spp.), population densities recovered have largely been low however. Other relatively common species include *Pratylenchus* spp. (lesion nematodes) and *Helicotylenchus* spp. (spiral nematodes), but also in low densities. Results suggest root-knot nematodes are widespread on cassava.

Diseases results. Three of the traditional common diseases known to affect cassava production throughout tropical Africa were present in Mozambique. These were the cassava mosaic disease (CMD). However, based on the distribution and severity, only CMD was found as a threat to cassava production. CBB and CAD were found in very few locations and their severity was low. In addition to CMD, the cassava brown streak disease (CBSD), recently reported as devastating cassava in many countries in Eastern Africa (Tanzania, Kenya), was also found in the three northern provinces of Mozambique—Cabo Delgado, Nampula, and Zambezia. Zambezia appeared as the most affected province. The incidence and damage severity for both CMD and CBSD are shown in Figures 3a and b and 4a and b.

CMD virus identification. The results of the identification are reported in Table 11. The African cassava mosaic virus (ACMV) was the most commonly found in the samples collected. About 50% of the total fields with positive identification were infested with this type of virus. The virus was found particularly in Inhambane, Zambezia, and Nampula and was absent in Cabo Delgado and Gaza. The second most common virus was the mixed African cassava mosaic virus (ACMV) and Eastern cassava mosaic virus (EACMV). About 34% of the total fields were infected. The least common virus identified was the East African cassava mosaic virus (EACMV) with only 17% of the fields infected. The devastating Eastern Africa cassava mosaic virus –Ugandan variant (EACMV-UG2) was not found in any of the fields during the April–May survey.

Conclusions and recommendations. Based on the frequency results, Zambezia, Gaza, Inhambane, and Nampula are in that order the greatest cassava producing provinces of Mozambique. However, this may change if more districts and more feeder roads were included during the survey.

CMD and CBSD are the most threatening diseases of cassava in Mozambique. CBSD is still located in the Northern provinces (C/Delgado, Nampula, and Zambezia); however, urgent measures need to be taken now to prevent its spread southward. Although the Eastern African cassava mosaic-Ugandan variant was not found in the samples analyzed during this survey, all ingredients are present for the development of the disease. Preventive measures should be taken now.

CGM remains a problem in areas where the crop is planted on poorly managed soils and where *T. aripo* has not established or spreads slowly as a result of cultivation of unfavorable varieties. Therefore, further redistribution/release of *T. aripo* should be made along with the introduction of varieties with favorable shoot characteristics. An integrated approach including soil management should be encouraged. In addition as vectors of CMD virus, whiteflies can be independent pests of cassava. There is need to determine whether the whiteflies on cassava are the same species.

Table 11. Virus identification of samples collected from individual fields in different provinces in April–May 2003.

Province	Number of fields and types of virus identified				
	ACMV	EACMV-UG2	EACMV	ACMV+EACMV	Total/ province
Cabo Delgado	0	0	2	0	02
Nampula	9	0	2	0	11
Zambezia	12	0	2	7	21
Sofala	7	0	0	15	22
Manica	2	0	1	1	04
Inhambane	15	0	4	6	25
Gaza	0	0	5	2	07
Total/virus	45	0	16	31	92

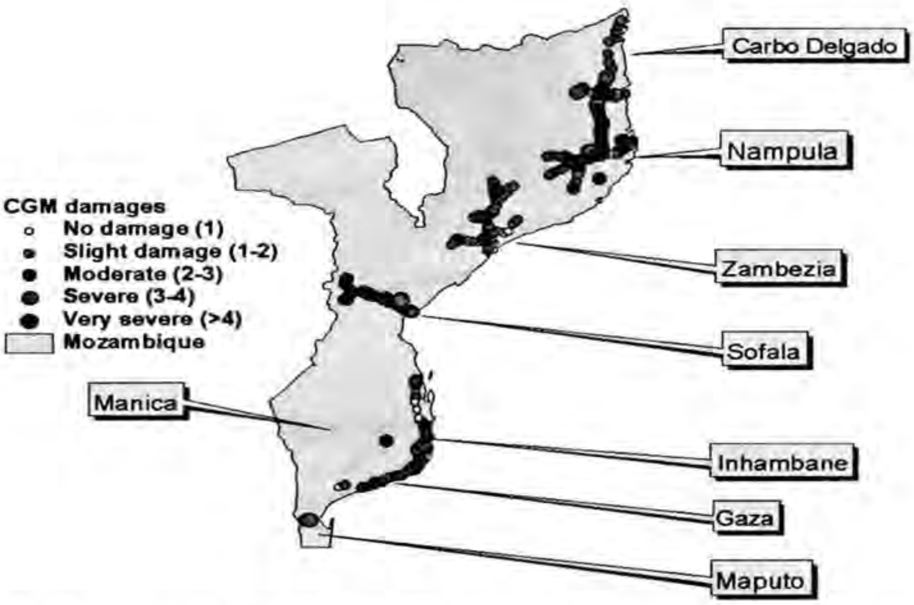

Figure 2a. Damage severity of CGM in different cassava growing provinces in Mozambique.

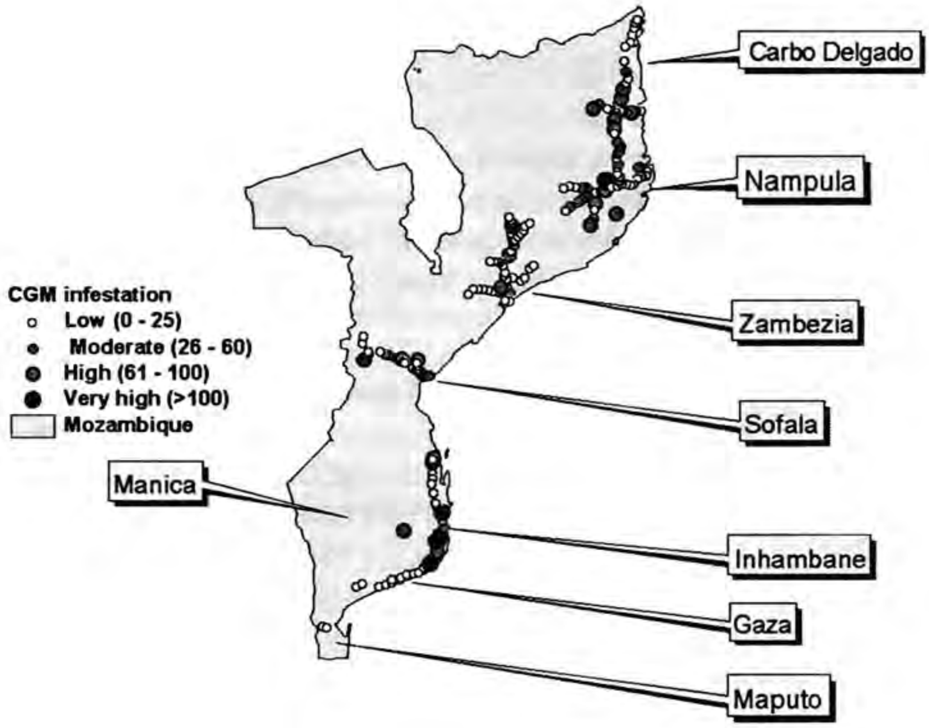

Figure 2b. CGM population densities in different cassava growing provinces in Mozambique.

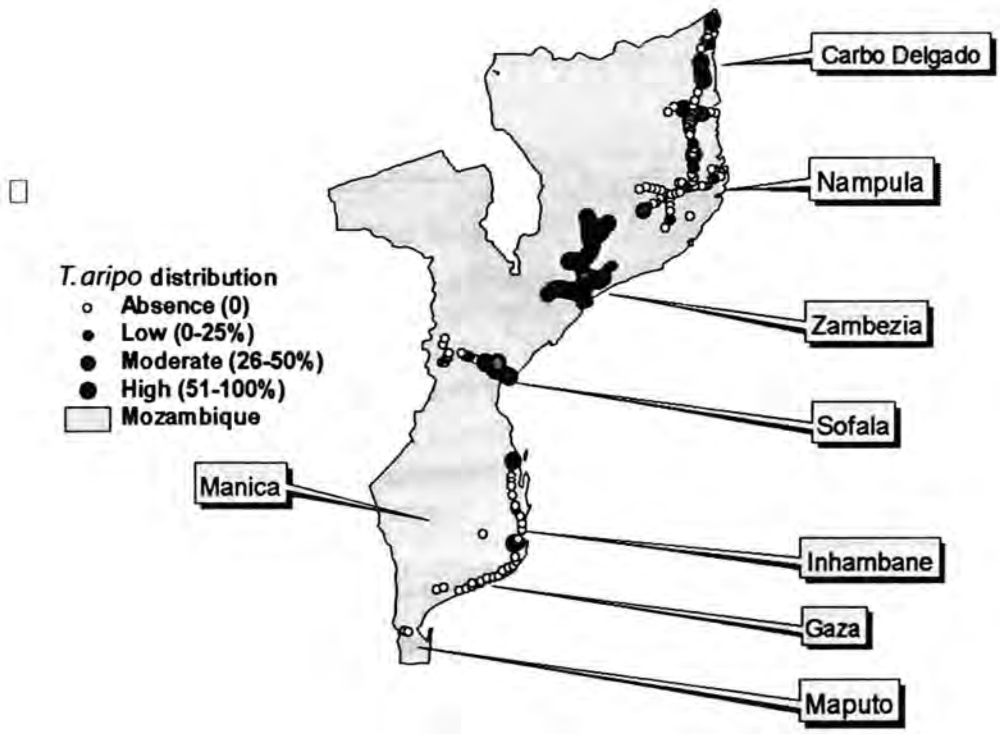

Figure 2c. Percentage infestation of *T. aripo* in different cassava growing provinces in Mozambique.

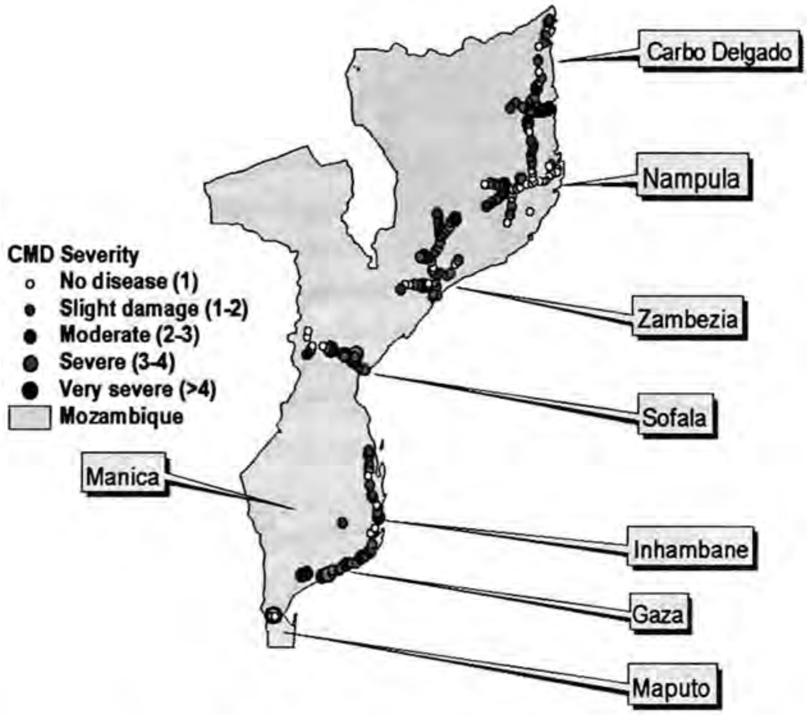

Figure 3a. Damage severity of CMD in different cassava growing provinces in Mozambique.

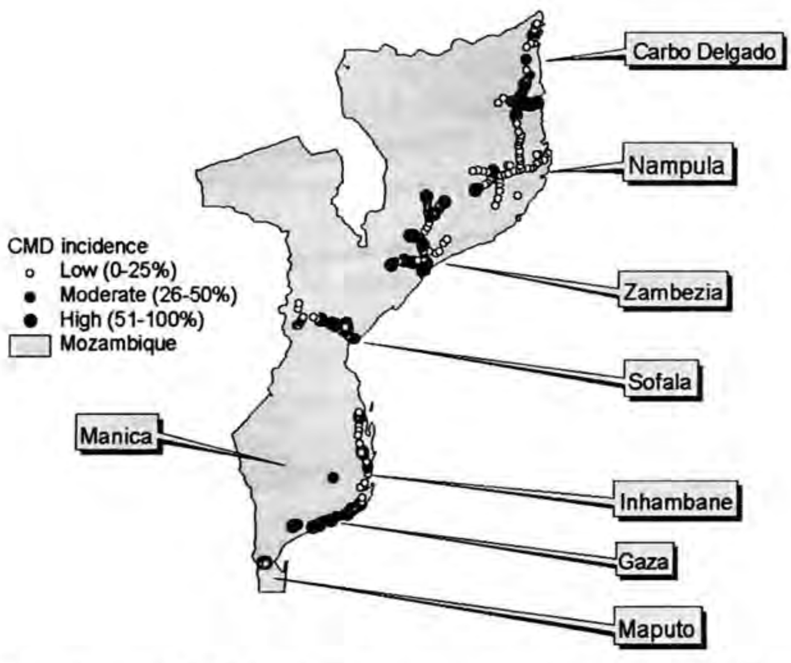

Figure 3b. Incidence of CMD in different cassava growing provinces in Mozambique.

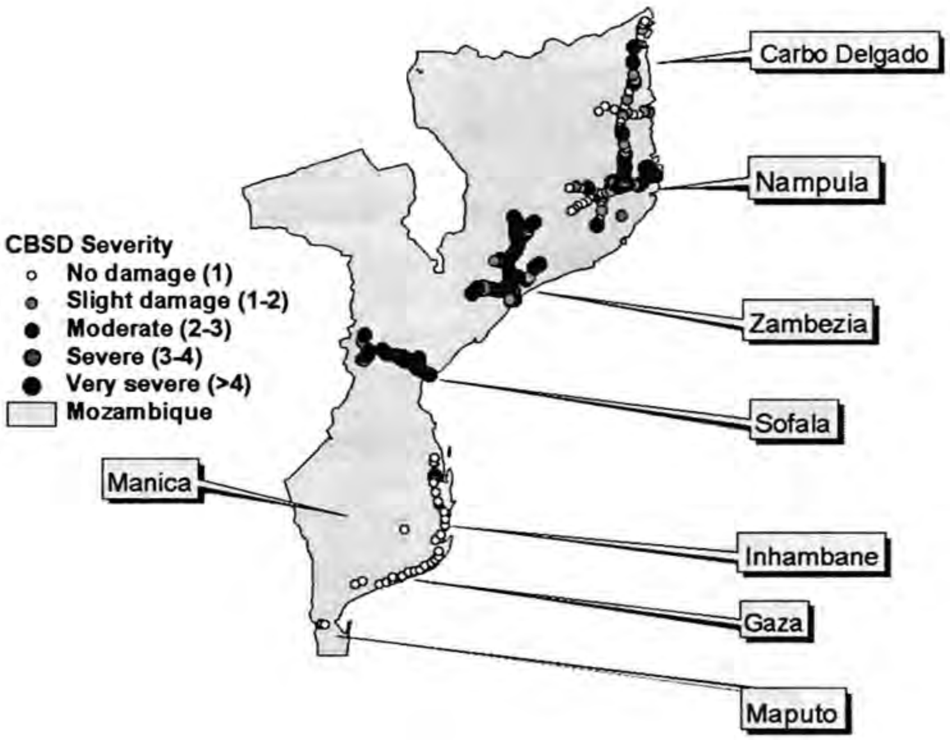

Figure 4a. Damage severity of cassava brown streak disease in different cassava growing provinces in Mozambique.

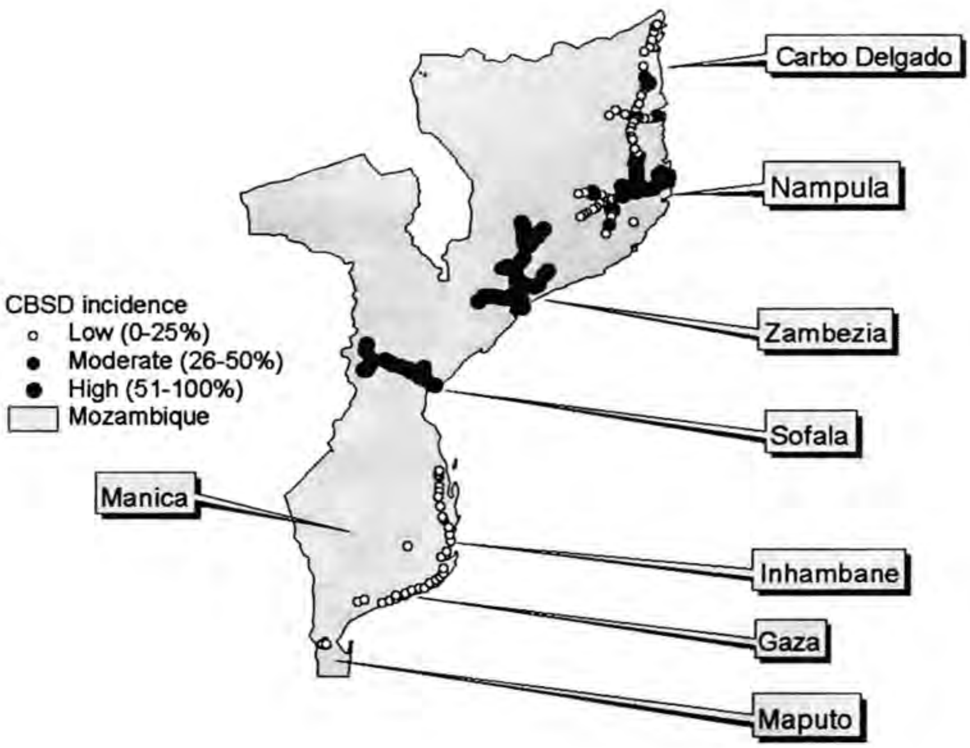

Figure 4b. Incidence of cassava brown streak disease in different cassava growing provinces in Mozambique.

4.12 Country-wide survey on the impact of cassava pests and diseases on cassava production in Mozambique

by M. Toko[1], R. Hanna[1], M. Andrade[1], J. Legg[1], and D. Coyne[1], in collaboration with M. Otema[1], R. Obonyo, A. Jone[2], and A. Sitole[2]. [1]International Institute of Tropical Agriculture (IITA) [2]Department of Sanidade Vegetal, Mozambique

The survey in September–October 2003 was a follow-up of the survey carried out in April–May 20 03. This survey was mainly conducted to determine the impact of the most severe pests and diseases that were evaluated in April–May when cassava fields were still young (> 3 months and < 8 months) on cassava production when the fields had matured in September–October 2003. The same itinerary followed in April–May 2003 was also followed in September–October 2003, except that in the September, the survey started from the Northern region (Cabo Delgado) moving down to Maputo.

Field preselection was done from the office. The fields that were sampled in September–October were preselected among the 202 fields sampled in April–May 2003. The fields were chosen on the basis of their mean damage severity recorded in April–May. Fields that had in April-May a mean severity above 2 (based on 1 to 5 scale) for one or more of the most important pests (CGM) or/and diseases (CMD, CBSD) were selected for the evaluation of pests and diseases and yield parameters. The selection was based on the assumption that the fields that were severely infested/infected in April–May when they were young (> 3 months and < 8 months) would have a greater negative impact on yield parameters. A total of 79 fields from Gaza, Inhambane, Sofala, Manica, Zambezia, Nampula, and Cabo Delgado provinces responded to these criteria. The fields were later identified using the GPS information and others recorded in April–May 2003. Fields in Gaza and Inhambane were particularly chosen because of their severe CMD infection and CGM attacks in April–May, while the fields in Nampula, Zambezia, and Cabo Delgado were chosen mainly because of the severity of attacks by CBSD. When the preselected field was not found or had been harvested, the next closest field (within 2–3 km) was selected.

In each sample field, 30 cassava plants of the two most common varieties were randomly selected across the field and were evaluated for their severity of CMD and CBSD for the diseases, and CGM and the presence/absence of the predatory mite, *Typhlodromalus aripo* for the pests. The damage severity for all pests and diseases as well as the collection of leaf samples for virus identification was done the same way it was done in April–May 2003. Nematodes were evaluated on the same 10 plants that were harvested for yield parameters (see yield parameters).

Ten of the 30 plants sampled for pests and diseases were selected and tagged for harvesting. Each target plant was uprooted using a hoe and/or a machete that served to dig the soil around the plant to facilitate the pulling of the whole plant. The harvested plants were left near the place they were uprooted from. Each uprooted plant was separated into stems and leaves, and tuber roots. All stems and leaves from the same plant were cut in pieces and placed in a bucket to facilitate weighing of the samples. The tuber roots were cut off from the base of the stems and separated into marketable (that can be accepted for sale at a market) and unmarketable tuber roots (that many buyers would not like to buy either because they are rotten or are too small). The damage caused by nematodes to tuber roots was determined by recording the presence/absence of the galling on a 1–5 scale. The number of tuber roots in each category (marketable and unmarketable) was then counted, placed in a bucket, and weighed using weighing balances of 5 to 25 kg to accommodate low and heavy weights. Rotten tuber roots as a result of disease, physical damage, or rodents were not included among the marketable roots even when they were of a good size. They were considered unmarketable. After weighing the tuber roots, a few tubers from each category (marketable and nonmarketable) were cut in pieces with a machete to determine the presence/absence of root necrosis considered to be the symptoms of CBSD attack on the tuber roots. A rating scale from 1 to 5 developed by INIA was used.

Pest and diseases. A total of 79 fields were sampled. The incidence and damage severity of CGM were low throughout the survey area, except in two locations in Cabo Delgado and Inhambane where the severity was moderate (Fig. 5a). As a result, the populations of the predatory mite *Typhlodromalus aripo* were equally low (Fig. 5b). The distribution and severity of CMD are shown in Figure 6. Except in Manica where all cassava fields sampled were CMD symptom free, CMD was found throughout the other provinces although the damage severity varied greatly. Figure 7 shows the distribution and severity of CBSD, which was as in April-May only observed in Cabo Delgado, Nampula, and Zambezia. The severity, however, varied from slight to moderate, except in Nacala, Nampula province where the mean damage severity was as severe as (> 3.0 based on 1–5 scale). For the nematodes, the mean number of galls per plant varied between provinces. The highest infestation was recorded in Manica.

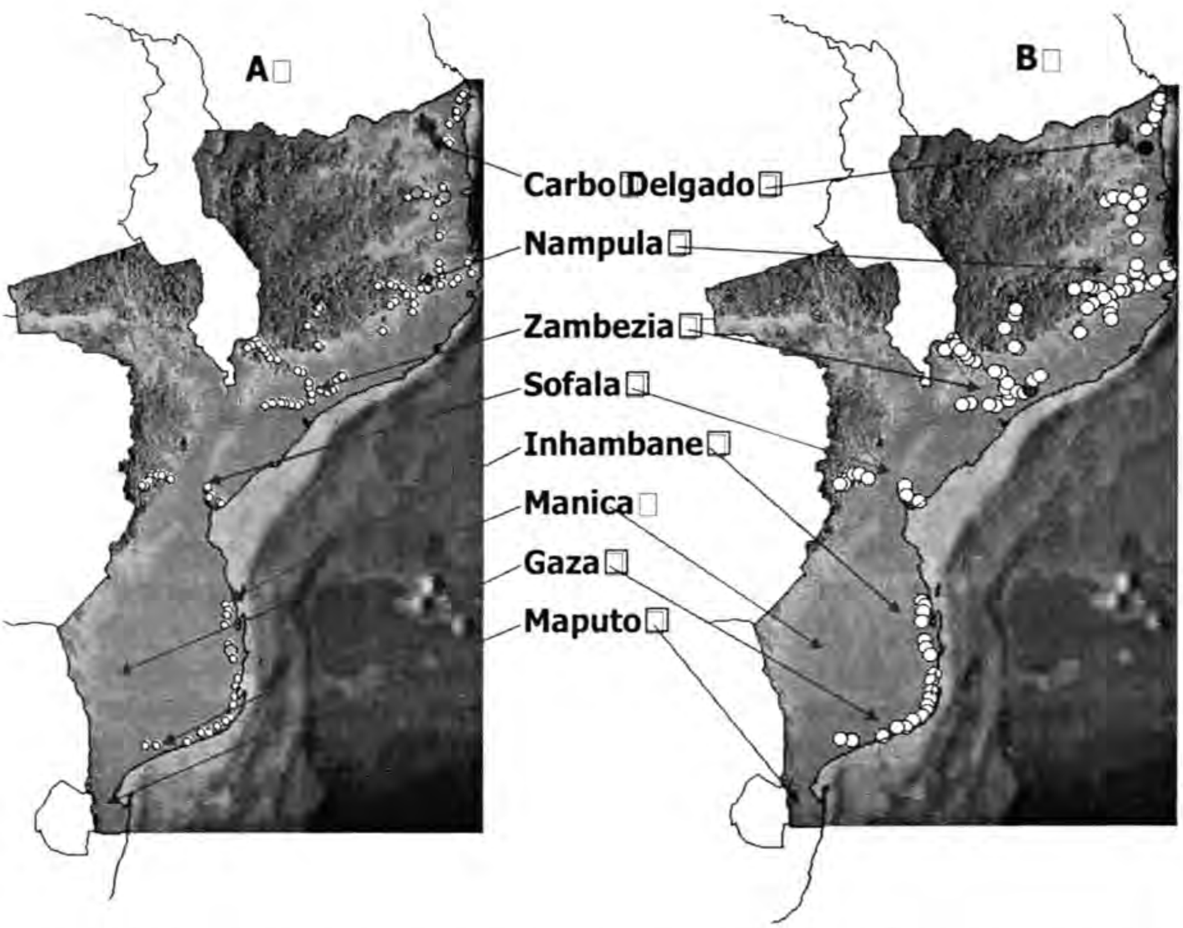

Figure 5. Distribution and severity of cassava green mite (CGM) and incidence of the predatory mite, *Typhlodromalus aripo* in September–October.

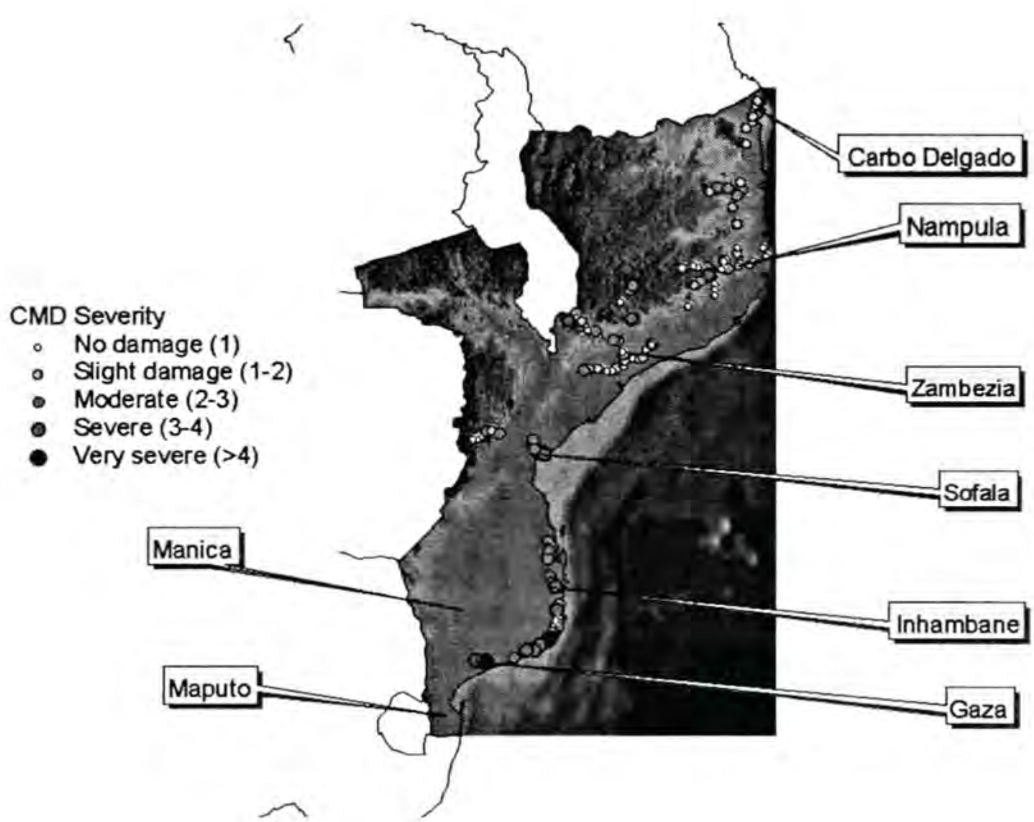

Figure 6. Distribution and severity of cassava mosaic disease (CMD) in September–October survey.

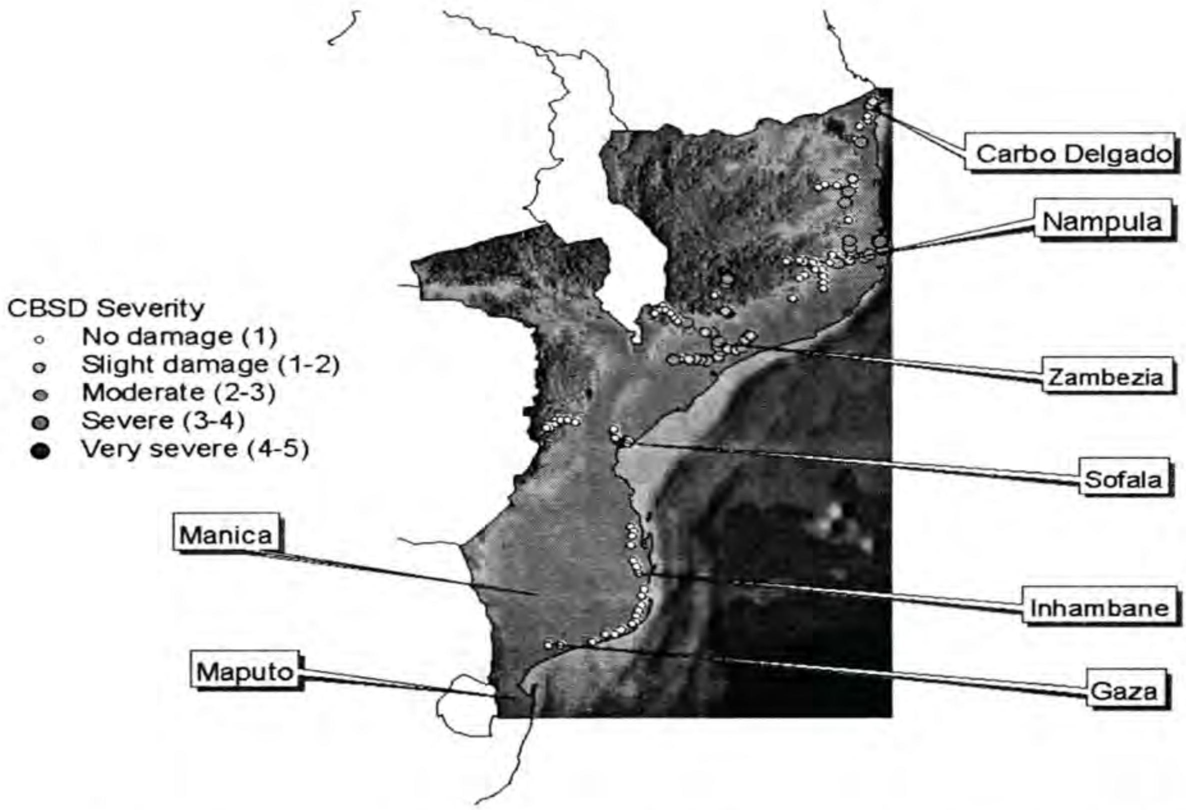

Figure 7. Distribution and severity of cassava brown streak disease (CBSD) in September–October.

CMD virus iidentification. The virus identification of the samples collected in September–October is shown in Table 12. The majority of the samples collected (about 80.5%) were infested by the Eastern Africa Cassava Mosaic Virus (EACMV) throughout the seven provinces surveyed. However, there were 11 fields (7.6%) infested with mixed African Cassava Mosaic (ACMV) and Eastern African Cassava Mosaic Virus (EACMV) and six fields (4.1%) infested with the African Cassava Mosaic Virus (ACMV). Unlike in April–May, the devastating Eastern Africa cassava mosaic virus–Ugandan variant (EACMV-UG2) was identified in seven fields (4.8%) of the total samples. However, all the samples were identified from Nampula province. The strain was not identified in any other province.

Overall yield parameters. The mean number and mean weight of marketable and unmarketable tuber roots and the weight of the stems and leaves are presented in Table 13. The *greatest mean number of tuber roots per plant* (marketable and unmarketable) was recorded from Manica followed by Nampula and Zambezia provinces. The mean numbers were moderate in Sofala and Manica provinces while the lowest mean numbers were reported from Inhambane and Gaza. The mean weights of tuber roots and the mean weights of stems and leaves followed the same trend as those of tuber roots. The highest mean weight of tuber roots and of stems and leaves were found in Cabo Delgado followed by Nampula province. These means in the two provinces were greater than the means recorded in Zambezia and Sofala provinces. The lowest mean weights were reported from Manica, Inhamabane, and Gaza.

Table 12. Virus identification of samples collected from individual fields in different provinces in September–October 2003.

Province	Number of fields and types of virus identified				
	ACMV	EACMV-UG2	EACMV	ACMV+EACMV	Total/province
Cabo Delgado	0	0	2	0	02
Nampula	0	7	4	1	12
Zambezia	0	0	47	2	49
Sofala	0	0	47	1	48
Manica	0	0	4	1	05
Inhambane	6	0	13	1	24
Gaza	0	0	4	5	05
Total/virus	6	7	121	11	145

Table 13. Weights of stems and leaves per plant and number and weight of marketable and unmarketable tuber roots at harvest during September–October survey.

Provinces	No MR	MR Wt	No UR	UR Wt	Wt of Stems + leaves
Carbo del Gado	6.129	3.121	5.028	0.837	3.615
Nampula	4.675	2.819	4.404	0.906	3.199
Zambezia	4.379	1.836	3.532	0.622	2.123
Sofala	3.075	1.701	3.025	0.523	1.855
Manica	3.457	1.053	2.957	0.313	1.473
Inhambane	2.812	1.329	1.935	0.385	1.141
Gaza	2.888	1.373	2.158	0.407	1.124

No MR = number of marketable tuber roots; MR Wt = marketable tuber root weights
No UR = number of unmarketable tuber roots, UR Wt = unmarketable tuber root weights
Wt of stems + leaves = weight of stems and leaves

Conclusions and recommendations. The results of September–October survey for pests and diseases confirmed the observation made in April-May that CGM, CMD, and CBSD are the most threatening cassava pest and diseases, respectively, in Mozambique. Although the incidence and severity of nematodes was not very severe in April–May, the damage caused to tuber roots in the form of quality and source of secondary infection may be important. There is need from the samples collected to identify the most common species found in Mozambique.

There was no clear evidence of the impact of pests and diseases on cassava production. It is difficult to determine such an impact from a regular field survey as a single field was often infected or infested by more than one disease or pest. In addition to pests and diseases, agronomic and other soil or varieties etc. varied from province to province even within the same province. For instance, one would have expected lower yields in Cabo/delGado, Nampula, and Zambezia where CBSD was present in addition to other constraints, but this was not the case as reported in Table 13.

4.13 Monitoring and diagnostic survey study in the Republic of Congo

by P. Ntawuruhunga (consultant) under the supervision of J. Legg and J. Whyte

Cassava is the main food staple and source of income of the population of the Republic of Congo. It constitutes the backbone of the farming system and the major commodity of the Congo population. However, since 1997/1998 CMD has become the most important constraint to cassava production in the Republic of Congo, threatening cassava production and the food security, having already caused food shortage in the country. Diagnostic tests of CMD-diseased samples collected in the Plateaux region in a 1999 survey in ROC revealed the presence of EACMV-UG, suggesting the possibility that the pandemic of severe CMD had expanded right across Central Africa. The most severely diseased plants were infected with both EACMV-UG and ACMV, as observed for the severe CMD associated with the pandemic in East Africa. The principal objective of the study following that done in the previous year was to provide a comprehensive and detailed assessment of the status of CMD in ROC and to determine whether the disease was spreading, in the characteristic manner reported for the pandemic in East Africa.

An informal approach to sampling was used where stops were made at regulars intervals of at least 10 to 15 km along the main roads in the regions surveyed, occasionally penetrating areas away from the main road to try as much as possible to obtain all variation existing between fields in surveyed areas.

In total, 163 fields were sampled in 35 districts in nine regions and Brazzaville Commune. They were 11 (6.7%) in Bouenza, 29 (17.8%) in Cuvette Centrale, 20 (12.3%) in Cuvette Ouest, 10 (6.1%) in Lekoumou, 12 (7.4%) in Likouala, 15 (9.2%) in Niari, 40 (24.6%) in Plateaux, 10 (6.1%) in Pool North, 10 (6.1%) in Sangha, and six (3.7%) in Brazzaville.

Cassava fields aged between three and six months were sampled. Thirty plants in each field were selected along the two diagonals running across it. Crop field sizes, crop mixture, and the names of local cassava cultivars grown were recorded. Geographical data were recorded using GPS equipment, while biological assessments were made for CMD, and whitefly population, cassava green mite (CGM), cassava bacterial blight (CBB), cassava mealybug (CM), and *Typhlodromalus aripo*.

The adult whitefly population was assessed on each plant sampled. Five apical open leaves of the tallest shoot of the plant were each observed taking it by the petiole turned gently upside down to expose the flies and count their number and the total flies on the five leaves was recorded. One to three CMD-diseased leaf samples were collected from each field for subsequent virus diagnosis. A two-stage process was used for this, in which DNA was extracted daily from leaf samples during the course of the survey in ROC and final diagnoses were done using polymerase chain reaction (PCR) techniques in the laboratory of IITA-ESARC, Uganda.

CMD was observed throughout the country and in all regions surveyed. The CMD situation in Cuvette Centrale and Plateaux had not changed compared to last year's observations, however it had deteriorated in Pool north where both incidence and severity had increased. *Whitefly populations were relatively low even in the forest areas compared to* the observations made in 2002. More regular monitoring, however, would be required to gain a clearer understanding of whitefly population dynamics, since whitefly populations vary considerably from season to season. *T. aripo*, the introduced predator of CGM, was observed everywhere and with a greater abundance compared to 2002. Whilst this was true in all regions, it was particularly marked in Niari where it was first released (personal communication). Cassava bacterial blight was observed in all regions with a high incidence in Cuvette Centrale combined with high severity. The districts of Boundji and Gamboma were most severely affected by bacterial blight.

Total incidence for the country was 86.2% with 81.7 % due to cutting infection diseased while only 4.3% was attributed to whitefly infection, indicating that the disease is primarily being sustained through the planting of diseased cuttings (Table 14). These data show that CMD has increased and is characterized by high incidence and severity throughout the country. In 2002, total incidence was 80.3%.

Table 14. Type of infection and total incidence of CMD and abundance of whitefly population by region in 2003, Republic of Congo.

Region	Cutting infection	Whitefly infection	Without infection	Total Incidence (%)	Number of *B. tabaci*/ plant
Bouenza	145 (80.8%)	8 (2.4%)	39 (11.8%)	88.2	2.1
Brazzaville	145 (80.6%)	4 (2.3%)	31 (17.2%)	82.8	0.4
Cuvette C.	667 (76.7%)	65 (7.5%)	138 (15.9%)	84.1	3.4
Cuvette O.	513 (85.55%)	13 (2.2%)	74 (12.3%)	87.7	1.2
Lekoumou	264 (88.0%)	8 (2.7%)	28 (9.3%)	90.7	1.6
Likouala	321 (89.2%)	3 (0.8%)	36 (10.0%)	90.0	2.1
Niari	400 (88.9%)	13 (2.9%)	37 (8.2%)	91.8	2.8
Plateaux	923 (76.9%)	67 (5.6%)	210 (17.5%)	82.5	1.6
Pool North	206 (68.7%)	28 (9.3%)	65 (21.4%)	78.0	0.6
Sangha	281 (93.7%)	3 (1.05)	16 (5.3%)	94.7	1.9
Mean	4004 (81.7%)	212 (4.3%)	674 (13.8%)	86.2%	2.0

Table 15. CMD severity scores for the regions of the Republic of Congo, 2003.

Region	CMD severity score 1	2	3	4	5
Bouenza	40 (11.6%)	68 (19.7%)	109(31.6%)	84 (24.3%)	44 (12.8%)
Brazzaville	31 (17.2%)	61 (33.9%)	57 (31.7%)	20 (11.1%)	11 (6.1%)
Cuvette Cs.	157 (18.0%)	175 (20.1%)	266 (30.6%)	219 (25.2%)	53 (6.1%)
Cuvette O.	74 (12.3%)	80 (13.3%)	198 (33.0%)	191(31.8%)	57 (9.5%)
Lekoumou	28 (9.3%)	98 (32.7%)	115 (38.3%)	45 (15.0%)	14 (4.7%)
Likouala	36 (10.5%)	138 (40.4%)	115 (33.6%)	43 (12.6%)	10 (2.9%)
Niari	37 (8.2%)	43 (9.6%)	125(27.8%)	159 (35.3%)	86 (19.1%)
Plateaux	229 (19.1%)	161(13.4%)	362(30.2%)	313 (26.1%)	135 (11.3%)
Pool Noth	65 (21.7%)	51 (17.0%)	40 (13.3%)	78 (26.0%)	66 (22.0%)
Sangha	16 (5.3%)	32 (10.7%)	167 (55.7%)	74 (24.7%)	11 (3.7%)
Mean	13.3%	21.2%	32.6%	23.2%	9.8%

CMD severity was much higher in Niari and Cuvette Ouest where more than 30% of fields had scores equal to or more than four (Table 15). The change in increasing incidence and severity observed in the Pool region compared to 2002 suggest continued epidemic expansion in this region, although whitefly populations were relatively low.

An overall percentage of more than 86.2 % of the cassava plants expressing CMD symptoms indicates clearly that CMD continues to be the dominant pest/disease constraint in the Republic of Congo. Furthermore, most stands were diseased through the use of infected planting material. An alarming situation therefore continues to persist in the country.

Cassava mosaic virus types distribution in the Republic of Congo. The results (Table 16) indicated that out of the 163 CMD infected samples 153 (82.2%) responded positively to the test while 28 (17.2%) did not yield a PCR product. More detailed characterization would be required to determine if this was due to the occurrence of a CMG not detected by the universal primers used, or deficiencies in the field-based DNA extraction. A totoal of 49.6% of the positive samples were dual infections of ACMV and EACMV-UG2 [1]. Single infections of ACMV and EACMV-UG2 [1] made up 26.7% and 21.5%, respectively. Single EACMV was detected only in Sangha region and appeared to be a novel type unlike those occurring in East Africa. Dual infections of ACMV and EACMV were detected in two samples from Cuvette Centrale. The overall picture indicates that most of the plants (71%) were infected with EACMV-UG2 [1] in both single and dual infections. ACMV infected 77.7% of all plants sampled in both single and dual infections while EACMV infected 2.2% for both single and dual cases. In conclusion, the present results show that the dominant viruses in the Republic of Congo are ACMV and EACMV-UG2 [1] and these results confirm what was reported previously from the 2002 survey.

Germplasm development. Out of a total of 117 genotypes introduced into the Republic of Congo in 2002, 97 genotypes were developed and cloned in 2003 at Odziba research station for further evaluation work. Evaluation of 17 IITA genotypes at three sites of CMD indicated that clone 92/277 was considered the best in all the three sites followed by clones 92/167 and 92/ 269. Clones 92/106, 92/130, and 92/ 647 did not show any CMD symptoms, indicating resistance, but were poor in yield performance.

Multiplication. The multiplication activity was conducted in collaboration with Agricongo on a contract basis whereby multiplication of clone MM 86 at three locations of three hectares each (Odziba, Lekana, and Ewo) was done. In total 700,000 cuttings were distributed to farmers starting September 2003 by the FAO emergency program in collaboration with the Ministry of Agriculture. New multiplications on 9 ha of the clone MM 86 were established again in June 2003 at the same three locations in collaboration with FAO.

Training. Four cadres' scientists from Congo were trained in monitoring, sampling techniques, and virus diagnostics at ESARC. An in-country training course on Root crops production and CMD management of 30 technicians was organized in Brazzaville. Five hundred farmers were trained in CMD management in Congo in four regions.

Table 16. Distribution of virus species and strains in the different regions of the Republic of Congo, 2003.

Region	Virus types ACMV		EACMV-Ug2[1]	EACMV-Col	ACMV + EACMV-Ug2 [1]				ACMV + EACMV-Ug1	Total
	Virus strains Ak	An	EACMV-Ug 2[1]	EACMV-Col	An+U1	Ak+U1	An+U2	Ak+U2	An+E1	
Bouenza	2	1	3	0	2	1	0	0	0	9
Brazzaville	1	0	2	0	1	0	0	0	0	4
Cuvette C.	0	7	5	0	14	0	0	0	2	28
Cuvette O.	0	0	4	0	14	0	0	0	0	18
Lekoumou	0	5	2	0	0	0	0	1	0	8
Likouala	0	0	1	0	6	0	1	0	0	8
Niari	0	1	1	0	5	4	0	0	0	11
Plateaux	0	10	8	0	13	0	0	0	0	31
Pool North	3	5	1	0	0	1	0	0	0	10
Sangha	1	0	2	0	4	0	0	0	0	8
Total	7	29	29	1	59	6	1	1	2	135
%	5.2	21.5	21.5	0.7	43.7	4.4	0.7	0.7	1.5	100

Where ACMV = African cassava mosaic virus; EACMV-Ug2 = Uganda variant of East African cassava mosaic virus; EACMV-Ug1 = Putative East African cassava mosaic virus; Ak = ACMV Kenya strain; An = ACMV Nigeria strain; U1 = EACMV-Ug2 [1]; U2 = EACMV-Ug2 [2]; E1 = EACMV-Ug1; EACMV-Col = Unusual EACMV strain; An+UI = ACMV Nigeria strain + EACMV-Ug2 [1]; An+U2 = ACMV Nigeria strain + EACMV-Ug2 [2]; Ak+U1 = ACMV Kenya strain + EACMV-Ug2 [1]; Ak+U2 = ACMV Kenya strain + EACMV-Ug2 [2]; and An+E1 = ACMV Nigeria strain + EACMV-Ug1

Collaborators included:

- Dr Armand Claude Mvila et Mr Albert Bembé, chercheurs au Center de Recherche en Amélioration Génétique des Plantes (CERAG), Ministère de l'Enseignement Supérieur Chargé de la Recherche Scientifique, Délégation Générale de la Recherche Scientifique
  - Mr Maurice Obambi du Ministère de l'Agriculture et de l'Elevage Chargé de la Promotion de la Femme, Brazzaville, République du Congo
  - Mr Amadou Ouattara, the FAO representative in the Republic of Congo
  - Dr Majema J.M, the international consultant for the FAO cassava mosaic in Congo
  - Ministry of Agriculture
  - Ministry of Research and Technologies
  - NGO, Agricongo

A project proposal entitled "Development of cassava technologies and enterprises for improved livelihood in the Republic of Congo" was developed and submitted to donors in the effort of mitigating the CMD effects. Cassava may not only be described as food security for the population of Congo, rather it is more than that. Each meal in Congo has cassava as major component either as *chikwangue*, leaves (*sakasaka*), or paste. During the diagnostic surveys studies, it was observed that the daily work in all villages was related almost to cassava.

4.14 Targeted multiplication of CMD resistant varieties in East and Central Africa

by J. Legg., P. Ntawuruhunga, J .Whyte., B. Khizzah., A. Dixon, and B. Owor, in collaboration with H. Obiero, S. Akhwale, E. Kanju, S. Jeremiah, I. Ndyetabura, R. Mayiga, S. Bigirimana, A. Ouattara, and J. Mabanza

A program to mitigate the effects of the CMD pandemic in East Africa has been implemented by IITA and it country partners since 1999, with the primary approach being the development, dissemination, and multiplication of CMD resistant germplasm. Through this program, more than 1000 clones with a background of CMD resistance have been introduced each to Kenya and Tanzania, and smaller but substantial numbers to Rwanda, Burundi, and eastern Democratic Republic of Congo. Following germplasm introduction through open quarantine arrangements, clones have been evaluated using a "fast-track" approach in which a small number of top performers (10–20) are identified from the open 0quarantine-based evaluation, multiplied up rapidly, then tested directly on-farm at multiple, agroecologically contrasting sites.

During 2003, highlights of the germplasm evaluation and exchange work included the completion of the evaluation of the second tranche of 17 fast-track clones in western Kenya, the initiation of multiplication of the best performing of the first group of 10 fast-track clones in Tanzania, the completion of the evaluation at three CMD hotspots of 17 IITA-derived clones in ROC and the identification of seven CMD-resistant clones from 15 tested under extreme CMD inoculum pressure conditions in northeastern Burundi.

In partnership with NARS, NGOs, extension, and other stakeholders in Uganda, Kenya, Tanzania, ROC, and Burundi, more than 24 000 ha of CMD-resistant germplasm were multiplied, distributed, and planted in farmers' fields to mitigate the effects of the CMD pandemic. Much of this multiplication and dissemination work was still based around the early TMS-type, CMD-resistant varieties, and in many areas these have been readily accepted. However, increasingly, a greater diversity of germplasm, including TMS, TME, and TMS by TME cross material, is being introduced into the mass multiplication program. This provision of greater choice of germplasm with the whole range of quality characteristics has had a marked beneficial effect on farmer adoption.

A regional stakeholders workshop with the twin aims of reviewing project progress and planning for future work was held at Bukoba, Tanzania and involved participants from research, quarantine services, extension, and NGOs from Uganda, Kenya, Tanzania, Burundi, and the Republic of Congo. A proposal for a further one-year phase to run from October 2003 to September 2004 was approved by USAID, but will involve a smaller group of countries, comprising Kenya, Tanzania, and Burundi.

4.15 Development of an action plan for casssava brown streak disease research in East and Southern Africa

by J. Legg, M. Andrade, J. Whyte, B. Khizzah, E. Kanju, and R. Hanna, in collaboration with R. Njeru, T. Munga, K. Mtunda, A. Zacarias, F. Chipungu, G. Kaitisha, R. Hillocks, M. Thresh, and D. Jennings

Proceedings of the October 2002 cassava brown streak disease (CBSD) stakeholders workshop, held in Mombasa, Kenya, were edited and published through DFID's Crop Protection Programme. Six hundred copies were printed and these were distributed to participants, institutions, and other stakeholders, many of them in the different countries of Eastern and Southern Africa affected by CBSD. In order to strengthen IITA's role as a stakeholder in CBSD research for development, a proposal was developed which targeted the strengthening of IITA fundamental research on CBSD. An important element of this was the collection of molecular data on isolates of Cassava brown streak virus from all areas affected by CBSD, so that new IITA plans to develop a transgene-mediated approach to resistance development would be fully supported by required baseline data. The strategic CBSD research program was to be financed through an extra core contribution to IITA from the Canadian International Development Agency. This program is expected to be initiated during 2004. Another of the main objectives of the new project will be to start to implement the action plan developed during the CBSD workshop and to strengthen IITA's coordinating role in this field of research.

4.16 Assessment methods for banana weevil

by C. Gold and P. Ragama, in collaboration with R. Coe and N.D.T.M. Rukazambuga

The banana weevil is an indirect pest on bananas and plantain. The larvae attack the corm, weakening stability of the plant and impeding nutrient uptake. Damage assessment requires destructive sampling and is most often done on recent harvested plants. A wide range of methods have been developed to assess banana weevil damage. These include estimates of damage to the corm periphery (exposed by corm paring) and to the corm cortex and central cylinder (in cross cuts). The different damage estimates are not always well correlated with each other. In one screening trial, Nsowe had the highest level of damage to the corm periphery and the lowest level of damage to the central cylinder. Thus, interpretation of Nsowe's level of resistance to banana weevil depends upon the sampling parameter selected.

At present there is no agreed sampling protocol. This is, in part, because there is no clear understanding on which damage parameters are most important, i.e., which types of damage have the greatest effect on banana yield.

Preliminary analyses comparing assessment methods were reported in 2002. Further analyses were conducted in 2003, incorporating additional data. Multiple damage assessment parameters were employed in two long duration yield loss trials (cv. Atwalira, *Musa* spp. AAA-EA) and a cultivar screening trial in Uganda. Parameters included two estimates of peripheral damage on pared corms and estimates of damage to the central cylinder and cortex (plus a derived total damage score) observed in cross sections. In the first two trials, estimated yield losses to banana weevil exceeded 40% in latter cycles.

Damage to the central cylinder had a greater effect on plant size and yield loss than damage to the cortex or corm periphery. In some cases, a combined assessment of damage to the central cylinder and cortex showed a better relationship with yield loss than an assessment of the central cylinder alone. Correlation analysis showed weak to modest relationships between damage to the corm periphery and damage to the central cylinder. Thus, damage to the corm periphery (less labor intensive to assess) is not a strong predictor of the more important damage to the central cylinder. Therefore, banana weevil damage assessment should be made for the central cylinder and cortex.

4.17 Fungal endophytes for the microbial control of the banana weevil, nematodes and *Fusarium* wilt

by B. Niere, T. Dubois, C.S. Gold, D. Coyne, and C. Nankinga, in collaboration with R. Sikora, E. Adipala, A. Viljoen, S. Kapindu, N. Labauschagne, S. Athman*, P. Paparu*, P. Kilama* , and E. Mukwaba**

Banana weevil (*Cosmopolites sordidus*), nematodes (*Radopholus similis, Helicotylenchus multicinctus*, and others) and *Fusarium* wilt (*Fusarium oxysporum* f. sp. cubense) are soilborne pests which attack the roots, corm, and vascular system weakening plant support and impeding nutrient uptake. Clean planting propagules, like tissue-culture-derived plants, can be used to establish new fields, although pest (re)infestation remains a vital concern. Microbial control offers excellent possibilities for controlling these pests. The primary focus of this project is the use of endophytes for the management of banana pests and diseases. Fungal endophytes are microorganisms that colonize plant tissue internally for at least part of their life cycle without causing symptoms of disease. Many endophytes have formed mutualistic relationships with their host plants and serve as antagonists to pests and diseases. These endophytes can be inoculated into tissue culture plants and reduce pest and disease pressure.

Screening of endophytes against banana weevils and nematodes. Fifteen endophytic *F. oxysporum* isolates that were obtained from highland banana have been screened in vitro for effects of fungal culture filtrates on banana weevil eggs and nematode juvenile stages using a banana corm tissue medium and an artificial medium. In vitro screening protocols have been successfully established for weevil screening, and most isolates cause between 40 and 50% egg mortality compared to 5% in the control. In vitro screening protocols using endophytic *F. oxysporum* against nematodes were improved by reducing mortality rates in the control from 30% to 5%. Fifteen in vivo screening experiments were conducted, screening a total of 14 endophytic *F. oxysporum* isolates. The effects of several isolates on banana weevil or nematode infested plants were very promising. For example, in banana weevil infested plants, inoculation of isolate Emb2_4o reduced inner corm damage by 45%, reduced oviposition by 46%, and increased dry shoot weight by 39% compared to control plants. In nematode infested plants, isolate V5w2 reduced nematode population densities by 29%, decreased root necrosis by 11%, and increased fresh shoot weight by 11%. Interestingly, the data show that some isolates can contribute to the control of both pests. Isolate V5w2 is now being tested in two on-station field experiments under different levels of nematode infestation.

Studies on endophyte colonization, persistence and interactions. For an endophyte to provide sustained protection against banana pests, it is essential that the fungus successfully colonizes and persists from the time of inoculation beyond the screenhouse period into the time of field planting. Also, interactions of endophytic fungi with their host plant, banana pests, and each other are not well understood. Two in vivo screening experiments that investigate combining different endophyte isolates for nematode control at different infestation levels revealed that endophyte cocktails (multiple isolate inoculation) might enhance their beneficial effect against nematodes and that endophytes retain their full beneficial effect even at increased nematode pressure. Three in vivo screenhouse and field experiments that investigate endophyte inoculation methods and subsequent persistence showed that endophytes can persist within the banana corm for at least 16 weeks, showing colonization rates of up to 81%.

Biodiversity and isolation of fungal endophytes in highland banana. A biodiversity study at selected sites in Uganda on the occurrence and distribution of fungal endophytes in banana yielded more than 400 new endophytic isolates. Results from morphological studies confirm earlier studies that *F. oxysporum* is the dominant fungal species growing endophytically in banana corms, roots, and pseudostem bases. Diversity among these endophytic strains of *F. oxysporum* and relatedness with pathogenic forms will be determined with molecular marker techniques. These isolates have been carefully documented and stored and are now also being used in new in vitro and in vivo screening for control of banana weevils and nematodes.

Screening of endophytes against *Fusarium* wilt. Ten endophyte isolates were tested in in vivo screening experiments for activity against *Fusarium* wilt. A very aggressive *Fusarium* wilt (i.e., reflecting a highly virulent isolate of *F. oxysporum* f. sp. cubense) was used in these experiments and this explains in part why none of the isolates tested so far showed consistent activity against *Fusarium* wilt.

Characterization of *Fusarium* wilt in Uganda. As a foundation for conducting endophyte–*Fusarium* wilt studies, proper characterization of 108 *Fusarium* wilt isolates in Uganda, employing detailed morphological, molecular (AFLP), biochemical (VCG), and biological (pathogenicity tests) characteristics, is being compiled. The isolates were obtained from diseased banana plants in the major banana growing areas in Central and Southwestern Uganda and as far north as Arua district. *Fusarium* wilt was, among other cultivars, also found on the banana cultivar Bluggoe, the differential host for race 2 of *Fusarium* wilt. Race 2 was up until now thought to be absent in Uganda. Since our preliminary data suggest that both race 1 and race 2 of the pathogen are present in Uganda, this finding might have profound implications in banana breeding programs.

Field-testing of different banana planting materials. Although tissue culture technology is already accepted and used in many Central and East African countries, this technology is currently not available to Ugandan farmers. Tissue-cultured banana is however an excellent source of pest- and disease-free planting material. The high cost of the tissue-culture-derived planting material is seen as one of the reasons for slow dissemination and adoption of this technology in Uganda. To further the promotion and acceptance of tissue culture technology in Uganda, a field trial comparing different types of planting material of banana (tissue culture, hot-water treated suckers, and untreated suckers) of the widely grown East African highland banana cultivar Enyeru was planted in 2002. Harvest of the mother plants began in mid-2003 and will continue into mid-2004. In the ongoing field trial, each type of planting material is tested under high nematode pressure and under two different management practices, with and without mulch and manure. Economic analysis of the obtained data will help to determine the best type of planting material for farmers in Central Uganda. Preliminary results show that tissue culture banana plants produce heavier bunches and grow faster than sucker-derived plants. Since the present project depends on the promotion and acceptance of tissue culture plants, this finding is exciting because it highlights the potential of using tissue culture plants during the first crop cycle, even without endophytes, and will without doubt aid in the promotion of tissue culture in Uganda.

Use of *Paecilomyces* spp. against banana nematodes. The use of *Paecilomyces* spp. for the control of *R. similis* was investigated in 12 in vitro bioassays and two in vivo screening experiments, using 30 isolates obtained from the banana rhizosphere. Bioassay protocols were not well established and as a result control mortalities were too high. Several improvements, such as pH control, filtering of the fungal medium, rinsing of the bioassay medium and stimulation of nematodes, reduced control mortality from > 60% to ± 10% and yielded at least two promising *Paecilomyces* spp. isolates (23N5-2 and 11N8-4).

Tissue culture facility. A tissue culture lab is fully operational and routinely producing plants of six banana cultivars for all in vivo screenhouse and field experiments conducted at Sendusu, Uganda. Monthly output stands at 250–350 plants at the moment. A total of 3750 plants were weaned in the reporting period. Output is currently maximized due to space limitations.

4.18 Banana weevil response to synthetic pheromone lures and other infochemicals

by C. Gold and C. Nankinga, in collaboration with W. Tinzaara, M. Dicke, A. van Huis, G. Kagezi, and W.K. Tushemereirwe*

Olfactory cues may be utilized by banana weevils in locating host plants, conspecifics, and/or mates. A male-produced aggregation pheromone, sordidin, to which both female and male banana weevils respond, has been identified and synthesized. Chemtica International, Inc. in Costa Rica has begun commercial production of banana weevil pheromones in a product called Cosmolure+. These pheromones are distributed in small packets that are most often used as lures to pitfall traps. Studies in Costa Rica suggest that placement of only four traps per hectare, changed monthly and systematically moved through a banana stand, can reduce weevil populations and damage and lead to yield increases within one year.

Trap effectiveness has not been well investigated under African agroecological conditions. Preliminary field tests have shown up to 18 times higher capture rates in pheromone traps than in traditional pseudostem traps. The attractiveness of the banana weevil to these pheromones might be enhanced by the addition of plant kairomones but further research is needed in this area.

The overall objective of this PhD research project is to develop an infochemical-based trapping system that is cost effective and can control the banana weevil under Ugandan conditions. To do this, the chemical and behavioral ecology of the banana weevil must be understood. The research focus of this study is therefore to elucidate pheromone and kairomone trap efficiency as related to weevil behavior and environmental conditions. This study is also investigating the impact of adult removal through trapping on weevil population dynamics. An effort will also be made to evaluate the potential of combining infochemical use with biological control methods (i.e., entomopathogens) for the management of banana weevil.

The relative attractivity of host plant volatiles and synthetic pheromone to banana weevil. Laboratory experiments were conducted in the dark room at Sendusu using a double pitfall olfactometer. The olfactometric results indicated that fermented banana pseudostem tissue (Cultivar Mbwazirume, *Musa* spp AAA-EA group) was equally attractive to banana weevil as pheromones but more attractive than fresh pseudostem tissue. Laboratory results demonstrated the additive effect of pseudostem tissue to the pheromone. Although all the four field experiments conducted showed an additive effect to the pheromone, a significant effect was only showed with two out of four experiments. Both results of laboratory and field experiments indicated an increased weevil attraction with an increase in pheromone release rate. A regression analysis should showed significant relationship between the amount of fermented pseudostem tissue used and the weevil trap catches.

The influence of female mating status, age and density on *C. sordidus* response to the pheromone. Laboratory activities were conducted in the dark room at Sendusu using a double pitfall olfactometer. Sexually immature and mature banana weevils (i.e., 1–14 and 30–40 days after eclosion, respectively) collected from the culture were tested for their response to pheromone lures in a double pitfall olfactometer.

Response by mated and unmated females to synthetic pheromones. Unmated weevils responded significantly more (P-value = 0.031, $\chi 2$-test, 2x2 contingency table test) to pheromones than mated ones. Previous weevil density appears not to have a significant effect on weevil response to pheromones. Field experiments were conducted at Kawanda and Sendusu. There were more weevils captured at higher weevil density (17.9 % of the released weevils) than at low weevil density (9.8% of the released weevils). More unmated weevils (24.1% of the released) than mated (19.2%) were recaptured in pheromone baited-traps.

Factors influencing the effectiveness of the pheromone trap in attracting banana weevil. Experiments were conducted at Kawanda and Senge (5 km NW of Kawanda) to determine: (1) the effective radius of pheromone traps for attraction of banana weevil; (2) the sex and mating status of banana attracted to the pheromone traps in different locations relative to the host plant; (3) the upwind and downwind orientation of banana weevil in response to the pheromone source; (4) the effect of covering pheromone traps on weevil response; and (5) the effect of weevil behavior around the trap on catches. Trap performance decreased with increase in radius of a given trap area, and the effective trap radius tended to level off after 9 m. More weevils were recaptured within less than 5 m (15%) from the pheromone trap than from within 5–10 m (9%) and 10–15 m (5%). Relative humidity showed a significant positive relationship to banana weevil catches in pheromone traps while wind speed, temperature, and rainfall showed a weak relationship. Pheromone-baited traps that were covered with banana leaves captured lower numbers of *C. sordidus* compared to uncovered traps. More weevils were captured in pheromone-baited traps placed in alleys than on mats.

The effect of mulching on weevil movement relative to pheromone traps. The experiment was conducted in the field established at Sendusu to: (i) determine the effect of mulching on weevil catches in pheromone traps; (ii) to determine the distance and direction moved relative to the location of pheromone traps in mulched and nonmulched areas; and (iii) discriminate differences between sexes in terms of weevil response to pheromone traps in mulched and nonmulched plots. The treatments were: (i) heavy mulch, (ii) light mulch, and (iii) no mulch (trash). The percentage of weevils recaptured was higher in heavy mulch plots (10.9%) as compare to light mulch (8.1%) and no mulch plots (6.9%). There were twice as many females than males recaptured and the mulch level had a limited effect on the sex ratio of recaptured weevils. Direction had a limited effect on weevils recaptured in mulched and nonmulched plots. This experiment is being repeated (December 2003–March 2004).

Effect of pheromone-baited trap density on banana weevil populations. An on-farm study to evaluate the effect of pheromone trap density on the population of the banana weevil was conducted in Masaka District, Uganda. Forty-two farms were assigned to one of three treatments: control, four and eight traps/ha. The density of the traps depended on banana stand size. Lures were changed monthly at which time the traps were moved to a different location within the stand. Adult populations were estimated by using mark and recapture methods at 0, 6, 12, 18, and 21 months, while damage was evaluated at 0, 3, 6, 12, 18, and 21 months. Pheromone trap captures were generally low and not influenced by rainfall. Changes in banana weevil populations and corm damage were negligible. Doubling the number of traps did not increase catches.

Response of banana weevil predators towards herbivore-induced plant volatiles and pheromones. Laboratory bioassays are being conducted to (i) investigate the efficacy of different volatiles in attracting the banana weevil predators and (ii) determine the role of pheromones in enhancing the host finding by predators of the banana weevil. The predators that are being evaluated for response to host plant volatiles and the pheromone are (i) Dactylosternum abdominale (Hydrophilidae: Coleoptera) and (ii) the ant *Pheidole* megacephala (Hymenoptera: Formicidae).

The potential of using pheromone traps in disseminating *B. bassiana* for the control of banana weevil. The objectives of these trials were: (1) to determine the potential for the pheromone-baited traps to aggregate banana weevils around the trap mat; (2) to investigate the potential for banana weevils to become infected with pathogens in or around the trap; (3) to determine the rate of dissemination of the pathogens by infected individuals of banana weevil; and (4) to determine the effect of using *B. bassiana* in combination with pheromone traps in suppressing banana weevil populations and damage.

Aggregation potential. The experiment was conducted at Kawanda and Sendusu. Twice as many *C. sordidus* were captured in pseudostem traps at the base of the trap mat (pheromone-baited mat) than at mats < 5 m from the trap mat, and four times as many at mats > 5 m away. The results suggest that many weevils may be attracted to pheromone lures but fail to enter the traps (only a small proportion are caught). This may result in weevil aggregation in the vicinity of pheromone traps.

Field transmission. Of the weevils that were recovered by searching, 13.1 % that were released uninfected and 3.1% of the weevils unmarked died due pathogen infection after incubation in the laboratory. Of the weevils, which were recovered by pseudostem traps, 7.1% of the weevils released uninfected and 1.8% unmarked weevils died due to pathogen infection after incubation in the laboratory. The weevils (released uninfected and unmarked) that died due pathogen infection picked it from the weevils that were released infected. The results show that the pathogen could be transmitted from an infected weevil to a noninfected weevil in the field.

Effects of *Beauveria bassiana* infection on weevil behavior. The experiments were conducted in the field and in open cages at Sendusu. The effect of *Beauveria* infection on weevil location and movement was evaluated. The effect of the level of infection with *Beauveria* on weevil behavior was also studied. Most dead weevils (>70%) due to pathogen infection were found in the leaf sheath and in soil by a mat in the field trial. In the open caged trial, most weevils (70.7%) were found on the corm surface and then leaf sheath (8.6%) and in soil by the plant (9.2%). About 30% of the infected weevils were found to move between 3 and 12 m, suggesting that transmission of the fungus from a mat to another is possible.

Delivery systems of *Beauveria bassiana* using pheromones. The experiment was conducted at Sendusu in the former yield loss trial. The treatments were: control (nothing), pathogen only applied to central mat, pheromone + pathogen inside trap, pheromone + pathogen around the trap mat, and pheromone + pathogen on trap mat and mats less 5 m. More weevils died due to *B. bassiana* infection in plots where *B. bassiana* was applied on the trap mat and four adjacent mats (14.2%) than where the pathogen was applied in the pheromone trap (4.1%) and around the pheromone trap (7.2%). There were more weevils that got infected per 200 g weight of *B. bassiana* for the pathogen applied around the pheromone trap (16.7 weevils/200 g *B. bassiana*) than when the pathogen was applied inside the pheromone-baited trap (9.0 weevils/200 g *B. bassiana*) and on the trap mat and four adjacent mats (5.7 weevils/ 200 g *B. bassiana*).

Impact of integrating *B. bassiana* with pheromones. The experiments are currently in progress at Kawanda and Sendusu to determine the impact of using *B. bassiana* in combination with pheromone- baited traps on weevil population and damage. The treatments are: (i) control, (ii) *B. bassiana* on entire plot of 35 mats, and (iii) Pheromone + pathogen at trap mat and adjacent mats.

4.19 Diagnostics in banana–coffee systems

by S. Okech, C. Gold, and S. Abele

Banana and coffee form the economic base for the majority of the population of the Great Lakes region of Africa. The two crops are grown in various patterns as intercrops or separately as monocultures. However, the yield trends of the two crops over the last 20 years suggest that the system is declining, and this decline severely affects rural livelihoods in the region. It is important to generate information about the system on (i) the interaction (socioeconomic, agronomic, pests and diseases) of these two crops and (ii) how best these systems can be established, developed, and improved.

A multidisciplinary team comprising specialists in Integrated Pest Management (IPM), agronomy, economics, and agricultural extension from the International Institute of Tropical Agriculture (IITA), National Agricultural Research Organization (NARO)—banana and coffee research programs, and Mbarara District Department of agriculture conducted a survey in April and May 2003 with the following objectives:

- Determine the importance of banana as a food security and cash crop vis-à-vis coffee as a cash crop.
- Explain trends and shifts in production of banana and coffee, management practices, production constraints, market opportunities etc.
- Elucidate farmers' perceptions on production and management constraints with a view to developing collaborative an on-site research program on a sustainable banana–coffee production system.
- Derive hypotheses for participatory research on the above-mentioned topics.

PRAs and diagnostic surveys were conducted at seven sites in Uganda during May/June 2003 and a diagnostic survey at one site in December 2003 to answer the above objectives.

Economic aspects of the banana–coffee system. The most important economic relationship between the two crops is that they provide seasonal liquidity (especially coffee) for their mutual benefit on management. During the whole year, banana sales provide liquidity for hiring labor for banana and coffee management; coffee provides liquidity for banana management during the coffee-harvest season.

Banana and coffee production systems. Three systems of production were reported across all the sites: (i) banana or coffee monoculture, (ii) banana, and (iii) banana + coffee + annual crops (mainly beans). Perceived benefits from the banana coffee intercropping system were given by the farmers as: (1) to maximize on space and labor resources utilization, all sites; (2) to maximize on limited land, all sites; (3) to replace an old banana plantation on a poor land, two sites; (4) bananas provide nutrients/moisture for young coffee, five sites; (5) banana provides shade and mulch for coffee, five sites; (6) coffee husk is used for soil fertility maintenance, six sites. The only constraint associated with the banana coffee intercropping system reported by the farmers was that coffee mines the soil and kills banana after some time—reported at all sites. Intercropped plots eventually turn into coffee monoculture. Time taken for bananas to die out in the intercrop depends on management and soil fertility but takes about five to more than 10 years.

Constraints to the banana–coffee system. Market (low fluctuating prices) for both bananas and coffee was the common leading constraint at all sites followed by pests and diseases. Declining soil fertility was ranked third or fourth at most sites. Poor management was noted at all sites and was associated with lack of resources including equipment/tools and labor. Shortage of land was ranked high among the constraints but it was given a low priority in this PRA because of the survey objectives.

The key pest that farmers associated with banana in the system was banana weevil while coffee wilt was the main coffee disease. Farmers' observations on relationships between banana weevil and the production system adopted varied. Farmers at three sites believed that the weevil incidence was low in the banana–coffee intercrop while farmers at four sites reported that the incidence was high in the intercrop because of poor management of bananas usually associated with the intercropping. Coffee wilt was a new problem and farmers understood very little about it. Diagnostic survey results showed that banana weevil incidence was consistently low in farms where coffee husk was used as mulch.

The way forward. Both farming and marketing systems at the surveyed sites are complex and diverse and a lot of research is required to provide optimal support for the development of these systems. Both the economic and agronomic potential, especially of intercropping systems, is not yet fully exploited. Banana and coffee play a major economic role as cash crops and food crop (banana) at all the sites. Whether they are grown intercropped with each other or cultivated in pure stands, banana and coffee have many economic and agronomic relationships, both positive and negative. These relationships have to be further developed and improved. Behavior patterns of the farmers are not only profit orientation, but also liquidity and food security, and play an important role in economic decision-making. The major constraints to production are land scarcity, poor marketing options, and therefore a lack of liquidity, which leads to poor crop management and poor exploitation of the economic potential.

The survey team proposed the following hypotheses to be tested during further research: (a) Optimizing banana–coffee intercropping management (proper spacing and adoption of improved technologies) will improve soil fertility, minimize pest problems, increase longevity of the plantations, and result in higher yields of both banana and coffee under the current key constraint of land and labor shortage. (b) In particular, application of coffee husk as mulch and soil fertility amendment in banana plantation reduces the banana weevil constraint and increases banana yield. (c) Improved marketing organization, by establishing better market information, by taking over marketing functions through the farmer (replacing middlemen with farmers' organizations) will increase farmers' cash income.

4.20 Banana weevil pest status: effects of NPK fertilizers on yields loss from banana weevil in Mbarara, Uganda

by S. Okech and C. Gold

In Mbarara, a long-term yield loss trial was planted to test the hypothesis that bananas growing under fertile soil conditions are more tolerant of banana weevil attack than those grown in less fertile soils. Amendments of NPK fertilizer to banana plots (cv. Enyeru) provided different levels of soil fertility in a trial planted at the Mbarara stock farm. Treatments were: (1) fertilizer plus weevils; (2) no fertilizer plus weevils; (3) fertilizer without weevils; and (4) no fertilizer and no weevils. The study has been going on since 1996. The first five crop cycles (1996–2001) did not receive mulch as part of crop management. The subsequent crop cycles (6–8) received uniform application of mulch in all treatments. Plot size per treatment was 49 mats at a spacing of 3 × 3 m. Plots were separated by 20 m grass alleys. Fertilizers were applied at the rate of 100 kg N/ha/year in a four-split application (Urea 46%), 50 kg P/ha/year in a two-split application (Triple Supper Phosphate 46%) and 100 kg K/ha/ year (Muriate of Potash 52%) in a two-split application. Dursban was applied regularly to treatments 3 and 4 to maintain the plots free of weevils.

Adding fertilizer provided minor yield advantages (< 15%) during the first three cycles and a major yield advantage during the fourth cycle in both weevil free and weevil infested plots. In unfertilized plots, yield losses (of the cycles that did not receive mulch) increased from 5% in the plant crop to 40% in the 3rd ratoon. Weevil damage was 4.8%. The losses declined to 31% in the 7th ratoon after two years of application of mulch. Average weevil damage in the 7th ratoon was 3.5%.

Whereas application of fertilizers provided a yield gain of up to 40% in the third ratoon (no mulch application phase) in both weevil free and weevil infested plots, a yield loss of 14.9% was recorded in the 7th ratoon (after two years of mulch application) in the fertilizer with weevil plots. The yield gain from fertilizer without weevils was 7.8%. Application of mulch increased the plant vigor and growth of those plots that did not receive fertilizer. The results demonstrate that weevil damage, as low as 3%, can cause stunting of banana suckers and loss in yield when soil fertility is low.

Banana weevil larvae feeding on the banana corm periphery can effect root detachment, while internal feeding is likely to influence root initiation and development. However, there are no available data quantifying the effect of weevil damage on banana root number. A study to investigate the effect of weevil attack on banana root number at flowering was conducted in three sites in Uganda (Kawanda, Masaka, and Ntungamo). Two hundred and ten recently flowered plants were uprooted, assessed for weevil and nematode damage, and for root number. All peripheral and internal weevil damage indicators were negatively correlated with the number of roots, whereas nematode root necrosis was not. In this study root number appeared to be more affected by damage to the corm interior than to the corm periphery (even though earlier observations suggested that root loss was proportional to the degree of attack on the corm surface). Heavily weevil-damaged plants had 30% fewer roots at flowering than lightly damaged plants.

4.21 Studies on endemic ants and banana weevil in Uganda

by C. Gold, in collaboration with A.M.K. Abera and R. van Driesche*

The potential of indigenous natural enemies, especially ants, to control banana weevils in Uganda is being investigated through laboratory, screenhouse, and field trials as part of a PhD research program that will be completed in 2004. Ants are a major component of the arthropod community in the banana farming systems in the tropics. Surveys in Uganda and Tanzania have shown highly diversified ant fauna to be active in banana stands. Although ants are opportunistic predators, they are increasingly being used in biological control because they possess attributes that make them effective foragers.

A survey conducted in major banana growing areas showed that banana-farming systems have a high species complex. Fifty species were encountered at the survey sites, while the number on individual farms ranged from 19 to 34. Many of these species could be considered as potential predators on banana weevil eggs. Myrmicine ants, which have been reported as effective predators on banana weevils in Cuba, were abundant on banana farms. For example, the *Pheidole* species complex comprised the predominant ant group on most farms. These were observed nesting in the soil, in standing plants, and in crop residues. Another important species, *Odontomachus troglodytes*, was considered by most farmers as a pest, but has also been reported as a predator. These were commonly found nesting at the base of banana mats or in crop residues.

Both *Pheidole* sp. and *O. troglodytes* attacked and removed live baits of banana weevil eggs and larvae in the lab and in the field. This served as an indicator but could not be deemed conclusive, as many species of ants will remove readily available protein sources. We then tested the potential of these two ant species to extract weevil stages from living plants in microcosm experiments conducted within the laboratory. At low weevil density (i.e., two males and two females per plant), the consistent presence of ants in the experimental arena resulted in a 54% reduction in weevil eggs, 44% weevil larvae, and 100% reduction in weevil pupae. Weevil damage was 25% lower on the corm periphery and 57% lower in the corm interior (i.e., cross section measurement) than in controls. At higher weevil densities of five males and five females, a smaller proportion of weevil immature stages were removed. Proportionately more weevil stages escaped predation and damage reductions were 12% on the corm periphery and 38% in the corm interior.

We also tested the ability of *Pheidole* sp. and *O. troglodytes* to remove weevil stages from banana crop residues. In drum experiments, the two species reduced weevil egg numbers by 72% and 67%, respectively. *Pheidole* sp. also removed 16% of banana weevil larvae, while neither species removed banana weevil pupae. In four runs of a field experiment using larvae inserted into decomposing banana corm residues, neither species had much impact on larval number. In these experiments, it appeared that the ants were unable to extract larvae that had burrowed away from the corm's surface.

Trials were planted at Sendusu in 2002 to determine the effects of *Pheidole* sp. and *O. troglodytes* on banana weevil damage under field conditions. This trial will continue through 2004.

4.22 Efficacy and persistence studies of the entomopathogen *Beauveria bassiana* under different banana management practices

by C. Nankinga, C. Gold, and T. Dubois, in collaboration with I. Godonou, D. Moore, S. Gowen, W.K. Tushemereirwe, E. Magara, V. Tumuhaise*, R. Kawuki, and S. Kyamanywa*

The effectiveness of a biopesticide depends not only on its initial capacity to kill the pest but also on its capacity to persist in the environment where it is applied and on its killing action. Some of the abiotic factors that can influence a biopesticide are pH, temperature, soil moisture, and UV light. The presence of antagonistic fungi, bacteria, and microorganisms that exist in soil with high organic matter have been reported to influence the efficacy and persistence of *B. bassiana*. Earlier, we observed that soil amendments such as ash, urine, tobacco, and pepper could influence the efficacy and persistence of the entomopathogenic fungi. Stable manure and coffee husks are common types of soil organic amendments that farmers apply in banana plantations to enhance soil fertility. These amendments can also influence the physical and chemical factors (e.g., pH, moisture content) of the soil. Studies were undertaken to investigate how such farmer practices like application of organic amendments and spacing of the banana plants can influence the performance of *B. bassiana*.

In one experiment, maize formulated *B. bassiana* was applied at a rate of 200 g: (1) around the mats and then mulched; (2) around banana mats without mulch, and (3) applied 2–3 cm below the soil surface. *B. bassiana* was applied on four randomly selected banana mats. The persistence of *B. bassiana* was assessed at two-week intervals by picking the *Beauveria* formulation from the field and exposing it to ten live adult weevils overnight. Microorganisms associated with *B. bassiana* formulations were also collected and identified. Results indicated that infectivity of *B. bassiana* gradually decreased after field application from 90–99% after 14 days to 9.2 to 64.2% after 56 days. *Beauveria* formulation degradation was markedly faster when buried, as reflected by the low mortality (<10%) caused to weevils exposed to buried samples picked from the field after 56 days. Two microorganisms, *Penicillium chrysogenum* and *Aspergillus flavus*, were identified attacking the formulation substrate. Of these, *P. chrysogenum* more frequently colonized the maize-based formulation of *B. bassiana*.

A field trial on the effect of spacing and plant density on efficacy and persistence of *B. bassiana* was established at Kawanda in October 2001. Banana plants were planted at spacings of 2 ×2 m, 2.5 × 2.5 m, and 3 × 3 m. These spacings were chosen to simulate common plant densities in farmers' fields. It was hypothesized that different plant densities would affect the soil environment (sunlight penetration, soil moisture and temperature, microorganism activity) and growth characteristics of the plant, which will directly or indirectly influence the performance of the formulations or fungus applied in a banana field. The efficacy and persistence of *B. bassiana* is being evaluated with a solid maize-based formulation applied at two doses and two application frequencies (every 8 and 12 weeks). The two doses being tested are: dose 1 (high dose = 200 g of maize-based formulation, measuring to approximately 10^{15-16} conidia/hectare) and dose 2 (low dose = 100 g of maize-based formulation, measuring to approximately 10^{11} conidia/hectare). Preliminary results showed low naturally occurring weevil populations and damage levels with no significant differences in the three plant spacings. Growth parameters show that plants planted at 2 × 2 m spacing show lower girth, height, and bunch weights. Data collection will continue for at least two more plant cycles. *Beauveria bassiana* samples have also been taken from the field to assess viability of the applied fungus.

To investigate how organic materials applied in banana fields can influence the performance of *B. bassiana*, pot experiments were conducted to evaluate the efficacy and persistence of *B. bassiana* applied as a maize-based formulation to soil amended with different levels of coffee husks, decomposed cow dung, and artificial fertilizers and planted with suckers of local cooking banana "Mpologoma". The treatments involved applying *B. bassiana* to 10 combinations of soil and organic amendments (loam soil not mixed with any organic amendments or soil mixed with coffee husks, cow dung, and inorganic fertilizers [NPK at rate of 69 g/plant] in the ratios of 1:1, 1:2, 1:3). Coffee husks and cow dung were also evaluated as pure stands without soil. To check on the persistence of the fungus, 10 banana weevils were released into the pots (applied with 100 g of maize-based formulation of *B. bassiana*) at four-week intervals and monitored for mortality and *Beauveria* infection for 16 weeks.

Generally *B. bassiana* applied to soil without any amendment caused higher mortality than all the other treatments and *B. bassiana* applied to pots with only coffee husks showed the lowest infectivity. Infectivity of the maize-based formulation of *B. bassiana* was observed to decrease in all soils mixed with the different organic and chemical amendments. Higher mortality (30–70%) was obtained in weevils released to the pots immediately after *B. bassiana* application. The mortality decreased below 50% in weevils released 60 days after applying *B. bassiana*. This decreased infectivity was attributed to the degraded maize-based formulation of *B. bassiana* that led to contamination of the fungus by other microorganisms in the soil. These results confirm earlier observations that suggested that the fungus on the maize-based solid substrate would need to be applied every 60–90 days to enhance its infectivity in the field. Otherwise, if longer persistence is required, more stable formulations will have to be developed that can stand this environmental degradation.

Further evaluations were carried out from Kawanda on *B. bassiana* conidial yield from selected substrates, efficacy of different formulations against the banana weevil, and efficacy and persistence of the fungus under organic and inorganic soil amendments. The substrates evaluated were cracked maize, maize bran, "machicha", bagasse, cotton husks, maize bran + bagasse, maize bran + cotton husks, and bagasse + spent yeast and they were formulated with clay or loam soils. Evaluation of the substrates was based on conidia counts using a haemocytometer. Cracked maize grains were the best substrate (3.2×10^9 conidia per gram), even though it was not significantly different from that of maize bran (3.1×10^9 conidia per gram). Cracked maize and cracked maize formulated with clay soil were the most effective with over 80% weevil mortality in 30 days.

So far studies investigating abiotic and biotic factors affecting the efficacy and persistence of *B. bassiana* have focused on understanding how organic and inorganic amendments applied in the banana fields can influence the physical and chemical properties of the soil, and the possible effects of these changes on the performance of the fungus. The soil amendments evaluated were unamended soils, coffee husks, decomposed cow dung manure, and inorganic fertilizers. During the study, weevil mortality was assessed on five-day intervals, soil temperature, and moisture at 10-day intervals, while soil fauna and antagonists were assessed at 30-day intervals. After 30 days, highest mortality (67%) was registered in the unamended soils, while in soils amended with coffee husks, decomposed cow dung manure, and artificial fertilizers caused respective mortalities of 30%, 40%, and 43%. The reduction in weevil mortality was attributed to the degradation of the *B. bassiana* by the microbial decomposers and colonizers that could have lead to first degradation of the maize-based *B. bassiana* formulation. Overall, the soil amendments significantly reduced the efficacy and persistence of the entomopathogenic fungus over time. We intend to build on these findings. Follow-up studies to address persistence and infectivity of *B. bassiana* under different banana agroecological zones are ongoing.

4.23 The use of semiochemicals in delivery of *B. bassiana*

by C. Gold and C. Nankinga, in collaboration with W. Tinzaara, M. Dicke, and A. van Huis*

The use of semiochemicals in aggregating banana weevils was investigated by studying the insect's attractivity to traps made from various banana tissues that were pounded and placed in pots. Fresh pounded tissues of the susceptible highland banana cultivar "Atwalira" (genome AAA-EA) and the resistant banana cultivar "Keying" (genome ABB) were immediately placed at 0, 5, 10 and 15 cm below the soil surface in 6-liter buckets. Thus, we had eight kairomone treatments, i.e., two cultivars and four soil depths. The buckets were grouped into four subsets of three buckets per treatment. Ten adult field-collected banana weevils were released per bucket in the subsets at 0, 1, 2, and 3 weeks, respectively, after placement of the banana tissues. There was a progressive decline in the percentage of weevils attracted to processed banana tissues with an increase in the depth at which the tissues were placed. Correlation analysis revealed a strong negative relationship ($r = -0.86$) between the percentage of banana weevils recovered from pounded banana tissues and the depth at which the tissues were placed within the buckets. The declining trend was general for the fresh and one-, two-, or three-week-old processed banana tissues. Pounded banana tissues remained attractive to banana weevils up to three weeks, with one-week-old tissues attracting the highest number of weevils, though not significantly ($P > 0.05$) different from the fresh and two-week-old tissues. However, a significant ($P < 0.05$) difference was observed between the number of weevils attracted to one-week and three-week-old banana tissues. Correlation analysis revealed a weak negative relationship ($r = -0.14$) between the percentage of weevils in pounded tissues and age of the tissues. Analysis of weevil attraction to banana tissues grouped according to cultivars showed no significant difference between the two cultivars tested.

Two field experiments were conducted to further test processed banana tissues as weevil trapping materials. The first experiment was conducted in May 2003 in which the trapping processed banana tissues were buried at 5 cm under the soil while the second one was conducted in December 2003 with the processed tissues placed at the soil surface. Tested banana tissues included fresh pounded corm, chopped corm, pounded pseudostem, and chopped pseudostem from the susceptible cultivar Mpologoma (AAA-EA) and the resistant cultivar Keying (ABB). Thus, a total of eight processed banana tissues were evaluated. Banana tissues placed at the soil surface caught more weevils (range 1.97–2.73 weevil/trap) than tissues buried at 5 cm below the soil surface (range 0.08–0.54 weevils/trap). In addition banana tissue traps at the soil surface were more attractive than split pseudostem traps (i.e., 1.97–2.73 vs 1.5–1.8 weevil/trap) as compared with buried tissues that were less attractive than split pseudostem traps (0.08–0.54 vs 1.0–1.7 weevil/trap). However, correlation analysis revealed a positive, though weak, relationship between the number of weevils captured by processed tissues both at 5 cm depth ($r = 0.1$) and at the soil surface ($r = 0.29$) and split pseudostem trap captures on the same banana mats. Further analysis revealed no significant ($P > 0.05$) difference in weevil catches among the various processed tissues within each of the two experiments. Similarly, no significant ($P > 0.05$) differences between the two cultivars tested, i.e., Keying (ABB) and Mpologoma (AAA-EA) and also between corm and pseudostem tissues.

The next set of experiments concerned the use of semiochemicals in the delivery of *B. bassiana*. A laboratory study was conducted using an olfactometer in the darkroom at Sendusu to determine the quantity of *B. bassiana* conidia picked by a weevil from semiochemical-baited traps treated with the fungus. At the same time, we determined the ability of weevils infected by *B. bassiana* in semiochemical traps to transmit the fungus to other weevils. The following comparisons were made: (i) Pheromone + *Beauveria* vs *Beauveria* alone, (ii) pounded banana pseudostem + *Beauveria* vs *Beauveria* alone (iii) split pseudostem + *Beauveria* vs *Beauveria* alone. In all the three comparisons, pheromones attracted the highest number of weevils, followed by the split pseudostem, while the fresh-pounded pseudostem (unprocessed kairomones) showed least attraction to the weevils. In the olfactometer, the weevils spent more time at pheromone sources, followed by the pounded pseudostem and finally under the pseudostem. Weevils picked up the most spores from the split pseudostem (perhaps because exudates wetted the formulation and facilitated adhesion) although differences were not significant. This experiment suggested that pheromone and kairomone-based traps could facilitate the delivery of *B. bassiana* to banana weevils. The weevil behavior might also influence the amount of spores picked the by the insect. Some weevils walked over the surface of the fungus such that only their legs and abdomen were exposed to the inoculum. Other weevils burrowed into the fungus thus exposing their whole body to the spores.

A field experiment was conducted to evaluate the ability of *B. bassiana* treated semiochemical traps to attract banana weevils from various distances, and assess weevil infection from the traps. The following treatment traps were evaluated: (i) pheromone trap, (ii) covered pounded corm (covered with split pseudostem), (iii) exposed pounded corm, (iv) split pseudostem, and (v) control (empty pitfall trap). Ten banana weevils (five males: 5 five females) were released on mats at 0, 3, 6, and 9 m with respect from the trap mat. Weevils collected from the traps were taken to the laboratory and maintained in moist chambers to monitor for *B. bassiana* growth on dead weevils. Generally, percentage weevil recapture was very low ranging between 3 and 10% for the various treatment traps. Pounded corm tissues covered with split pseudostem apparently recaptured the highest number (10%) of the released weevils while the control had the lowest recapture rate of 0.5%. The high recapture value exhibited by a combination of pounded corm and split pseudostem could have been as a result of "double" quantity of the banana tissues (i.e., pounded corm tissues + the split piece of pseudostem). The same value could have perhaps been obtained by doubling the number of split pseudostems (use two pieces) or doubling the quantity (by volume) of pounded corm materials. Lower weevil recaptures of the pheromone trap could have resulted from setting up the trap without water. No single trap recaptured weevils from all the weevil release positions. For all the traps, there was a higher recapture rate from the trap mat compared with other release positions. The pounded corm tissues covered with split pseudostem had the highest overall percentage recapture value and it recaptured weevils from all distances. Exposed corm tissues never attracted weevils beyond 3 m from the trap. A total of 227 weevils (including the recaptured and the natural population) were collected from all the traps over a one-month trapping period, and 56% of these weevils got infected with *B. bassiana* under moist chambers in the laboratory. This study further demonstrated that *B. bassiana* applied around semiochemical traps can successfully infect and kill weevils that are aggregated by the traps.

Another field experiment was conducted to further evaluate banana weevil attractivity to kairomone traps made from banana tissues and treated with *B. bassiana*, and also to assess the dissemination of *B. bassiana* by weevils infected from the traps to healthy weevils within the habitat. Pretreatment pseudostem trapping (two traps/mat) was conducted in all plots, targeting the selected trap mats and a sample of five mats around the each of the selected mats. Samples of the trapped weevils per plot were taken to the laboratory to monitor for weevil mortality and growth of *B. bassiana* due to natural infection from the field. Treatments included (i) disk-on-stump trap (with one disk) + *B. bassiana*, (ii) disk-on-stump (with two disks) + *B. bassiana*, (iii) pounded pseudostem tissues + *B. bassiana*, (iv) split pseudostem trap + *B. bassiana*, and (v) *B. bassiana* alone. The number of weevils collected per trap was recorded and the weevils were taken to the laboratory for monitoring mortality and *B. bassiana* growth. In addition, 200 g samples of *B. bassiana* were collected from around each treatment trap and taken to the laboratory in dry Petri dishes. Ten adult weevils were released into the *B. bassiana* containing dishes and left in contact for 24 hours. The weevils were transferred to Petri dishes lined with moist tissue paper to monitor for mortality and mycosis. Posttreatment saturation trapping was conducted at two-week intervals for two months on the trap mat and four mats randomly selected around the trap mat. A record was taken of the total number of weevils trapped per mat, and weevils collected from the trap mat and from the neighboring mats were taken to the laboratory to monitor for mycosis. Detailed data analysis for this study has not yet been done. However, exploratory analysis indicates that the disk-on-stump trap (with two disks) attracted the highest number of weevils while pounded pseudostem tissues captured the lowest. Weevils captured at the various treatment trap mats exhibited higher rates of mycosis (range 9–22%) compared with weevils trapped from mats at 3 m (range 6–13%). Surprisingly, for the control trap, weevils trapped at the trap mat and those from 3 m showed as high as 16% and 13% infection, respectively, which were generally higher than the kairomone-based traps.

4.24 Farmer perceptions and adoption of technologies for clean planting material

by C. Gold, S. Okech, and C. Nankinga, in collaboration with C. Kajumba and W.K. Tushemereirwe*

An MSc study on farmer adoption of clean planting material technologies was completed in 2003. Banana weevils and nematodes (especially the aggressive *Radopholus similis*) are often transferred to new fields through infested planting material. To address this constraint, clean planting material technologies, including corm paring and hot-water treatments were developed and disseminated to farmers in the districts of Ntungamo, Mpigi, and Luweero in Uganda, Oyuges and Kakamega in Western Kenya, and Bukoba in Tanzania. Approximately 1500 farmers in the five districts were trained using various approaches on the use of the clean planting material technology. Farmers then established banana fields using clean planting material.

A survey was later done in these districts with 257 randomly selected farmers (trained and not trained by researchers) at training sites to gain insight into the factors that influenced adoption of these technologies. An interview guide was administered to the farmers. The results obtained revealed that farmers perceived corm paring as a simple technology that did not require a lot of labor and was cost effective. On the other hand, hot-water treatment did not require a lot of labor, was not a simple technology, and required more additional costs in purchasing the thermometer, tank, and fuel.

The farmers observed that the clean planting material led to improved sucker production, reduced pests, and better yields. Negative observations by the farmers included susceptibility of the germinating suckers to drought and to livestock. Training and involvement of the farmers in the use of the technology helped improve their understanding of the banana pest status and also helped meet their expectations. Adoption of the technology was influenced by the farmers' characteristics including sex of the head of the household, farm size, land-tenure system, farmers' perception of the technology and its output, ability of the technology to met farmers' expectations, their understanding of the pests, and the approaches used in disseminating the technology.

4.25 Effects of crop sanitation on banana weevil populations and damage

by C. Gold, S. Okech, and P. Ragama, in collaboration with M. Masanza and A. van Huis*

Research on the effects of crop sanitation on banana weevil populations and damage were conducted through a PhD study that was completed in 2003. Laboratory, on-station, and on-farm trials were conducted to determine relative banana weevil ovipositional preferences and egg and larval survivorship on crop residues vis-a-vis standing plants and the effects of crop sanitation on banana weevil populations and damage. Crop residues have been reported as an adult refuge and breeding ground for the banana weevil. It has been hypothesized that removal of these residues will reduce banana weevil numbers and damage to growing plants. An alternative hypothesis is that the residues draw ovipositing adults away from growing plants, thereby reducing damage. Little data has been available to support either of these hypotheses.

Influence of different aged banana crop residues on attraction and host acceptance of the banana weevil. Two choice experiments were conducted in the laboratory at Kawanda to determine attraction and acceptance of crop residues of different ages to the banana weevil. In the first experiment, studies focused on different types and ages of residues of one susceptible highland banana clone "Nabusa" (genome group AAA-EA). Corms attracted 65% of the test weevils, pseudostems 30%, and 5% were nonrespondents. Oviposition levels and the number of eggs per female were higher on young than old corms. In the second experiment, the same parameters were measured on banana residues of selected clones based on their levels of resistance and tolerance to banana weevil damage. Corms were more attractive to adults than pseudostems and flower stalks except for fresh residues of resistant clones. Pseudostems were more attractive than flower stalks with a few exceptions. The number of eggs per female did not differ across clones, but varied with residue age. The number of eggs per female was highest on flower stalks, followed by corms and pseudostems. Old flower stalks were more acceptable for oviposition than any other residue part.

Influence of plant and residue age on egg eclosion and larval survival of the banana weevil. We conducted laboratory trials to investigate banana weevil eclosion success and larval survivorship on banana residues of different ages at Kawanda in Uganda. When we inserted 24-hour-old eggs into corm pieces of susceptible banana cultivar "Kisansa" (genome group AAA-EA) of four different ages, eclosion rates were 66% in fresh, 67% in moderately old, 64% in old, and 58% in very old residues. To assess immature survival, 24-hour-old larvae were put on banana corms of suckers and crop residues of the same cultivar Kisansa in single rearing chambers. The number of surviving individuals was recorded at three-day intervals until adults emerged. The number of surviving individuals 48 days after eclosion was 12% on sword suckers, 10% on maiden suckers, and 7% on flowered plants, after 51 days 12% on fresh, 8% on old, and 5% on very old corms. Larval duration and mean date of adult emergence increased with plant and crop residue age. Crop residue age did not affect adult weight, but the females were heavier than males. These results imply that fresh residues offer better nutrition for banana weevil than old residues. However, since all residues offered a successful breeding place for the weevil, they should all be destroyed to prevent population build-up of the banana weevil.

Distribution, timing of attack and oviposition of the banana weevil on banana crop residues. On-station and on-farm trials were conducted in Uganda to investigate the effect of crop residue management on attack, oviposition, and distribution of the banana weevil on crop residues and growing plants. Oviposition and distribution were assessed on standing and prostrate residues of different ages by destructive sampling. Similar data were collected from fields maintained at three sanitation levels. In the first experiment, oviposition occurred on residues as old as 120 days, but mainly between 0 and 30 days postharvest. Weevil infestation varied among banana clones. In the second experiment, oviposition levels on standing residues were not significantly affected by age. Oviposition levels on prostrate four-week-old residues were two times higher than those on two-week-old residues, while the number of larvae on eight-week-old residues was three times higher than on two-week-old residues. The number of pupae did not differ at all ages of prostrate and standing residues. The number of adults in standing and prostrate residues on 16-week-old residues was two times higher than that on two-week-old residues. In the third experiment, farmers' fields maintained at high sanitation level had 50% lower eggs per residue than those kept at low sanitation level. The number of immatures per residue was 50% higher on banana corms than on pseudostems. Larvae were three times more abundant at low than at high sanitation. The number of pupae per residue at low sanitation was six times higher than at high sanitation level. Residues in fields at high sanitation hosted 50% less adults per residue than in fields at low sanitation. The results suggest that removal and splitting of corms after harvest is effective and practical in destroying immature growth stages of the pest.

Effects of covering highland banana stumps with soil on banana weevil oviposition. The effect of covering postharvest banana stumps with soil on banana weevil oviposition levels was investigated at Sendusu, Kawanda, and in Ntungamo district of southwestern Uganda. In the first experiment we assessed oviposition levels in a banana system comprising growing plants and residues. Oviposition increased from sword suckers, reaching a peak one to seven days after harvest and decreased thereafter. In the second experiment conducted on farmers' fields, corms received 70% of the eggs and pseudostems 30%. The area 5–10 cm below the collar received 27% of the eggs, the area 0–5 cm above the collar 30%, and the area 5–10 cm above the collar 0.3%. The remaining eggs (43%) were laid 0–5 cm below the collar. The effect of stump height and covering the stumps was evaluated in both the wet and dry seasons at Kawanda and Ntungamo. Cutting stumps to ground level alone had no effect on oviposition. Covering postharvest banana stumps reduced banana weevil oviposition in the wet but not in the dry season.

Effect of crop sanitation on banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) populations and crop damage in farmers' fields. An on-farm study of the effect of crop sanitation on the banana weevil populations and corm damage was conducted through farmer participatory trials in Ntungamo district, Uganda. Farmers practiced sanitation levels that were broadly defined as low, moderate, and high, with most farmers at the lower end. During the study, some farmers were asked to maintain their original level of management, while others were asked to increase sanitation levels. However, farmers did not strictly adhere to prescribed treatments so that an incomplete block design was used in analysis of data. Increase in sanitation level from low to high significantly reduced adult banana weevil populations, lowered corm damage, increased plant maturation rates, and increased yields. The data suggest that improved sanitation management can contribute to control and improved banana productivity.

Effect of crop sanitation on banana weevil and natural enemy populations in an on-station trial. We evaluated the effect of crop residue removal on weevil population, weevil damage (over four crop cycles), and nematode and arthropod natural enemy incidence in isolated young banana stands at Kawanda. A closed banana weevil population assumes no emigration or immigration between plots. We infested isolated banana plots with 5–10 weevils and a complex of 3000 nematodes per plant. As harvesting of the plant crop started, we subjected the plots to low, moderate, and high crop sanitation levels. High sanitation levels reduced trap catch by up to 40%, and weevil population by up to 43%, and seemed to expose standing plants to increased weevil attack causing up to 34% reduction in yield. Crop sanitation seemed to reduce nematode populations but not damage. Plant growth was not affected until the fourth crop cycle when girth reduced by 10% and height by 6% in plots under high sanitation compared to plants in low sanitation fields. Plant girth and height increased with crop cycle. Complete removal of crop residues resulted in a three-fold reduction in arthropod natural enemies compared to leaving the residues intact, but did not affect total oviposition on growing plants. In young banana stands with closed weevil populations, removal of crop residues exposes growing plants to increased weevil attack.

4.26 On farm validation of banana IPM methods

by C.S. Gold, C.M. Nankinga, P.E. Ragama, S.H. Okech, in collaboration with W. Tinzaara, A. Bareyke, W.K. Tushemereirwe, M. Byabachwezi, and S. Inzaule

On-farm testing of banana IPM practices, including the use of clean planting material, application of neem and other biorationals, the use of crop sanitation, and testing of new cultivars being studied in ongoing on-farm trials in Masaka district, Uganda, Bukoba district, Tanzania, and Kakamega district, Kenya was completed in late 2003. Data analysis and write-up will be completed in 2004.

4.27 Variability in reproductive fitness and virulence of four *Radopholus similis* populations from Uganda

by C. Dochez, J. Dusabe, M. Pillay, and J. Whyte, in collaboration with D. De Waele (KULeuven, Belgium)

Different populations of *Radopholus similis* from Uganda were compared for reproductive fitness and virulence. Different pathotypes might exist within a nematode species, and the resistance might only be effective against some pathotypes, but not all. If the target nematode species has a high level of genetic variability, the durability of the resistance might be affected. Therefore, populations of different locations within Uganda (Namulonge, Mbarara, Ikulwe, and Mukono) were collected and cultured monoxenically on carrot discs. Reproductive fitness of the four populations was compared on carrot discs in function of time and inoculum level. Pathogenicity experiments on host plants were carried out in pot trials. The population from Mbarara showed a higher reproduction ratio compared to the other populations, both on carrot discs and plants. Also the percentage root necrosis was highest on plants inoculated with the population from Mbarara. This population managed to break the resistance of Pisang Jari Buaya, worldwide known to be resistant to *R. similis*. The diploid hybrid TMB2x 9128-3 and Yangambi km5 showed resistance against the four *R. similis* populations. These results indicate that differences in pathogenicity among different *R. similis* populations exist and should be taken into consideration in the breeding program.

4.28 Importance of yam nematodes in East Africa established and genetic variability of *Pratylenchus sudanensis* compared with morphological variability

by D. Coyne, in collaboration with J. Mudiope, Makerere University, Uganda; and M. Moens, L. Waeyenberge, University of Gent, Belgium

Pratylenchus sudanensis is the dominant nematode species associated with yam in Uganda, while *Meloidogyne* spp. commonly occur on yam across the country. *P. sudanensis* is strongly associated with cracking of tuber surfaces and *Meloidogyne* spp. with galled tubers. In pot studies, *P. sudanensis* was shown to cause cracking of tubers, increased root death, and reduced tuber production. *Meloidogyne* spp. caused galling of tubers and reduced tuber weight, which was more prominent on *Dioscorea cayanensis* ($P \leq 0.05$) than *D. alata* or *D. rotundata*. During storage, it was observed that galled *D. rotundata* tubers desiccated more quickly ($P \leq 0.05$) with greater weight loss than clean tubers. Molecular analysis of different isolates of *P. sudanensis* show that considerable variation exists between some isolates, some of which closely resemble sequences of *Pratylenchus glutierrezi, P. loosi, P. coffeae*, and *P. pseudocoffeae*, though none matched exactly. No reference sequence exists for *P. sudanensis* yet and therefore it was not possible to compare against a reference. Some isolates however had very little variation between them, while others had wide variation and are most probably different species. Assessment of the reproductive fitness of three isolates of *P. sudanensis*, isolated from yam, found that one isolate (from Jinja) had a lower ($P \leq 0.05$) reproductive fitness (and therefore most likely pathogenicity) than the other two isolates (from Rakai and Masaka).

4.29 Comparative efficiencies of mulching quantity of *Tithonia* for nematode management and *Musa* crop improvement assessed

by D. Coyne, in collaboration A. Tenkuano, IITA

Use of *Tithonia diversifolia* applied as fresh mulch, was assessed for its affect on plantain crop growth and production and on nematode activity, in a microplot experiment and field experiment conducted in Nigeria. In microplots, the experiment, which is currently being repeated, was terminated after nine months growth. Application of mulch at the equivalent of 2 t/ha dry weight gave higher plantain leaf dry weight ($P \leq 0.001$) compared with no mulch and higher stem ($P \leq 0.01$) and leaf ($P \leq 0.001$) dry weight at 4 t/ha dry weight application. No differences in root weight were observed between the treatments ($P \leq 0.05$) at nine months. Nematode densities of *Helicotylenchus multicinctus* and *Radopholus similis* appear to be suppressed at high application rates of mulch (> 8 t/ha dry weight application) and resulting in lower root damage indices. In the field experiment mulch was applied annually at 0, 6 (in one application), 6 (in 2 × split application), and 6 t/ha dry weight application (split in between 5 × monthly application). In all mulched plots, plant height was greater than without mulch ($P \leq 0.01$) but increased the number of days to flowering ($P \leq 0.05$). Yields were higher in the single application and 5 × split application ($P \leq 0.05$) than the remaining two treatments to date, although harvests are continuing for the mother crop and therefore not finalized. The effect of mulching with *T. diversifolia* on plantain nematode activity and multiplication is so far not conclusive, but appears to have a suppressive effect. Both microplot and field trials are continuing.

5 Crop and natural resource management practices for sustainable, competitive, and commercially based production systems developed and disseminated

5.1 Literature review on soil quality constraints in EA highland bananas

by Piet van Asten

Banana research in the East African highlands has traditionally focused on pest- and disease-related issues and the introduction of improved exotic cultivars. However, soil quality constraints are generally considered to be one of the primary reasons for the low and declining banana yields in this region. IITA has assigned a VVOB associate scientist to conduct research on this topic. Before starting on-station and on-farm activities, there is a great need to get an overview of what has been done already in the field of soil quality constraints in banana cropping systems, both in the East African Highlands and elsewhere in the world. The literature study was conducted in Uganda, sourcing key informants, personal libraries of banana scientists in the region, and the Internet (a.o. INIBAP's *MUSALIT* banana library).

The review has shown that: (i) there is scanty evidence for soil fertility decline in banana systems, (ii) that banana soils have relative good soil fertility compared to annual cropped fields and grassland, (iii) that, nonetheless, nutrient deficiencies (mainly K, N, Mg) are frequently detected in banana fields, (iv) that yields can increase substantially (> 50%) when fertilizers are applied, but (v) that fertilizers are only efficient when pest pressure is low, (vi) that there is great risk of accelerated soil fertility decline due to the increasing export of banana bunches to the farmers, in combination with the reduced availability of organic matter and fallowing to restore soil nutrient stocks, (vii) that there are clear indications that balanced plant nutrition can improve the plants' resistance against pest attacks and that micronutrients might play an important role in this. The review will be published in the African Crop Science Journal as part of a series of papers that were presented at the IPM conference in Kampala, Uganda, in December 2003.

5.2 Cassava soil fertility program Uganda and Kenya

by A. Fermont, J. Wendt, Yona Baguma (NARO Uganda), and Hannington Obiero (KARI Kenya)

The cassava mosaic disease (CMD) epidemic that started in Uganda in the early nineties has presently reached most of eastern and central Africa with devastating effects on cassava production. IITA and its national partners are successfully developing and releasing CMD resistant cassava varieties to counteract its impact. The latest introductions have a high yield potential characterized by multiple resistance to the major biotic stresses, drought tolerance, earliness, and higher dry matter content. Yield levels up to 50 t/ha in advanced yield trials have been obtained in Uganda and western Kenya under nonfertilized conditions. These yield levels have raised concerns about the impact of the new varieties on soil-fertility depletion.

Soil-fertility depletion has been described as one of the most important constraints to food security in sub-Saharan Africa. Nutrients are commonly not replaced to the degree that they are removed in crop harvesting and other losses, resulting in highly negative nutrient balances. Soils in western Kenya and Uganda are predominantly Ferrasols, Acrisols, and Nitisols; old weathered soils that contain predominantly kaolinite and are virtually free of weathering minerals. The general trend of soil-fertility decline that has been noted by many authors, particularly in western Kenya, reinforces the concern on the impact of the introduction of high yielding cassava varieties on soil fertility.

Recently, cassava has no longer seen as a pure food security crop. Instead it has been identified as an important commodity for both income generation and food security in Africa in the future. There is a careful trend to commercialization of cassava production, both for the local market (fresh roots and dried chips or flour) as well as for industrial usage (animal feed, flour, starch). In Kenya, small-scale pilot processing units are being put in place by IITA and KARI to stimulate local commercialization of cassava products, while in Uganda, Ugachick, a big animal-feed industry, has recently started using cassava roots in the production of animal feed.

Cassava soil-fertility issues in Eastern Africa have been largely neglected as a research theme due to the image of cassava as a food security crop, which grows reasonably well on marginal soils. However, the release of high yielding cassava varieties in combination with the general trend of soil fertility decline in this part of Africa requires that more attention is given to these issues. Specifically there is a need to understand and quantify the impact the introduction of improved cassava varieties will have on soil fertility levels and the performance of cassava-based cropping systems, and develop cropping practices for various types of cassava cropping systems (low, medium, high input levels) which maintain both yield and soil-fertility levels.

Activities undertaken. In collaboration with researchers from NARO and KARI three trial protocols were developed to start answering the above questions:

- *Variety × fertilizer trial.* Objectives: (a) Compare the impact on soil-fertility depletion of three local cassava varieties versus three improved varieties under both fertilized and nonfertilized conditions using three methods; and (b) screen these varieties for their response to fertilizer.
- *Intercropping trial: Objectives*: (a) Compare the impact on soil-fertility depletion of two local versus two improved varieties in the three most common cropping systems (sole/cereal/beans) using three methods, and (b) evaluate the impact of the improved varieties on the performance of the intercropping system as a whole.
- *Nutrient response curve trial*: Objective: Determine the limiting macro and/or meso elements for cassava production.

All trials have a CRBD and four repetitions. Plot size is 8 × 9 m. Harvest area is 20 plants. The trials were installed at one location in central Uganda (Namulonge) and at one location in western Kenya (Alupe) in April 2003. Soil-fertility samples using the mass sampling method were taking before planting in the harvest areas of all plots. Agronomic data (plant height, pest, and disease scoring) are taken at 3, 6, 9, and 12 MAP. Harvesting will be done in March 2004.

Results available from 2003 are preliminary as the trials will only be harvested in March 2004. In general aboveground biomass production is much better in Namulonge than in Alupe. Fertilizer use seems to promote aboveground biomass production in Namulonge, both in improved and in local varieties. In Alupe, none of the varieties seems to develop additional aboveground biomass due to fertilizer usage. Fertilizer use seems to have no negative impact on the occurrence of pests and diseases. Intercropping reduces plant height in similar percentages in improved and in local varieties.

Trials will be continued for 2–3 years before final conclusions can be drawn. This work will be part of the PhD work of Anneke Fermont with Wageningen University in the Netherlands (promoter: Ken Giller). On-farm work will start in 2004 in both Kenya and Uganda.

5.3 Soil sampling methods for detecting changes in soil properties

by John Wendt

Sustaining soil fertility is one of the most pressing issues facing African farmers. Continent-wide, nutrient removal from crops considerably exceeds nutrient addition through inorganic and organic sources. As a result, soil fertility decline is widespread.

Integrated natural resource management (INRM) strategies involve combinations of improved germplasm, crop arrangement/rotation, inorganic and organic inputs, residue management, and weeding strategies. These elements, individually or in combination, work to achieve sustainability of the soil resource. IITA as a leader in sustainable INRM management must therefore have the necessary tools to evaluate whether its INRM strategies degrade, sustain, or enhance soil nutrient status.

Measuring soil changes requires special soil sampling procedures based on soil mass rather than soil depth. Many researchers, including soil scientists, still use soil depth sampling procedures, which result in errors and consequent data misinterpretation and erroneous conclusions regarding soil change. Soil mass sampling procedures are not new, but the necessity of using soil mass to precisely calculate nutrient changes has until now been difficult. Previous procedures required soil bulk density determination, which is laborious and time-consuming.

Soil mass sampling procedures were developed that do not require a bulk density determination. This greatly speeds up soil sampling. Working with a soil sampling equipment company, AMS Soil Samplers, modified soil sampling equipment was developed to rapidly take samples for nutrient determinations on a soil mass basis. The equipment modifications include a modified soil probe tip made of special hardened steel that lasts much longer, and a modified tip design that accelerates removal of the soil sample from the probe, which speeds up the soil sampling process.

An equation was developed that relates soil nutrient content to soil mass, as follows:

$$M_{nutr} = a(M_{soil})^{n}$$

where M_{nutr} is the nutrient mass, M_{soil} is the soil mass, and a and n are constants that describe nutrient distribution, and are calculated from the soil mass and nutrient mass from two or more depths in a sample core. Using the soil sampling equipment developed in collaboration with AMS Soil Samplers, it is possible to calculate the nutrient mass to a high degree of accuracy for any chosen soil mass in below the first depth increment in a soil core using interpolation procedures.

The calculation procedure is complicated and tedious. Therefore, an Excel spreadsheet was developed to perform all of the necessary calculations from raw data input. The inputs include the diameter of the soil sample probe, the laboratory analysis, the number of cores taken for the sample, the weight of the soil, and the soil laboratory analysis. Any reference soil mass can then be chosen by the researcher. The calculation procedure also corrects for large inputs of organic matter which may occur when mulches are applied.

These new soil sampling and calculation techniques were taught at trainings in Yaoundé, Ibadan, and Kano in 2003. Approximately 20 technicians from Yaoundé, 40 from Ibadan, and 15 from Kano participated in these half-day trainings. Soil sampling equipment from AMS was purchased for all three of these locations. The spreadsheets were distributed to soil scientists to facilitate the calculations.

A publication of this work will be completed in 2004. Already, the methods are being employed to evaluate changes in soil fertility in Cameroon, Kenya, Mozambique, Nigeria, and Uganda. These procedures should greatly enhance IITA's abilities to evaluate the effects of INRM strategies on soil fertility.

5.4 Improved cassava distribution and fertilization trials

by N. Mahungu

Four cassava varieties have been selected for distribution and multiplication in Malawi. These are *Mbundumali* (for fresh market and dried chips), *Maunjili* (for silage production), and *Sauti* and *Yizaso* (for dried chips and flour). Over 6 500 000 one-meter cuttings have been distributed to farmers across the project sites. This quantity can plant about 2000 ha. In Tanzania, 23 000 stems were used to establish multiplication plots at Alavi and Kibaha.

Table 17. Effect of fertilizer application on cassava storage root yield (t/ha) at 10 months after planting, (Alavi estate, Kibaha, 2003).

Clone	No fertilizer	35 kg N, 15 kg P_2O_5, 30 kg K_2O /ha	35 kg N, 15 kg P_2O_5, 15 kg K_2O /ha	0 kg N, 0 kg P_2O_5, 15 kg K_2O /ha	Mean
TMS4 (2) 1425	16.2	22.9	22.1	18.3	19.9
Kiroba	14.6	31.2	23.8	15.9	21.3
Kalolo	21.5	35.2	32.6	30.7	29.9
NDL90/034	15.4	21.3	21.2	15.4	18.3
Kibaha	15.2	22.5	12.0	18.7	17.1
Bola Kupata	14.4	19.0	14.6	14.7	15.7
Mean	16.2	25.3	21.0	18.9	
S.E. +	1.81	2.55	2.08	5.11	
C.V. (%)	43.4				

Table 18. Effect of fertilizer application on cassava storage root dry matter content (%) at 10 months after planting (Alavi estate, Kibaha, 2003).

Clone	No fertilizer	35 kg N, 15 kg P_2O_5, 30 kg K_2O /ha	35 kg N, 15 kg P_2O_5, 15 kg K_2O /ha	0 kg N, 0 kg P_2O_5, 15 kg K_2O /ha	Mean
TMS4 (2) 1425	33.2	29.8	35.4	35.5	33.5
Kiroba	36.6	35.1	41.4	36.6	37.4
Kalolo	34.9	35.3	32.9	36.9	35.0
NDL90/034	39.2	42.2	40.6	43.3	41.3
Kibaha	37.3	38.8	36.3	39.3	37.9
Bola Kupata	42.1	38.8	37.1	38.1	39.0
Mean	37.2	36.7	37.3	38.3	
S.E. +	0.58	0.82	0.67	1.64	
C.V. (%)	7.64				

Trials aimed at evaluating breeders' lines for responsiveness to fertilizers are also being conducted in Malawi and Tanzania. In Tanzania, six cassava varieties, TMS4 (2) 1425, *Kiroba*, *Kalolo*, NDL90/034, *Kibaha*, and *Bora Kupata*, are being evaluated with fertilizer inputs at Alavi estate (METL) for their suitability for starch production after 10, 12, 14, and 16 months of growth. Three harvests have been made and root yield and dry matter content for the first harvest are presented in Tables 17 and 18, respectively. All agronomic parameters and starch content are being determined.

6 Public and private sector partnerships that promote information and technology exchange with emphasis on scaling up strategies for increased trade developed and/or strengthened

6.1 Strengthening regional trade intelligence and trade information services

by Shaun Ferris, Martin Nahamya*, Luwandagga David*, Charles Lwanga*, Nick Maunder♦, Thomas Awuor♦, Andrew Mutengu♦, Harriet Nsubuga¥, Mark Wood¥, and Stephen Njukia# (FoodNetT*, FEWSNET♦, ADC/IDEA¥, RATES#)*

The Regional Agricultural Trade Intelligence Network (RATIN) was designed in early 2003 and kicked off in mid-2003 with the launch of an interactive website: www.ratin.net which is perceived as a platform for exchange of information on trade for major food commodities in Kenya, Tanzania, and Uganda. The information exchanged included trade news, cross-border trade information, trade balance sheets, weather forecasts, food aid updates, millers' prices, and crop forecasts. Through this project, monthly trade meetings have been held in Kenya, Tanzania, and Uganda and this has created a forum where traders, market researchers, food aid agencies, and development NGO partners interact and discuss trade-related issues. A couple of regional monthly bulletins have been produced and disseminated in two languages: Swahili and English, since April 2003. Links with world space satellite have been initiated and information will be syndicated to several radio stations within the region for faster dissemination. Under this same activity, personnel have been stationed on border posts of the three countries to monitor volumes traded across the borders.

6.2 Market Information Services

by Shaun Ferris, Geoffrey Okoboi*, and David Luwandagga* (FoodNet*)*

Provision of market information is crucial for improving market access and efficiency. This particular component of FoodNet is funded by ACDI-VOCA under a five-year arrangement, which started late last year. The governments, donors, and several development partners have acknowledged the importance of market information. FoodNet has continued to excel in collection, processing, and dissemination of market information in Uganda and this is used as a model for other countries to emulate. Market agents record daily wholesale and retail price data for major markets in Kampala and also for upcountry towns covering 28 commodities in 19 districts of Uganda. This information is mainly disseminated using FM radio stations and is broadcast in eight local languages. Data is also sent to policy makers, food aid agencies, development partners, research institutions, and private sector members via email, internet SMS, newspapers, and through world space satellites.

6.3 The NAADS local Marketing Information Service

by Dennis Bisase and Emily Arayo* (FoodNet*)*

The NAADS/FoodNet market information project was designed to provide a micro-market information service for producers at the subcounty level in six Districts of Uganda where the project is being implemented. These districts include Arua, Mukono, Kibaale, Kabale, Tororo, and Soroti. At present, 20-minute market information programs run on six community radios twice daily in respective local languages. A "market–market" serial radio drama program has been developed in English to run on the radio stations that are under the project arrangement.

Client-based trainings on how to utilize market information have been conducted with district market officers and government officials in 22 subcounties of the six target districts in Uganda. Over 600 farmers have been trained how to interpret and utilize market information.

A market information dissemination method at village level has been developed and this involves pinning price bulletins at some subcounties' headquarters of the local markets covering both low-value crops and high-value priority commodities such as livestock, Moringa, and Vanilla.

6.4 Market analysis

by Shaun Ferris, John Jagwe*, Robinah Nyapendi*, Kelly Wanda*, John Spilsbury^, James Mbwika^, Jackson Nkuba+, and Samson Makworo+ (FoodNet*, Private consultant^, NARS+)*

A number of market studies have been conducted in the past year, the summary of which is shown in Table 19. Most of them have been submitted for review before they can be

Table 19. Summary of market studies conducted by FoodNet in 2003.

Study	Partners	Coverage	Status
Sesame	CRS, FoodNet	Uganda, Kenya, Tanzania	Ready for publication
Banana	ARDI-Maruku INIBAP, KARI, Food-Net, CIAT-ATDT-ISAR	Uganda, Kenya, Tanzania, Rwanda	Ready for publication
Maize	Makerere University, University of Nairobi, Sokoine university, EARO	Uganda, Kenya, Tanzania, Ethiopia	Almost complete
Beans	ECABREN, CIAT, Food-Net	Uganda, Kenya, Tanzania, EARO	Ready for publication
Rice	FoodNet, NARS	Uganda, Kenya, Tanzania	Almost complete
Soybean	FoodNet, NARS	Uganda, Kenya, Tanzania	Initial stages
Market opportunities studies on Agric, forestry, wildlife sectors	CRS, SSARP-USAID, FoodNet	Southern Sudan	Almost complete
Maize, beans, vegetables, livestock market study	EARO, FoodNet	Ethiopia	Initial stages
Dried fruit processing	NARO, FIT(U)	Uganda	Almost complete
Marketing of Vitamin A rich potatoes in Kenya	KARI	Kenya	Complete and ready for publication
Market opportunity identification for urban & peri urban farmers in Kampala	FoodNet, CIAT, Urban Harvest	Uganda	Complete and ready for publication
market opportunity identification farmers six districts of Uganda	FoodNet, NAADS-Uganda Gov't	Uganda	Study ongoing

published with IITA. The methodologies used in these studies were documented and shared with socioeconomists in research institutions equipping them with skills to conduct similar studies in the future. The draft reports of the above mentioned studies are available on the FoodNet website: www.FoodNet.cgiar.org and the publications will be availed to interested parties on request.

6.5 Agroenterprise development

by Robinah Nyapendi, Rupert Best, and Shaun Ferris*(FoodNet*, CIAT¶)*

A "learning alliance" has been developed between Catholic Relief Services (CRS) and FoodNet aimed at improving the capacity of CRS personnel and those of its partner institutions to support the development of sustainable links between their target farmers and markets. The 'territorial' approach to agroenterprise development is what is being used in the alliance. Four major workshops have been conducted for the alliance in phases and the participating countries (Burundi, Ethiopia Kenya, Madagascar, Malawi, Rwanda, Sudan, Tanzania, and Uganda) facilitated in the course of their work. A report of the process undertaken is yet to be produced.

Within this learning alliance, two manuals have been developed and utilized in the market opportunity identification process and improvement of competitiveness of market chains in small-scale producers. These manuals were developed in collaboration with CIAT's Carlos Ostertag and Rupert Best with funding from the International Development Research Center (IDRC), the Swedish Development Corporation (SDC), and the Inter-America Development Bank (IDB).

6.6 Training

by Shaun Ferris, John Jagwe*, Robinah Nyapendi*, Rupert Best[♦], Andrew Temu[•], Hugo De Groote[§], Carlos Ostertag[♦], and Charles Lwanga* (FoodNet* CIAT[♦], CYMMIT[§], IFPRI[•])*

Since capacity building is one of the priority areas of FoodNet, a number of trainings have been conducted by FoodNet with an aim of building capacity of partners and stakeholders in dealing with market challenges in their domains of operations. Table 20 is a summary of trainings conducted by FoodNet in 2003– mid-2004. High profile agricultural economists and agroenterprise experts from IFPRI, CIAT, and CYMMIT conducted the agroenterprise and marketing course. The course material included Marketing basics, Agricultural Reforms, and Designing and executing a market opportunity identification survey together with data analysis and utilization of statistical packages such as SPSS.

The website development course was conducted by IITA-FoodNet webmaster to a group of private sector partners working with a market-oriented NGO (Faidha Mali) operating in the northeastern part of Tanzania. The participants acquired skills on how to develop and maintain simple websites using user friendly website development software such as Dreamweaver.

Table 20. Summary of trainings conducted by FoodNet, 2003 to mid-2004.

Course title	Participants	Partners	Location	Dates
Market analysis training course	31 Socioeconomists from Ethiopia Agric. Research Org. (EARO)	IFPRI, CIAT, EARO, CYMMIT, FoodNet	Nazareth, Ethiopia	March 2004
Market analysis training course	42 CRS staff and partners in agric extension activities	Catholic Relief Services (CRS)	Dire Dawa, Ethiopia	March 2004
Website development course	20 Faidha Mali (private sector partners)	Private sector	Arusha, Tanzania	April 2004

6.7 Website development

by Charles Lwanga and Shaun Ferris* (FoodNet*)*

Under a bilateral arrangement made between FAO and FoodNet, a webmaster was hired two years ago with the aim of developing and maintaining websites for FoodNet and its partners since ICTs were perceived as crucial media channels for both now and the future. FoodNet was to avail the same services and skills to partners. Under this arrangement, the FoodNet Webmaster has been able to design seven websites for partners both in research institutions and the private sector. Some of the websites developed under this arrangement include the potato research network website: www.asareca.org/prapace, the bean research network website: www.asareca.org/ecabren, the root crop research network: www.asareca.org/earrnet, the regional trade network website: www.ratin.net, and the IFPRI scrip project: http://www.FoodNet.cgiar.org/scrip.

7 Capacities of NARS and other stakeholders to generate, evaluate and disseminate appropriate knowledge and intervention technologies for target subsectors enhanced

7.1 Backstopping of Ugandan NARO national banana research program

by C. Nankinga, C. Gold, S. Okech, and P. Ragama, in collaboration with W. Tushemereirwe

During 2002, IITA helped coordinate on-farm banana research activities in 10 subcounties in Masaka and Luwero districts, Uganda on banana integrated pest management and germplasm evaluation. More than 26 000 improved and East African highland banana clones were disseminated to over 1000 farmers. In collaboration with NARO, IITA conducted GIS mapping of banana o-farm sites in seven subcounties in central Uganda and selected sites for multilocation banana germplasm evalaution.

IITA also worked with NARO in developing technology disseminination tools with NARO through the production of posters on (1) Banana germplasm improvement, (2) Conventional breeding of bananas, (3) A cell suspension system for highland bananas, (4) Banana micropropagation, (5) Postharvest processing of bananas to chips and flour, and (6) Clean planting material: a key to a successful banana plantation.

In collaboration with NARO-National Banana Research Program, IITA produced brochures on Postharvest processing of bananas to chips and flour and clean planting material: a key to a successful banana plantation. These brochures were distributed to over 2000 participants of agricultural shows conducted in Masaka district, Jinja district and the Buganda Kingdom.

Jointly with NARO-National Banana Research Program, IITA produced a summary of Highlights of banana research activities and Highlights of banana germplasm improvement in Uganda that have been distributed to over 500 visitors that visited the National Banana Program.

IITA and NARO-National Banana Research Program conducted four stakehoders' meetings (farmers, agrictural extension, NGOs, donors, community leaders, opnion leaders) at two banana benchmark sites, reaching over 1000 stakeholders. IITA jointly organized with NARO-National Banana Research Program an open day at Bamunanika benchmark site that attracted more than 4000 show participants. This open day was intended to transfer banana management and utilization technologies being evaluated and disseminanated at the site.

7.2 Student training

by C. Gold, B. Niere, C. Nankinga, T. Dubois, S. Okech, and P. Ragama

PhD project formulation and research was supported in host plant resistance to banana weevil through conventional and nonconventional methods (three students); biological control of banana weevil using ants; the effects of crop sanitation on banana weevil; the use of infochemicals in banana weevil control; and the use of endophytes for control of banana weevil and nematodes (two students). MSc research supported by IITA included the use of *Beauveria bassiana* against banana weevil (two students); the use of endophytes against banana weevil and nematodes (two students); technology transfer of hot-water treatment for control of weevils and nematodes; and data base management. Research partners include Wageningen University, the University of Massachusetts, Cornell University, the University of Pretoria, and Makerere University.

7.3 Postgraduate training

by J.P. Legg, in collaboration with J. Brown, J. Colvin, D. Gerling, C. Rey, T. Aveling, G. Thompson, C. Fauquet, S. Kyaanywa, M. Latigo, D. Osiru, and E. Adipala

A male Ugandan PhD student, registered with the University of Greenwich, UK, completed a PhD study of *Bemisia tabaci*, as vector of cassava mosaic geminiviruses. His research aimed to identify the factors leading to the superabundance of *B. tabaci* populations in CMD pandemic affected areas of East Africa. A second male Ugandan PhD student, registered at the University of Witwatersrand, South Africa, conducted molecular characterization studies of cassava mosaic geminiviruses and their associated whitefly vectors at the University of Arizona, USA, and began to examine the bionomics, mating compatibility, and genetics of different cassava *B. tabaci* genotypes at the Natural Resources Institute, UK. Two other Ugandans completed a Rockefeller Forum Makerere University based master's program project on sustainable IPM for CMD and whitefly management. One of the two, a male student, examined the potential for using aphelinid parasitoids to manage whitefly populations, whilst the second, a female, investigated interactions between cassava mosaic geminiviruses, their effects on yield, and putative cross protection. A further Ugandan, doing an MSc at Makerere, was in the second year of a program examining the parasitoid diversity in *B. tabaci* on sweetpotato and assessing the potential for augmenting parasitism through using sweetpotato and cassava intercrops. A male Tanzanian finished the second year of a PhD program on cassava mosaic virus variability and interactions in Tanzania. In 2002 he carried out molecular characterization studies at the Donald Danforth Plant Science Center, St. Louis, USA. A second Tanzanian began the second year at Makerere University, Uganda on the topic of phytosanitation versus resistance in the management of CMD and sweetpotato virus disease. A second female student began the second year of a masters program with Egerton University, Kenya, developing elements of a CMD management program for Siaya district, western Kenya.

7.4 TARGET project

by M. Pillay and Guy Blomme (IPGRI-INIBAP)

Project partners were identified in Tanzania and Mozambique. Four main partners were identified in Tanzania: Adventist Development and Relief Agency (ADRA), the Agricultural Research and Development Institute (ARDI), a marketing institute (FAIDA), and the Kagera Community Development project (KCDP). The main project partners in Mozambique were: Instituto Nacional de Investigacao Agronomica (INIA), University Eduardo Mondlane, and the Institute of Tropical and subtropical Crops (ITSC) in South Africa. A training program was held in both countries. Weaning sheds were constructed and demonstration plots were set up. The demonstration plots were used to train the extension workers and farmers in banana field establishment, banana agronomy, pest and disease management, and postharvest techniques.

The planting material (FHIA 17, FHIA 21, FHIA 23, FHIA 25, SH3436-9, BITA-3 and Yangambi km 5) has been established in farmers' fields in both countries.

7.5 Training in cassava production and processing technologies in Malawi

by N. Mahungu

More than 250 individuals (farmers and extension staff) in Malawi have been trained in cassava production and processing technologies in collaboration with partners such as NGOs, the private sector, and the Ministry of Agriculture, Irrigation and Food Security.

In addition to farmers, SARRNET hosted four students from Bunda College of Agriculture, a constituent College of the University of Malawi and two students based in France on attachment (Table 21). These were trained in various activities of SARRNET.

A book entitled "Use of cassava in animal feed" has been published with a joint effort from CLAYUCA.

Table 21. Students on attachment to SARRNET in 2003.

Name of student	College	Field of specialization
Mr Nicolas Leley	Ecole Supèrieure D'Agriculture D'Angers, France	BSc in Agriculture
Mr Eric Nonry	Ecole Supèrieure D'Agriculture D'Angers, France	BSc in Agriculture
Betina Eliphas (Ms)	Bunda College of Agriculture, Malawi	BSc in Agriculture (Crop Science)
Harvey Tchale	Bunda College of Agriculture, Malawi	BSc in Agriculture (Crop Science)
Wilford Phiri	Bunda College of Agriculture, Malawi	BSc in Agriculture (Crop Science)
Patrick Chiwaya	Bunda College of agriculture, Malawi	BSc in Agriculture (Crop Science)
Wongani Chisala	Bunda College of agriculture, Malawi	BSc in Agriculture (Agriculture economics)
Tione Kaonga	Bunda College of Agriculture, Malawi	BSc in Agriculture (Agriculture economics)

7.6 Statistical and Geographic Information Systems training

by P. Ragama, C. Legg, S. Korie, S. Ofodile, H. Kisingo, and T. Alabi

A course in SAS/GIS was conducted for 2½ weeks between 15 September and 1 October 2003, where 12 IITA employees and 13 collaborators from NARO attended. The course was funded jointly between Biometric/GIS unit of IITA-Ibadan and IITA/ESARC as our colleagues from West Africa accepted to come and backstop us in conducting the course. Several topics in statistical models using SAS package were covered in a period of two weeks (Table 22). The GIS course was conducted in three days after concluding Statistics/SAS. Overall, participants rated the course above average and the general feeling was that the frequency of conducting such courses should be increased.

The course was designed for persons involved with handling experimental data from the field/laboratory and surveys that involve ordinal and/or continuous data. Participants were encouraged to come with their own data so that during practical sessions they would be assisted in analyzing their data. SAS package was used for statistical analyses while ArcView was used for GIS. The venue was the National Banana Resource Center, Kawan da.

The objectives of the course among others were to empower scientists and research associates/scholars in analyzing data collected efficiently in order to meet the mandate of IITA-ESARC in the region. The course compared different alternatives for obtaining modern analyses of key statistical designs in use. An attempt was made to review spatial methods and the linkage of geophysical and biological attributes through GIS. About 75% of the course was practical while 25% was theory.

Table 22. Timetable of statistical computing and data analysis with SAS course, 15 September to 1 October 2003.

Date	Topic	Resource person(s)
15–16/09/2003	SAS basics and data management	Hussein/Ragama
17/09/2003	Data entry through Access and linkage to excel and basic analysis	Ofodile/Korie
18/09/2003	Introductory statistics with SAS	Ofodile/Ragama
19/09/2003	Design concepts and ANOVA derivatives	Korie/Ragama
20/09/2003	Weekend practical session (morning only)	Ragama/Korie/Ofodile
22/09/2003	Two-way ANOVA (CRBD, factorial, split-plot,	Korie/Ragama
23/09/2003	etc.)	Ragama/Korie
24/09/2003	Mixed models	Korie/Ragama
	Longitudinal data analysis /repeated measures design/analysis (with mixed models)	
25/08/2002	Ordinary least squares and dummy variable regression, trend/partial	Korie/Ragama
26/09/2003	Multivariate analysis	Korie/Ragama
27/09/2003	On-farm design/analytical strategies and surveys	Ragama/Korie
29/09–1/10/2003	GIS course	Chris Legg & Alabi

Publications

Monographs

Collinson C.D., K. Wanda, A. Muganga, and R.S.B. Ferris. 2003 Cassava marketing in Uganda: constraints and opportunities for growth and development. ASARECA/IITA, Monograph 2 IITA, Ibadan, Nigeria.

Summary. This report presents research into constraints and opportunities within traditional fresh and dried cassava marketing in Uganda. DFID's Crop Post Harvest Program, DFID's bilateral aid section in Kampala, and the East African Research Network funded the research.

Key findings

- Dried cassava flour is an important food staple for particular groups of poor consumers within Kampala. Real cassava flour prices in Kampala are volatile and increasing in the long term, suggesting that food security among sections of the urban poor may be threatened.
- Improving the flow of market information would increase dried cassava marketing efficiency. This would lead to better spatial integration between urban markets (thereby reducing the absolute levels and volatility of consumer prices, and increasing marketing opportunities for farmers), and to a reduction of transaction costs throughout the marketing chain, particularly to the benefit of farmers.
- Efficiency could also be improved by increasing liquidity within the dried cassava trading chain. Greater capital availability would allow wholesalers and retailers to expand the scale of their businesses and spread their overhead costs over a greater volume of trade. Food retailing in general has poor cost efficiency, and consequently consumer food prices are much higher than is necessary. In the case of cassava flour, retailers add approximately 36% to the price of flour in between buying and selling, yet the greatest

part of this margin is accounted for by overhead costs. Retailing is a simple service and should not cost consumers so much.

- Product quality is not a problem during the dry season, when optimal drying conditions permit sufficient dried cassava production that is of adequate quality and affordable to urban consumers. However, during the wet season, good quality flour becomes expensive, not only because of low levels of interseasonal storage but also because farmers are unable to dry cassava roots effectively. Appropriate drying technologies might improve the situation, but they would have to be both nonlabor and noncapital intensive to find favor within prevailing farming systems.

- Current market facilities constrain wholesaling efficiency. Competition with alternative land uses limits business expansion, maintains high rents, and creates congestion and pollution.

- There is no evidence that any group within the dried cassava trading chain makes unjustifiably large profits. On the contrary, excessive competition at the retail level appears to squeeze profits to the extent that individual retail outlets operate at an inefficiently small scale.

- Fresh cassava trading is driven by the high perishability of the roots and by the price premia that consumers are willing to pay for freshness.

- Large marketing cost savings could be realized if current methods for reducing the perishability of cassava roots can be adapted to meet the requirements of Uganda's fresh cassava trade.

- Recent cassava breeding research has neglected widespread consumer preferences for medium sized, sweet varieties.

- Transport charges between farms and assembly points are more than ten times more expensive than interurban transport charges. Although this finding was made in the context of dried cassava trading, it probably applies to most domestically marketed farm produce, and may indicate the importance of public investment in reducing the costs of community level transport.

- Lending to the food marketing sector is not only constrained by high transaction costs and poor loan security but also by conservative attitudes among potential borrowers.

Recommendations

Many of the constraints that apply to fresh and dried cassava trading are common to other types of food marketing in Uganda. Examining cassava marketing in isolation can therefore lead to less than optimal research impact. The following are suggested as avenues of general food marketing research and technical assistance.

- Formal lending to the food marketing sector: This research should concentrate on finding innovative lending practices that will reduce costs and risks to both lenders and borrowers. Ideally, it should involve traders, commercial lenders, government policy personnel, and legal experts.

- Capturing economies of scale within food wholesaling and retailing: Building on the work into improved lending, this research should be broad ranging and include investigation into capital, business skill, entrepreneurial, cultural, and infrastructural constraints. An understanding of the relevant constraints will allow policy makers to develop strategies to encourage larger scale wholesaling and retailing.

- Improved market facility planning: If Kampala's urban authority is willing to cooperate, we recommend assistance aimed at improving the planning of Kampala's markets, with the ultimate aim of reducing marketing costs, improving sanitation, and reducing congestion in the city center. The work should engage urban planners and traders in a collaborative approach.

The final two recommendations apply specifically to technical innovation within cassava marketing systems.

- Drying technology: We do not recommend spending research funds on developing ways for drying cassava roots at the farm level. New drying techniques would only find relevance during the three months of the wet season. Furthermore, in order to find favor among farmers, drying innovations would have to satisfy the impossible combination of being nonlabor and noncapital intensive. We do, however, recommend further research on the financial viability of drying innovations at the village assembler level of the marketing chain, where capital constraints are lower. Village assemblers handle greater volumes of chips and may therefore be able to exploit economies of scale in the drying process.
- Fresh cassava storage: We recommend research into the feasibility of adapting CIAT/NRI fresh cassava storage technology for use by Ugandan traders. Costs and benefits to the traders should form the central theme of the research.

Robbins, P. and R.S.B. Ferris. 2003. The impact of globalization on the agricultural sectors of East and Central African countries. ASARECA/IITA, Monograph. IITA, Ibadan, Nigeria. 124 pp.

Executive summary. Globalization is the term used to describe the recent impact of innovations in communications and transport systems on trade and the growing interdependence of countries due to economic sophistication and burgeoning output. These innovations have encouraged nations to reduce the high levels of protection between trading blocks of countries and to adopt policies to liberalize their economies in order to increase their volume of trade, including trade in agricultural products.

It has been proved that, for many countries, increased economic liberalization and openness leads to growth. It has also been recognized, however, that for some countries and for some communities within countries the transition from a protected, centrally controlled economy may bring with it serious, negative, short-, and medium-term consequences.

Some Eastern and Central African countries have recognized the importance of striving to increase their role in the international economy and have, over the last two decades, adopted appropriate economic measures—others have done so more recently. These measures have resulted in benefits to ECA countries including the stimulation of private sector trading networks needed in a modern economy. However, the risks associated with adopting a more exposed position in a highly competitive global agricultural market have presented these countries with some serious difficulties. A combination of the impact of structural adjustment programs and partial reform of the rules governing international trade has reduced the prices of primary commodities exported by ECA countries and caused an increase in imports of agricultural products from more competitive producers, some of which remain highly subsidized in their country of origin.

The result of oversupply and weakening demand due to the current recession, has led to commodity prices falling to a 40-year low and analysts suggest that commodity prices are likely to remain at these low levels for the foreseeable future. This bleak outlook is reflected in the dramatically falling terms of trade for many ECA countries and suggests a profound downturn in their economic outlook and performance. The international community has recognized some of these difficulties and has made some effort to assist these countries to overcome them. Much remains to be done by these countries themselves, however, to take advantage of the opportunities offered by globalization and to ameliorate the negative impacts of the process.

In the next round of WTO talks, the radical reform of the trading relationship between ACP countries and the EU and the establishment of closer regional economic cooperation will have further major implications for agriculture.

In the opinion of the authors of this paper, ECA countries have not appreciated the scale and implications of these changes and that, without urgent action on their part, they may seriously weaken their economies in the years ahead. Measures need to be adopted by a very wide range of agencies in both the public and private sectors. These range from a major effort to increase the understanding of issues in multilateral trade negotiations, urgent efforts to devise strategies to reduce economic dependence on primary commodities, and major reforms of agricultural development and research strategies.

This paper attempts to set these issues in an historical context, to highlight the main issues that need to be addressed, and to list important questions that need to be asked of policy-makers throughout the agricultural industry. The conclusions of this study are that decision-makers should give urgent consideration to the following suggestions:

1. *Strengthening negotiating capacity in trade talks.* African countries have been disappointed by the effects of decisions made in previous WTO and ACP-EU negotiations. ECA countries are poorly represented in these and other multilateral and bilateral talks and they lack capacity to analyze important and highly complex issues, to develop negotiating positions, and to respond quickly and effectively to their various negotiating teams. Consideration should be given to establishing national and regional teams of experts with the necessary authority to analyze the interests of their stakeholder groups and to establish appropriate negotiating positions. Negotiating teams should be significantly strengthened in Brussels and Geneva especially. Resources should be made available by cutting diplomatic expenditure in other countries where necessary. The negotiators need to be directly linked to the policy analysis groups and to the line Ministries of Trade, Agriculture, and Finance, such that informed decisions can be made rapidly and effectively. Such reform will be particularly necessary in the forthcoming WTO trade round which will focus on greater inclusion of developing country interests and may take into account proposals associated with the "Development Box" and other nontrade issues proposed by developing countries.

2. *Managing the oversupply of primary product exports.* Over the last two decades the adoption of internal and international market liberalization polices have led to a catastrophic fall in the prices of many of the agricultural products exported by ECA countries. The plunge in prices has been caused by systemic overproduction stimulated by

components of structural adjustment programs. Economists call this phenomenon the *fallacy of composition*, i.e., less income is earned as more commodities are produced. ECA countries are highly dependent on the production of cash-crop commodities for employment, economic growth, and export revenue.

Countries that produce and export raw commodities such as coffee, sugar, tea, cotton etc. through small-scale production systems are unable to create new jobs or re-invest into alternative market sectors. Countries and individual farmers, who rely on cash-crop production for revenue, are obliged to continue to grow and sell these commodities, no matter how low prices fall.

To address this issue, efforts should be made to find a common cause with other producers of these commodities in Africa and in other continents to bring some order into these markets and to devise strategies that involve donors and support agencies such as the IMF and the World Bank to bring supply of these products in line with demand.

3. *Enforcing existing trade protection.* ECA WTO members have agreed to limit the protection given to domestic farming. Fixed import tariffs still apply in many categories, however. Greater efforts should be made to increase control of porous borders to discourage unwanted imports and to collect excise revenue. The dumping of heavily subsidized agricultural commodities from developed countries should be actively opposed where such imports disrupt local farming economies. These efforts need to be pursued within the WTO mechanism and in bilateral exchanges.

   Efforts should also be made to analyze the impact of imports of food aid and food monetization schemes on domestic and regional farming. Such imports should be controlled with the objective of meeting relief needs whilst avoiding the undermining of local and regional production.

4. *Stimulating production of added-value products.* Most analysts believe that the prices of primary agricultural commodities will continue to fall in the foreseeable future. Unless the mix of industrial activity is changed, economic growth will not occur.

   The "Everything But Arms' initiative", the "Africa Growth Opportunity Act", and other similar market-access measures now offer LDC countries in ECA the opportunity to attract investment into the region to improve the quality and range of products and, more importantly, to produce added-value products made from locally produced raw materials. Every effort should be made to capitalize on these opportunities by promoting inward investment now that many tariff barriers to added-value products have been removed in the main consuming markets. (Kenya should seriously consider applying to be reclassified as a Least Developed Country for this reason.)

   Consideration should be given to strengthening the role of existing export and investment promotion organizations to include the preparation of detailed investment plans and packages in added-value products that will attract greater foreign direct investment (FDI). Tax regimes should be modified where necessary to encourage this form of investment. Vertical diversification may represent the only option for ECA countries to avoid the economic damage caused by falling raw commodity prices.

5. *Establishing an Agricultural market analysis unit.* An Agricultural market analysis unit should be established in each ECA country. This unit would be concerned with coordinating and developing policy on the development of a market-orientated strategy

in agriculture and setting policy guidelines for agricultural research. The Unit should also coordinate its activities with relevant regional bodies. It should be staffed with appropriately qualified economists and market experts. The Unit should work closely with the private sector and, especially with those private-sector support groups working to stimulate production for growth markets.

6. *Establishing a National market education program.* Many actors in the agricultural sectors in ECA countries are still not familiar with the idea of competitive markets. A National market education program should be established targeted, primarily, at farmers, traders, and agricultural product processors. Such a program needs to be linked to the Agricultural market analysis unit (see above) and Market information services (see below) and run in conjunction with other stakeholders including Ministries of Agriculture, Education, and Trade, farmers' and traders' associations and other private sector actors, and with extension services.

   The program needs to set targets for training farmers to understand how competitive markets work, to take advantage of market information and to inform them of the difficulties and opportunities associated with market conditions. Issues addressed need to include the stimulation of collective activity to improve economies of scale, linking supply variety and quality to market needs, negotiation of sales and inputs, and the use of credit and business management.

   The program should have a limited duration and should be administered efficiently as a separate unit within a national agricultural development reform program.

7. *Establishing a Market information service.* Many typical, small- and medium-scale farmers, traders, and processors in ECA countries are very poorly informed about prices and market conditions of the commodities they produce. Farmers find themselves in a weak bargaining position with traders which results in lower-than-market farm-gate prices, high transaction costs, and wastage. Market nformation services need to be established at local, national, and regional level to gather, process, and disseminate market information in the appropriate language of intended recipients. Such services need to be fully coordinated with each other and involve full participation of stakeholders.

   The aim of these services should be to stimulate more competitive markets. They are likely to be supported by the agricultural industry itself as they are in more developed countries, once competitive markets become more established.

8. *Strengthening agricultural research and extension and services.* Research and extension services need to continue with their vital role in controlling plant and animal diseases and pests, discovering and distributing new varieties, training farmers to improve their technical abilities, etc. If ECA countries wish to compete successfully in the world economy, however, these institutions need to develop or acquire new skills and expertise in market analysis and market linkage. Producers need to ensure that there are viable markets for any existing or new products. They need to ensure that the quality and packaging of those products meet the requirements of customers both on the domestic and export market. Research and extension services have a vital role to play in this effort and must be prepared to reform quickly to meet the challenges of globalization.

In many respects national research programs have succeeded in their goal to achieve food security; the current emphasis should now be to develop dynamic and commercially orientated research that supports improved market analysis, market access, and added value processing. Extension services should now focus on assisting producers to trade more effectively within a liberalized market. Special attention should be given to aspects such as linkage of production to markets, access to credit, and collective marketing which will enable the millions of atomized, small-scale farmers to gain from economies of scale in their input and output markets.

Government research services need to work closely with the private sector which is increasingly developing its own research capacity, particularly in regard to higher value commodities and research related to issues and problems further up the value chain.

9. *Reducing imports of goods that can be competitively produced domestically.* Many ECA countries import fruit juices, soluble coffee, cooking oils, etc. when they are rich in all the raw materials needed to make these products and have low labor costs. An effort should be made to examine import data and to analyze the prospects for developing the local manufacture of such products and to encourage investment in the production of such goods but only if this can be done profitably without resort to market protection. It should be remembered that savings on imports are as valuable as export revenue.

10. *Strengthening the legal framework for market activity.* Market manipulation and collusion among traders to the detriment of farmers, consumers, and exporters are widespread practices in ECA countries. In some countries, road tolls and taxes are arbitrarily applied and often restrict trade and increase transaction costs. Where necessary, governments must institute a program to reform the legal framework within which agricultural product transactions take place, establish or reform laws of contract, outlaw restrictive practices, and regulate a competitive market in agricultural goods. In addition, governments must ensure that these laws are properly enforced.

Refereed journal articles

Bigirimana, S., P. Barumbanze, R. Obonyo, and J.P. Legg. 2003. First evidence for the spread of East African cassava mosaic virus-Uganda (EACMV-UG) and the pandemic of severe cassava mosaic disease to Burundi. New Disease Reports [http://www.bspp.org.uk/ndr/] Volume 8.

Chiwona-Karltum, L., L. Brimer, J.D. Kalenga, A. Mhone, J. Mkumbira, L. Johansson, M. Bokanga, N.M. Mahungu, and H. Rosling. 2004. Bitter taste in cassava roots correlates with cyanogenic glucoside levels. Journal of the Science of Food and Agriculture 84: 581–590.

Coyne, D.L., K.L. Sahrawat, and R.A. Plowright. 2003. The influence of mineral fertilizer application and plant nutrition on plant-parasitic nematodes in upland and lowland rice in Côte d'Ivoire and its implications in long-term experiments. Experimental Agriculture 20 (in press).

Abstract. Mineral fertilizer application and consequent plant nutrition has long been observed to influence associated plant-parasitic nematode population densities, offering the potential as a nematode management option. Observations were made on the influence of mineral fertilizer application on nematode populations on three separate long-term rice experiments, (differential mineral application on upland and on lowland rice and P application on upland rice) undertaken between 1994 and 1997 in Côte d'Ivoire. On upland rice, treatments with K or N withheld from the comprehensive mineral application treatment (range of elements including N, P, K, Ca, Mg and Zn) led to lower densities ($P \leq 0.05$) of *Pratylenchus zeae* at harvest than the comprehensive mineral application, in 1995. By withholding K or Mg, *Helicotylenchus psuedorobustus* densities were greater than with either the control (no mineral application) or comprehensive mineral application in the same year. No differences were observed between treatments in 1994, or between treatments for densities of other nematode species present (*Meloidogyne incognita, Criconemella tescorum*) or for total nematode density. In the lowland rice trial, no treatment effects on nematode species (*Hirschmanniella oryzae* and *Uliginotylenchus palustris*) were observed. In the P application trial on a P-deficient Ultisol, *Heterodera sacchari* densities were lower ($P \leq 0.05$) in treatments receiving 180 kg/ha P, than untreated in 1995; in 1996 no differences were observed between untreated and 135 kg/ha P, while in 1997 higher densities of *H. sacchari* were present in 135 kg/ha P than untreated. Regression analysis of nematode densities against mineral straw content in the P application trial revealed a negative correlation between *M. incognita* and Mn ($P \leq 0.001$) and Ca ($P \leq 0.05$), and between *P. zeae* and Zn or Fe ($P \leq 0.05$). A positive correlation was observed between *Helicotylenchus* spp. and Mg ($P \leq 0.05$). This study provides strong arguments for the assessment of nematode constraints in long-term research trials, the omission of which may severely limit the validity of the primary experimental objectives.

Coyne, D. L., H.A.L. Talwana, and N.R. Maslen. 2003. Plant-parasitic nematodes associated with root and tuber crops in Uganda. African Crop Protection 9: 87–98.

Abstract. In a nematode survey of eight commonly grown root and tuber crops (cassava, sweetpotato, potato, yam, tannia, taro, carrot, and turmeric) from 4303 fields in Uganda, 68 species of plant-parasitic nematodes from 28 genera were extracted from soil and roots. About twice as many nematode species were recovered from soil (64) as from roots (36), while 32 species were found only in soil and four species only in roots, usually in mixed populations. *Meloidogyne* spp. (root-knot nematodes) were the most frequently recovered nematodes across crops, with the major species (*M. arenaria, M. hapla, M. incognita,* and *M. javanica*) observed on cassava. Some nematodes were recovered only from specific crops. Sweetpotato was associated with the greatest diversity of species (55 species in 25 genera), followed by cassava (40 species in 19 genera) and yam, which was sampled principally in the northern and eastern regions of Uganda (39 species in 14 genera). The study examined the distribution of the plant-parasitic nematodes, which provides information for more detailed local population studies and nematode pathogenicity evaluation on important root and tuber crops.

Dixon A.G.O., R. Bandyopadhyay, D. Coyne, M. Ferguson, R.S.B Ferris, R. Hanna, J. Hughes, I. Ingelbrecht, J. Legg, N. Mahungu, V. Manyong, D. Mowbray, P. Neuenschwander, J. Whyte, P. Hartmann, and R. Ortiz. 2003. Cassava: from poor farmers' crop to pacesetter of African rural development. Chronica 43: 8–15.

Legg, J.P. and C.M. Fauquet. (2003). Cassava mosaic geminiviruses in Africa. Plant Molecular Biology (in press).

Mkumbira, J., N.M. Mahungu, and U. Gullberg. 2003. Grouping locations for efficient cassava evaluation in Malawi. Experimental Agriculture 39: 167–179.

Mkumbira, J., L. Chiwona-Karltun, U. Lagercrantz, N. Mahungu, J. Saka, A. Mhone, M. Bokanga, L. Brimer, U. Gullberg, and H. Rosling. 2003. Classification of cassava into "bitter" and "cool" in Malawi: from farmers' perception to characterization by molecular markers. Euphytica 132 (1): 7–22.

Nwakanma, D.C., M. Pillay B.E. Okoli, and A. Tenkouano. 2003. PCR-RFLP of the ribosomal DNA internal transcribed spacers (ITS) provides markers for the A and B genomes in *Musa* L. Theor. Appl. Genet 108: 154–159.

Abstract. *Musa acuminata* Colla (AA genomes) and *M. balbisiana* Colla (BB genomes) are the diploid ancestors of modern bananas that are mostly diploid or triploid cultivars with various combinations of the A and B genomes, including AA, AAA, BB, AAB, and ABB. The objective of this study was to identify molecular markers that will facilitate discrimination of the A and B genomes, based on restriction site variations in the internal transcribed spacers (ITS) of the nuclear ribosomal RNA genes. The ITS regions of seven *M. acuminata* accessions and five *M. balbisiana* were each amplified by PCR using specific primers. All accessions produced a 700 bp fragment that is equivalent in size to the ITS of most plants. This fragment was then digested with 10 restriction enzymes (*Alu*1, *Cfo*1, *Dde*1, *Hae*111, *Hinf*1, *Hpa*11, *Msp*1, *Rsa*1, *Sau*3A1, and *Taq*1) and fractionated in 2% agarose gels, stained with ethidium bromide and visualized under UV light. The *Rsa*1 digest revealed a single 530 bp fragment unique to the A genome and two fragments of 350 bp and 180 bp that were specific to the B genome. A further 56 accessions representing AA, AAA, AAB, AB, and ABB cultivars and synthetic hybrids were amplified and screened with RsaI. All accessions with exclusively A genome showed only the 530 bp fragment while accessions having only the B genome lacked the 530bp fragment but had the 350 bp and 180 bp fragments. Interspecific cultivars possessed all three fragments. The staining intensity of the B genome markers increased with the number of B genome complements. These markers can be used to determine the genome constitution of *Musa* accessions and hybrids at the nursery stage and, therefore, greatly facilitate genome classification in *Musa* breeding.

Keywords *Musa*, genome markers, internal transcribed spacers (ITS), PCR-RFLP.

Nwakanma, D.C., M. Pillay, B.E. Okoli, and A. Tenkouano. 2003. Sectional relationships in the genus *Musa* inferred from PCR-RFLP of organelle DNA sequences. Theor. Appl Genet 107: 850–856.

Abstract. The genus *Musa* is divided into the sections *Eumusa*, *Rhodochlamys*, *Australimusa*, and *Callimusa* on the basis of morphological characters and differences in basic chromosome number. Information on the evolutionary relationships in the genus would improve our understanding of taxonomic delimitations in *Musa* and assist in the choice of compatible sources of useful variation for the improvement of the cultivated bananas. The objective of this study was to construct a molecular phylogeny of the genus *Musa* using restriction site polymorphisms of the chloroplast and mitochondrial DNA. Six chloroplast and two mitochondrial DNA sequences were amplified individually through PCR. The amplified products were digested with 10 restriction endonucleases. A total of 79 restriction site changes were scored among 13 species sampled from the four sections of *Musa*. Wagner parsimony using the branch and bound option, with *Ensete ventricosum* as the outgroup, defined two lines of evolution in *Musa*. One lineage comprised species of the sections *Australimusa* and *Callimusa* which have a basic chromosome number of x = 10 while the species of section *Rhodochlamys* (x = 11) were in the other lineage. Species of *Eumusa* (x = 11) were distributed into both lineages. Section *Rhodochlamys* appeared as a sister

group of section *Eumusa* with *M. laterita* Cheesman having identical organelle genome type as some subspecies of the *M. acuminata* complex. The progenitors of the cultivated bananas, *M. balbisiana* Colla and *M. acuminata*, were evolutionarily distant from each other. *M. balbisiana* occupied a basal position in the cladogram indicating an evolutionarily primitive status. The close phylogenetic relationship between *M. laterita* and *M. acuminata* suggests that species of the section *Rhodochlamys* may constitute a secondary genepool for the improvement of cultivated bananas.

Okao-Okuja, G., J.P. Legg, L. Traore, and M. Alexandra Jorge. 2003. Viruses associated with cassava mosaic disease in Senegal and Guinea Conakry. Journal of Phytopathology (in press).

Pillay, M., C. Dimkpa, G. Ude, D. Makumbi, and W. Ushemereirwe. 2003. Genetic variation in the banana cultivar "Sukali Ndizi" grown in different regions of Uganda based on RAPD and AFLP markers. African Crop Science Journal 11: 87–95.

Abstract. The objective of this study was to assess genetic relationships among "Sukali Ndizi" clones collected from 16 different localities in Uganda using the RAPD (random amplified polymorphic DNA) and AFLP (amplified fragment length polymorphism) techniques. Thirty-four RAPD primers used singly and in combination produced 234 unambiguous bands. The RAPD primers produced identical banding patterns in all the samples and were, therefore, not useful in differentiating the clones. On the contrary, the nine AFLP primer pairs produced a total of 554 fragments, 17 of which were polymorphic. Genetic relationships were established from the AFLP data by UPGMA cluster analysis. Two groups of clones were clearly defined. It was interesting to find that while clones from some contiguous districts such as Lira and Soroti, Bushenyi, and Kasese were highly similar, other closely related clones were from disjunctive localities. The similarity of the clones in adjacent districts could be explained by local exchange of germplasm while similarity of clones in noncontiguous districts is probably the result of more purposeful and selective transfer of planting material. If we assume that a single clone of "Sukali Ndizi" was introduced into Uganda, then the observed variation is possibly due to somatic mutations.

Pillay, M., J. Hartman, C. Dimkpa, and D. Makumbi. 2003. Sukali Ndizi is a triploid with an AAB genome composition. African Crop Science Journal 11: 119–124.

Abstract: Cultivated bananas originated from interspecific hybridization of two wild diploid ($2n = 2x = 22$) species, *Musa acuminata* and *M. balbisiana* that were the donors of the A and B genomes, respectively. Most cultivated bananas are triploids with $2n = 3x = 33$ chromosomes. Banana improvement programs make use of interspecific hybridization for gene introgression. Consequently knowledge of the exact ploidy level and genome composition of a plant is important for breeding purposes. The ploidy level of a plant can be determined in two ways: (1) by a physical count of its chromosomes, and (2) by flow cytometry. In this study, the ploidy level of the dessert banana cultivar, Sukali Ndizi, was determined by conventional chromosome analysis and flow cytometry. Our results showed that Sukali Ndizi is a triploid. In the past, Sukali Ndizi was considered to be a diploid with an AB genome composition. We also determined the genome composition using a set of RAPD (random amplified polymorphic DNA) markers and found that it has an AAB genome composition.

Sseruwagi, P., W.S. Sserubombwe, J.P. Legg, J. Ndunguru, and J.M. Thresh. 2003. Methods of surveying the incidence and severity of cassava mosaic disease and whitefly vector populations on cassava in Africa: a review. Virus Research (in press).

Ude, G., M. Pillay, E. Ogundiwin, and A. Tenkouano A. 2003. Genetic diversity in a core African plantain collection using AFLP and RAPD markers. Theor. Appl Genet 107: 248–255.

Abstract. Fifteen AFLP primer pairs (*Eco*RI+3 and *Mse*I+3) and sixty 10-mer RAPD primers were used to detect polymorphisms and assess genetic relationships in a sample of 25 plantains from diverse parts of Western and Central Africa.. The discriminatory power of the AFLP technique was greater than that of the RAPD technique, since the former produced markers with greater polymorphic information content (PIC) than the latter. Hence, AFLP analysis appeared to be a more powerful approach for identifying genetic differences among plantain accessions. In this regard, significant genetic diversity within the plantains was shown by unweighted pair-group method of arithmetic averages (UPGMA) and multidimensional principal coordinate (PCO) analyses. The AFLP derived clusters indicated closer relationships between similar inflorescence types than the RAPD derived clusters. A small group of cultivars mainly from Cameroon were separated from the bulk of other plantains, suggesting that Cameroon may harbor accessions with useful or rare genes for widening the genetic base of breeding populations derived from plantains. A greater effort should be directed at collecting and characterizing plantain cultivars from Cameroon.

Book chapter, peer-reviewed

Legg, J.P., D.Gerling, and P.N. Neuenschwander. 2003. Biological control of whiteflies in sub-Saharan Africa. Pages 87-100 *in* Biological Control in IPM Systems in Africa, edited by P. Neuenschwander, C. Borgemeister, and J. Langewald. CABI, Wallingford, UK.

Conference papers, workshop proceedings, abstracts, newsletters

Abele, S., B. Bashaasha, and C. Gold. 2003. The need for improved marketing and processing to enhance rural livelihoods in Africa. Paper presented at the Workshop on Improved Banana Marketing and Utilization, 2–3 October 2003, Kampala, Uganda.

Abstract. Sub-Saharan Africa has the world's weakest agricultural performance, including lowest per capita calorie supply, and trade participation. Future prospects on world markets are bleak, as the 2002 US farm bill and the 2003 EU CAP reform are unlikely to reduce surplus pressure and thus will continue to hamper African agricultural exports and finally the commercialization of Africa's agriculture.

But problems are not only external in origin. Efficiency in African agriculture is low, processing is poor, and trade is hampered by poorly functioning institutions. Studies have proved that the removal of collusion, corruption, and poor infrastructure are more effective in stimulating agricultural trade than lowering tariffs. Public investments in infrastructure and market information systems are required. Competition must be fostered and institutional failures rectified. Promising new agrobusinesses are often hampered by poor access to credit and finance due to poorly developed capital markets. Increasing rural investment by combining public and private finance schemes could help foster competition by assisting new competitors through their "infant years".

Abele, S., U. Fiege, and K. Reinsberg. 2003. The impact of agricultural development on agricultural employment and rural labor markets: evidence from Eastern Europe and Africa. Poster presented at the International Agricultural Research for Development Conference, 8–10 October 2003, Goettingen, Germany: http:// www.tropentag.de/abstracts/full/354.pdf.

Abstract. Agricultural employment is the decisive factor for rural well-being in developing countries as well as in many eastern European transition countries. This is because, differently from Western Europe, there are, in many regions, almost no other employment opportunities than farming. Therefore, the decrease of agricultural employment opportunities yields social and economic distress, especially for the most vulnerable, the landless, and the small-scale farmers who have to seek supplementary income from working casually on other farms.

But agricultural employment is subject to many factors. Labor hiring is strongly affected by short-term productivity developments. Structural adjustment in the agricultural sector decreases labor by substituting it with capital.

This contribution analyses the effects of agricultural development on agricultural labor markets and thus on rural employment. It gives evidence from two regions that may seem different at first glance, but show surprising similarities: Eastern Europe and Western Africa, especially Niger. Using the method of calculating short-term and long-term labor demand elasticity for the agricultural sector, effects of both short-term distortions (e.g., price or yield declines) and long-term adjustments are assessed.

For both regions, it can be shown that short-term distortions in agricultural productivity, mainly caused by price decline, lead to a sharp decrease in hired labor employment. The following structural adjustment mostly leads to a substitution of labor by capital. Consequently, when the initial productivity losses are compensated, less labor than before is employed at the same productivity level so that the net effect is a decline in agricultural employment over time.

Based on this knowledge, recommendations are given for both Eastern Europe and West Africa. It is most important to establish a balanced structural policy that aims at both improving agricultural efficiency and creating off-farm labor, e.g., in the downstream sector.

Benesi, I.R.M., M.T. Labuschagne, N.M. Mahungu, A.G.O. Dixon, and C.D. Viljoen. 2003. Genetic distance analysis of elite Malawi cassava (*Manihot esculenta* Crantz) genotypes using morphological and AFLP marker techniques. Page 166 *in* Book of Abstracts. Arnel R. Hallauer International Symposium on Plant Breeding, 17–22 August 2003, Mexico City.

Ferris, S., S. Abele, and P. Robbins. 2003. Developing market information services as a first step in meeting the challenges of globalization in the small-scale farming sector of sub-Saharan Africa. Presentation on the Mini-Symposium "Market research for the development of commercialized agriculture in Sub-Saharan Africa", 25th IAAE-conference, 16–22 August 2003, Durban, South Africa.

Abstract. Globalization is the term used to describe the recent impact of innovations in communications and transport systems on trade and the increasing integration of world markets. Whilst it has been proved that increased economic liberalization and openness

leads to growth, it is also recognized that for many developing countries, liberalization has caused serious economic difficulties. A combination of structural adjustment programs and partial reform of international trade policies has had the overall effect of reducing the prices of primary commodities exported by many African countries. These effects combined with localized insecurity have also led to significantly increased imports of agricultural products, from more competitive producers, some of which remain highly subsidized. The result of oversupply of the commodities markets has led to commodity prices falling to their lowest levels in 40 years. This bleak situation is reflected in the dramatically falling terms of trade for many African countries and suggests a profound downturn in their economic outlook. At the same time, the profits of international trading processing houses and retail companies in developed countries have shown year on increases. The international community has recognized these marketing difficulties and is designing tariff reducing trading opportunities for LDCs and is attempting to reform agricultural support programs in a package that will assist developing countries to overcome them.

Despite these new trading initiatives, it is the view of the authors that many African countries have not fully appreciated the scale and implications of globalization on their futures and that, without urgent action on their part; they may seriously weaken their economies in the years ahead. Options for improving the competitiveness of small-scale agricultural producers in SSA, include (i) Improving the negotiating powers of LDCs for global trade, (ii) Managing the oversupply of primary product exports, (iii) Stimulating production for exports of added-value products, (iv) Strengthening internal institutions, especially markets. It can be shown that African trade is not only hampered from outside, but there are also severe impediments arising from inefficient structures inside African trade systems, such as collusion, taxation and trade policies, poor infrastructure, and poor market information. It is therefore vital to improve African markets by providing access for new actors such as businessmen and farmers' trade cooperatives, and to improve market information services, and (v) Reducing imports of goods that can be competitively produced domestically.

To make gains in any of these areas, African governments need to initiate practical, stepwise processes, in partnership with donors, NGOs, and private sector associations, to gradually shift their agricultural sectors to a more competitive basis. The way this reform process is both planned and implemented is particularly important in those countries that rely upon many millions of small-scale producers. As a starting point, this paper focuses on the opportunities for assisting small-scale farmers and small- to medium-scale traders to improve their understanding of market conditions and signals, through the provision of integrated market information services that target the specific needs of producers, processors, and traders. This educational/information based approach to market reform is considered a relatively low cost and practical means of supporting the different types of actors along the market chain, to gain a better understanding of the marketing dynamics that affect their ability to trade profitably, and to provide them with the necessary decision support tools for them to engage more effectively in the marketplace.

Gondwe, F.M.T., N.M. Mahungu, R.J. Hillocks, M.D. Raya, C.C. Moyo, M.M. Soko, F.P. Chipungu, and I.R.M. Benesi. 2003. Economic losses experienced by small-scale farmers in Malawi due to cassava brown streak virus disease. Pages 28–38 *in* Cassava Brown Streak Virus Disease: Past, Present and Future, edited by J.P.

Legg and R.J. Hillocks. Proceedings of an International Workshop, 27–30 October 2002, Mombasa, Kenya.

Kajumba, C., C. Gold, P.R. Speijer, W. Tushemereirwe, D. Coyne, A.R. Semana, and J. Mudiope. 2003. Farmers' perception on use of banana clean planting material for pest management in Uganda. *In* Integrated Pest Management Conference Proceedings, IPM Conference, edited by J.S. Tenywa, M.P. Nampala, S. Kyamanywa, and M. Osiru, 8–12 September 2002, Kampala, Uganda (in press).

The East African highland banana (*Musa* genome group AAA-EA) is a staple crop in the Ugandan diet consumed by a large proportion of the population. Banana weevils (Cosmopolites sordidus) and nematodes (especially the aggressive *Radopholus similis*) have been observed to reduce production. These are often and easily transferred to new fields through infested planting material. To address this constraint, an inexpensive and affordable method using clean planting material was developed and disseminated to farmers in three districts, i.e., Ntungamo, Mpigi, and Luweero. In these districts, approximately 1000 farmers were trained on the use of clean planting material technology using a farmer participatory approach. Farmers then established banana fields using clean planting material. From the study, a total of 180 farmers were interviewed on their opinions on the technology. Among the positive observations, 13% and 34% observed that the technology led to reduced pests and improved yields, respectively. Some of the negative observations by the farmers included drought susceptibility (19%) and 6% observed that they were more susceptible to livestock. According to the farmers' perceptions, the technology was appropriate and worthwhile under their circumstances, managed pests, improved banana yields, and proved profitable.

Kanju, E.E., E. Masumba, M. Masawe, S. Tollano, B. Muli, A. Zacarias, N. Mahungu, B. Khizzah, J. Whyte, and A. Dixon. Breeding cassava for brown streak resistance: regional cassava variety development strategy based on farmers'/consumers' preferences. Proceedings of the 13th symposium of the International Society for Tropical Root Crops, 10–14 November 2003, Arusha, Tanzania (in press).

Abstract: Cassava is an important food crop in the East African coastal lowlands. However, yields are low due to various reasons amongst which are pests and diseases. Cassava brown streak virus disease (CBSD) is one of the major diseases of economic importance in Kenya, Malawi, Mozambique, and Tanzania. Yield losses attributed to CBSD ranging from 49 to 74% have recently been reported in some coastal areas of Tanzania. It is estimated that in Tanzania alone, CBSD causes economic losses of more than USD 16 000 000 annually. The wide adoption of resistant varieties is the best sustainable control strategy. However, only a handfull of resistant/tolerant varieties is available in each of the severely affected countries. In order to increase the number of resistant varieties available to farmers, a seedling nursery was raised at Kibaha, Tanzania. About 513 seedlings were selected and cloned for further evaluation. At Kibaha, CBSD disease pressure and spread was very high therefore, 88% of the harvested seedlings were infected. This indicated that this site was ideal for screening cassava genotypes for resistance to CBSD. Although the vector is still unknown, it was very active and infective at this site. Because the seedlings were raised from botanical seeds, ruling out the chance of seedborne transmission, these results prove that vector transmission can account for a large percentage of plants infected in a field. Families with a high percentage of number of seedlings selected (PNSS) included Kiroba, 71762, and I88/00188. The importance of marking diseased seedlings during the growing season is discussed. Furthermore, massive introduction of germplasm through open quarantine, the establishment of crossing blocks to generate improved genotypes, and the use of a decentralized participatory evaluation procedure have been initiated as important strategies towards availing farmers of a wider choice of improved varieties.

Kanju, E.E., J. Whyte, and A. Dixon. 2003. Is resistance/tolerance of cassava to brown streak disease associated with the zigzag stem trait? ROOTS Newsletter 8(2): 15–19.

Abstract. Cassava brown streak disease (CBSD) first reported from Amani, Tanzania in 1936, is now considered to be one of the major biotic constraints to cassava production especially in the coastal lowlands of East and Southern Africa. Efforts to develop resistant varieties as the major control measure for CBSD started way back in the 1940s including intraspecific crosses, which, however, resulted only in few varieties with field tolerance to brown streak. In efforts to improve breeding efficiency, some researchers have investigated the correlation between morphological traits and resistance to CBSD. The zigzag stem growth habit is one of the marker genes identified in cassava. Marker genes control the expression of traits which can be easily classified into distinct states, each controlled by a different allele, and whose expression is little influenced by the environment. There is evidence to suggest that a single recessive gene (zz) controls the zigzag stem. Field observations have started to reveal that most of the cultivars, which are tolerant/resistant to CBSD, are heterozygous (Zz) for the zigzag stem characteristics. In Tanzania, the following cultivars that are tolerant to CBSD are all heterozygotes: Kigoma Mafia, Nanchinyaya, Kiroba, TMS 30001, and Amani 46106/27. In Kenya, two cultivars that are tolerant to CBSD are also heterozygotes: Kaleso (Amani 46106/27) and Kahoteli. Furthermore, in Mozambique two cultivars that are tolerant to CBSD are heterozygotes: Mulaleia and Macia 1. These observations imply that there is a strong possibility that the gene conferring resistance to CBSD is linked to the "z" allele. However, the heterozygote in most cases has a normal stem growth habit. Therefore, if it is true that the "z" allele confers resistance/tolerance to CBSD, it may prove difficult to use this correlation by visual scoring of clones.

Further evidence is needed to prove the association between CBSD resistance/tolerance and the zigzag stem trait. Rapid genetic progress will be made in breeding for resistance to CBSD if this association is proven.

Mahungu, N.M., M. Bidiaka, H. Tat, S. Lukombo, and S. N'luta. 2003. Cassava brown streak disease-like symptoms in Democratic Republic of Congo. ROOTS Newsletter 8(2): 8–10.

Niere, B., C. Gold, and D. Coyne. 2003. Endophytes and banana IPM: Current status and future prospects. Pages 171–178 *in* Integrated Pest Management Conference Proceedings, IPM Conference, edited by J.S. Tenywa, M.P. Nampala, S. Kyamanywa, and M. Osiru, 8-12 September 2002, Kampala, Uganda.

Endophytic fungi colonize living plant tissue without causing symptoms of damage to their hosts. Endophytic fungi have been isolated from all plants investigated and mutualistic relationships of fungal endophytes with their host plant could be demonstrated. Studies on banana material originating from Uganda have shown that banana corm and root tissue hosts a variety of endophytic fungi. Preliminary results in Uganda have shown that indigenous endophytic fungi from banana can effectively colonize tissue-cultured banana when plants are inoculated at an early stage. Inoculation could lead, depending on fungal

isolate and banana clone, to increased plant growth, reduced nematode multiplication, and reduced weevil damage. Control levels vary between fungal species and strains and host–endophyte interactions influence chances of success. Interactions of the fungi with their host plant and weevils and nematodes, respectively, and the mechanisms leading to effective control are not well understood. Similarly, the duration of protection provided by the endophyte to the plant is not known at present. Currently, research focuses on the inoculation of single strains onto endophyte-free planting material, such as tissue-cultured plants, and targets the initial period of plant establishment in the field. As our knowledge of the microbial biodiversity inside the plant increases, combinations of different fungal strains or species might be used in the future. This will help to achieve different levels of control for a number of pests and also to target specific periods. Long-term control might involve persistence of the fungal endophyte or the activation of effective and durable plant defense responses to pests. Ideally, fungal endophytes are applied only once and persist within the host plant to ensure protection for a considerable or the entire time span of the crop. This is a major advantage to biocontrol agents/biopesticides, which are more costly to produce, have to be applied more frequently, and are often highly influenced by environmental factors. The use of fungal endophytes also reduces the risk of side effects on nontarget crops and humans as no field applications are required. The use of indigenous strains further limits environmental risks. Acceptability of endophytes for pest control is therefore considered high from an environmental and economic point of view. Research at the International Institute of Tropical Agriculture in Uganda focuses on the identification of fungal endophytes that are effective against a number of pests and diseases of banana and the mechanisms leading to biocontrol. One of our prime objectives is the optimization and integration of this new technology into agricultural systems in East Africa. Management of endophytes must be seen as one component in IPM strategies and has to be combined with other control options such as tissue-cultured planting material.

Ntawuruhunga, P., J.B.A. Whyte, and P. Rubaihayo. 2003. Effects of altitude and plant age on cyanogenic potential, dry matter, starch and sugar content in cassava genotypes. Presented at the 13th Symposium of the International Society for Tropical Root Crops (ISTRC), 10–14 November 2003, Arusha Tanzania.

Abstract. A study was conducted at three locations in Uganda (Bulisa: 650 m asl; Namulonge: 1150 m asl, and Kapchorwa: 1750 m asl) to evaluate the effect of altitude on dry matter, starch and sugar content, and cyanogenic potential in cassava. Ten clones from five different sources were used in a randomized complete block design with three replications, and data were repeatedly measured at three monthly intervals up to 15 months after planting. The mixed model analysis indicated significant ($P < 0.001$) differences among genotypes at each elevation for dry matter production. Significant interaction between plant age and source and between genotypes within source and plant age at all elevations indicated genotypic differences among sources a well as among genotypes within sources in production and partitioning of assimilates. The study indicated that dry matter content was higher at high altitude than at low and midaltitude. Highly significant ($P < 0.001$) differences for CNP were also observed between sources and among genotypes within source at midaltitude. Plant age effect was significant for CNP. Significant ($P < 0.001$) interactions between plant age with source and with genotypes nested within source indicated that genotypes as well sources produced different amount of CNP during plant growth cycle, obtaining high levels at all elevations at around six months after planting. The study also showed that starch and sugar contents were high at higher altitude than at low and midaltitude,

a similar trend observed with dry matter content. This study showed that there is a need of further physiological investigation for a better explanation.

Ntawuruhunga, P., J.P. Legg, J. Mabanza, and A.J.C. Mvila. 2004. IITA's efforts in mitigating cassava mosaic disease crisis in the Republic of Congo-Brazzaville: A poster presented at the Sixth International Scientific Meeting of the Cassava Biotechnology Network (CBN), 8–14 March 2004, CIAT, Cali, Colombia.

Abstract. Cassava (Manihot esculenta Crantz) is the main food staple and source of income of the population of the Republic of Congo. It constitutes the backbone of the farming system and the main commodity of the Congo population. Its consumption per capita is the highest on the continent. However, since 1997/98 the cassava mosaic virus disease (CMD) has become the most important constraint to production following a period of unrests that complicated food security causing food shortage in the country.

The USA Embassy in Brazzaville requested an urgent intervention from the Office of United States Foreign Disaster Assistance (OFDA) through the Cassava Mosaic project managed by the International Institute of Tropical Agriculture (IITA) in East Africa. Subsequently, IITA conducted two follow-up diagnostic surveys in 2002 and 2003 that have shown that severe virus strain (EACMV-Ug or Uganda Variant) associated with the East African pandemic is the most important devastating disease constraint and had spread throughout the country. With limited funds, mitigation efforts were deployed through different activities: introductions of IITA resistant germplasm, collection of national germplasm, its evaluation under hotspots of the disease, and multiplication of tolerant cultivars accompanied with activities of sensitization through training programs of personnel and farmers.

Ntawuruhunga, P., J.B.A. Whyte, and P. Rubaihayo. 2003. Correlation and principal components studies of some plants attributes at early plant growth in cassava. Presented at the 6th Africa Crop Science Society Conference, 12–17 October 2003, Nairobi, Kenya.

Abstract. A potted experiment was conducted at Sendusu farm of ESARC to determine morphological and physiological determinants of yield performance using two genotypes from five sources of origin viz. East African lowland, midaltitude, highland, and West African lowland and midaltitude. A randomized block design with three replications was used. The results showed variability among genotypes in all the characteristics evaluated. Significant differences ($P < 0.001$) among sources for sprouting, plant height, leaf area, potential storage root, storage root formation, and differentiation were observed. The genotypes within sources did not differ significantly, indicating the importance of environmental source in guiding genotype development and germplasm exchange. Simple correlation and principal component analyses revealed that the meristem width played a key role in controlling plant development and storage root differentiation. Principal component analysis grouped the different cassava plant traits in three categories, (1) plant biomass (plant height, leaf area, and leaf dry matter), (2) plant physiology (meristem width, length, and volume) and (3) plant underground (total number of root and potential storage root). The findings will be used in guiding cassava breeding and selection at early stages.

Pillay, M., A. Tenkouano D. Makumbi, and P. Ragama. 2003. Genotype × Environment interactions in multilocational testing of *Musa* hybrids in three sites in Uganda. 6th African Crop Science Society Meeting, 12–17 October 2003, Nairobi, Kenya.

Abstract. Banana is an important starchy staple and income-earning crop in the highlands of East Africa. The crop is affected by a number of diseases and pests that are responsible for declining yields. The development and deployment of resistant hybrid cultivars is considered the most economically feasible way of enhancing banana production in East Africa. The challenge facing breeders is to select hybrids that will perform well in various agroecologies. Multilocational evaluation trials (MET) were set up to evaluate the stability of hybrids. The objective of this study was to determine genotype × environment interactions for bunch weights, fruit filling time, and black Sigatoka resistance in *Musa*. Fourteen genotypes were studied in three different ecoregions in Uganda. The experimental layout was a randomized complete block design with three replications and 10 plants per genotype. Data on various growth, disease, and yield components were collected over three cycles. Bunch weights varied amongst the hybrids within each site. Bunch weights were influenced by altitude and were greater at higher elevations. Fruit filling times also varied across the three locations and seemed to be dependent on altitude. Plants grown at higher elevations were observed to have longer fruit filling times. All the hybrids took longer to reach maturity than the control landrace in all three locations. The index of nonspotted leaves at flowering showed that all the hybrids were less susceptible to black Sigatoka than the control landrace. This was not unexpected since most of the hybrids had Sigatoka-resistant genes introgressed from a wild diploid species.

Talengera, D., M. Pillay, and C. Kasozi. 2003. Genetic diversity studies in East African highland bananas using RAPD markers. 6th African Crop Science Society Meeting, 12–17 October 2003, Nairobi, Kenya.

Abstract. Banana is a major staple food crop in the highlands of East Africa. The genetic diversity in the crop has not been investigated in detail. In this study we used the RAPD (random amplified polymorphic DNA) technique to assess the genetic diversity and relationships in banana germplasm from Uganda. Genetic relationships among the cultivars are useful to determine parents that could be used in a program breeding for superior hybrids with disease and pest resistance. DNA was extracted from 33 landraces using a modified CTAB procedure and amplified by PCR (polymerase chain reaction) using XX 10 base primers from OPERON Technologies. Gels were stained in ethidium bromide and photographed under UV light. The results showed that all the cultivars produced identical banding patterns with all the primers used in this study. These results suggest that the East African highland bananas in Uganda have a very narrow genetic base that may be due to domestication or genetic bottleneck effects. The results also showed that the DNA markers were not able to separate the "beer" and "matooke" bananas. Other multiplex DNA marker systems such as AFLP (amplified fragment length polymorphism) may have to be used to resolve differences in these unique bananas.

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Jeremiah, S.C., I. Ndyetabura, J.P. Legg, and H. Kulembeka. 2003. Monitoring the spread of severe mosaic diseases in the Lake zone of Tanzania. Page 185 *in* Abstract, 13th Symposium of the International Society for Tropical Root Crops, 10–14 November, Arusha, Tanzania.

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Owor, B., J.P. Legg, G. Okao-Okuja, R. Obonyo, and M. Ogenga-Latigo. 2003. Investigation of virus interactions and putative cross-protection through grafting and transmission studies with *Bemisia tabaci*. Page 62 *in* Abstract, 3rd International Bemisia Workshop, 17–20 March 2003, Barcelona, Spain.

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Semaganda, R., D. Gerling, J.P. Legg, S. Kyamanywa, and E. Adipala. 2003. Augmenting the activity of cassava whitefly parasitoids by intercropping cassava with sweetpotato. Page 39 in Abstract. 3rd International Bemisia Workshop, 17–20 March 2003, Barcelona, Spain.

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Sseruwagi, P., J.P. Legg, D. Rogan, and J.K. Brown. 2003. Molecular characterization and geographical distribution of cassava *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) genotypes in Uganda. Abstract, 6th African Crop Science Society Conference, 12–17 October 2003, Nairobi, Kenya.

Sseruwagi, P.P., J.P. Legg, C.M.E. Rey, J. Colvin, and J.K. Brown. 2003. Molecular variability of cassava *Bemisia tabaci* genotypes in East and Central Africa. Page 18 *in* Abstract, 3rd International *Bemisia* Workshop, 17–20 March, Barcelona, Spain.

Oral presentations

Coyne, D. 2003. Integrated nematode management in developing countries. First PINCNET-Africa Workshop, 21–26 September 2003, Ibadan, Nigeria. Oral presentation.

Coyne, D. 2003. Nematology research for development at IITA. First PINCNET-Africa Workshop, 21–26 September 2003, Ibadan, Nigeria. Oral presentation.

Coyne, D., J. Mudiope, and B. Hugues. 2003. Advances in yam and cassava nematology research at IITA. 16th Nematological Society of Southern Africa Symposium, 1–4 July 2003, Strand, South Africa. Oral presentation.

Dochez, C., J.B.A. Whyte, M. Pillay, D. Coyne, and D. De Waele. 2003. Reproductive fitness and pathogenic potential on *Musa* of different *Radophilis similis* populations from Uganda. Sixteenth Nematological Society of Southern Africa Symposium, 1–4 July 2003, Strand, South Africa. Oral paper presented by Dochez.

Mudiope, J., D. Coyne, E. Adipala, and R. Sikora. 2003. Pathogenicity of the lesion nematode, *Pratylenchus sudanensis* (Loof & Yassin) on Yam variety *Dioscorea rotundata*. Proceedings IV African Crop Science Conference, 12–17 October 2003, Nairobi, Kenya. Oral presentation by Mudiope.

Niere, B., C. Gold, and D. Coyne. 2003. Can fungal endophytes control soilborne pests in banana? IOBC, Bonn, Germany, 1–4 June 2003. Oral paper presented by Niere.

Paparu, P., N. Bjoern, C. Gold, D. Coyne, and E. Adipala. 2003. Colonization of banana by fungal endophytes. Proceedings IV African Crop Science Conference, 12–17 October, Nairobi, Kenya. Oral presentation by Paparu.

Extension/promotional material

Nematology at ITTA: research awareness poster. Coyne, D.
Nematology in *Musa* production: awareness poster. Coyne, D.
Pest identification sheet: insects on yam. Coyne, D. and L. Kenyon
Pest identification sheet: nematodes on yam. Coyne, D. and L. Kenyon
Pest identification sheet: fungal diseases on yam. Coyne, D. and L. Kenyon

Pest identification sheet: viruses on yam. Coyne, D., J. Hughes, and L. Kenyon
Yam pest identification poster: awareness poster. Coyne, D. and L. Kenyon

Training/ meeting/workshops

International (African) nematology workshop organized and conducted at IITA, Ibadan, 19–23 September 2003. Coorganized with University Gent, Belgium for Postgraduate International Nematology Course (PINC) African Alumni.

Mozambique (13–21 April). Training in nematology sampling and damage assessment for diagnostic survey on cassava for INIA technician, 13–21 April 2003, Maputo, Mozambique.