REPORT

Tanzania – Kenya Survey Mission
Coconut Lethal Yellowing Diseases

26.06.2007 to 05.07.2007

CIRAD Incentive Action 2007

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For the very smooth running of our mission in Tanzania, our sincere thanks to Dr Anatolia Mpunami, from MARI in Dar-es-Salaam. Thanks also to Dr Alois Kulaya, Director of MARI, for the warm welcome.

We thank Dr Muniu for welcoming us to the KARI research station at Mtwapa (Kenya) and for accompanying us on field visits along the coast to the north and south of Mombasa. Our thanks also to Dr Lusike A. Wasilwa, at KARI in Nairobi for her interest in our mission.

Lastly, we thank His Excellency the French Ambassador in Tanzania, and the staff of the cooperation and cultural service (SCAC) for seeing us, along with the SCAC at the Embassy in Nairobi.

Summary

The main aims of this survey mission in Tanzania and Kenya were:

1. Estimate coconut Lethal Yellowing incidence in those two countries

2. Assess the possibility of working together with the different institutes in those two countries.

On the whole, the coconut plantings in Tanzania are quite old, with a large proportion of palms around sixty years old. The disease would seem to be spreading quite rapidly in the South of the country, whereas its development seems to be more limited in the North (Tanga region, near Kenya).
In Kenya, the coconut plantings north of Mombasa are only around thirty years old and seem to be in very good phytosanitary condition. As in northern Tanzania, the coconut palms south of Mombasa are often much older, and although numerous crownless palms were seen, the responsibility of Lethal Yellowing is not obvious. However, some typical Lethal Yellowing symptoms were seen on some coconut palms around ten years old, but they were isolated cases and no large active focus was found.

The Tanzanians at the Mikochini Agricultural Research Institute – MARI - in Dar-es-Salaam have wide experience of research on coconut Lethal Yellowing diseases (known locally as Lethal Decline Tanzania - LDT). Although largely abandoned due to Tanzanian government disinterest in the coconut supply chain and a lack of funding to continue research on the disease, the Tanzanian researchers are highly motivated to reintegrate a research group working on this topic. The Kenyan researchers at KARI seem, in theory, to have little interest in the coconut supply chain at the moment and most of them are not aware what coconut Lethal Yellowing is. Yet, a recent study under the aegis of the Danish International Development Agency and the Coast Development Authority showed that the importance of the coconut supply chain in Kenya had been largely underestimated and that it had highly promising potential for development. Kenyan coconut plantations have been regularly replanted and LDT is not very active in them.

There seems to exist a fairly strong contrast in the possibilities of working on decay diseases of the coconut Lethal Yellowing type in these two countries. The molecular biology laboratory at MARI in Tanzania is very well equipped and the research teams are very active, and at least three researchers have very good experience of LDT. In Kenya, during our short visit, we only saw laboratories that were not particularly well equipped, with limited research operations. No experience of Lethal Yellowing was found there. However, not all possibilities in Kenya were explored (University, ICIPE,

etc.). Collaboration with Tanzania, under a regional project involving Kenya, Tanzania and Mozambique can be considered, centred on Tanzania and the MARI laboratories. The possibility of MARI and CIRAD Research Unit 29 jointly submitting a regional programme to the Common Fund for Commodities was discussed.

People met:

Tanzania

Dr Mohammed A. M. Msabaha, Assistant Director, Crop Research, Ministry of Agriculture

Dr Niakunga, Assistant Director, Crop Health Protection

French Ambassador in Tanzania, Mr Jacques Champagne de Labriolle

Patrick Thomas, SCAC Advisor, French Embassy in Tanzania

Raymond Lataste, Sciences and Education Attaché, French Embassy in Tanzania

Dr Alois Kullaya, MARI, Director

Dr Anatolia Mpunami, Scientist, MARI

Dr Julius Mugini, Scientist, Mari

Dr Suberu Seguni, Scientist, Mari

Mr Newton A. S. Temu, Technologist, MARI

Stéphanie Duvail, Researcher, IRD

Kenya

Dr P. T. Gicheru, Centre Director, National Agricultural Research Labs., Nairobi

Dr Lusike A. Wasilwa, Assistant Director, Horticulture and Industrial Crops Division, KARI, Nairobi

Dr Rahab W. Muinga, Centre Director, KARI, Mtwapa,

Dr F. K. Muniu, KARI Mtwapa

Dr Powon Micah Pkopus, Centre Director, KARI, Matuga

Mr Rindano Maingu, in charge of agriculture, KARI, Matuga

Mr Kalem Omundi, MOFA, in charge of Kololeni district

Cyrille Le Deaut, Cooperation Attaché, French Embassy in Kenya, Nairobi

Schedule

26.06.2007: Paris – Dar-es-Salaam

27.06.2007: - Visit to MARI. Met by Dr A. Kullaya and Dr A. Mpunani
Ministry of Agriculture, Department of Crop Research and Department of Plant Health Services

- MARI, presentation of research programmes by Dr A. Mpunami

- University of Dar-es-Salaam, meeting with S. Duvail, IRD

28.06.2007: - Tour of the MARI research laboratories
Departure to the south of Dar-es-Salaam: Sotele, Kifumangao (or Kif'ngao), Mbinga

29.06.2007: - French Embassy
- Tour of the MARI technology workshop

- Departure for the North. Visit to the MARI Chambezi station. Travel as far as Tanga

30.06.2007: - Visit to coconut plantations to the north of Tanga heading towards Kenya -Vuo-, south of Tanga – Mwambani; Livestock Breeding Station; Pongwe Station; Mlingano Station (main research station of NCDP). Vicinity of Tanga, Vuo, Livestock Breeding Station.
Return to Dar-es-Salaam

01.07.2007: - Dar-es-Salaam – Nairobi- Mombasa by air

02.07.2007: - KARI Research Station at Mtwapa near Mombasa.

Visit to coconut plantations to the northwest of Mombasa -Rabai, Kaoleni

03.07.2007: - Visit to coconut plantations to the south of Mombasa, as far as Ramisi near the Tanzanian border
Tanzanian border -

- Visit to the KARI station at Matuga

- Visit to the Ukunda Youth Polytechnic

- Evening: Departure for Nairobi by air

04.07.2007: - French Embassy -
- Different KARI units
- Evening: flight Nairobi-Amsterdam

05.07.2007: - Arrival in Paris / Montpellier

1. Tanzania

1.1 Background of the coconut palm and Lethal Decline in Tanzania

Tanzanian coconut plantings are mostly old and suffering from drought. The dry season from June to November is increasingly intense and, in 2006, many coconut palms were killed by drought, their death favoured by the desperate physiological condition of the majority of those palms, which were more than 40 years old (40 to 60 years old, or even older), most of which had never received a single application of fertilizer. In fact, pencil point symptoms are very often seen, i.e. the stem becomes increasingly slender towards the top, which is typical of severe deficiencies. These palms generally bear few fronds and produce a very small number of nuts. Moreover, they are often attacked by *Oryctes* beetles (FIGs 1, 2 and 3).

The first report on a syndrome of the type "Lethal Disease in Tanzania" (LDT) dates from 1905 in the North of the country, in the Tanga region. After that, cases were reported sporadically, both in the South near the Mozambican border (1907) and in the centre of the country. But for many years, the degree and spread of the disease have not been the same to the north and south of Dar-es-Salaam. Whilst the disease is currently spreading very actively in developing foci in the South, in the regions of Rufiji District and Kilwa District (we were not able to go there due to traffic problems and limited time), in the North LDT seems to occur at the moment in isolated cases with groups of 3 to 5 diseased coconut palms.

There may be various reasons for that difference. In theory, it could be due to a difference between one or two, or even three, components in the plant-vector-pathogen system.

Varietal difference has been considered by MARI as possibly being the source of these differences. The main reason lies in the different background of the coconut palms in the South and those in the North. The palms in the North were introduced and grown very early – as early as the 1400s – by the Persians. The Sultanate of Oman then controlled the region for many years and favoured the introduction of seednuts from southern Asia, most probably from India and/or the islands of the Indian Ocean and surrounding countries. The coconut plantations in the Pangani-Tanga region – the current border with Kenya, in the North, and the neighbouring islands of Pemba and Zanzibar, are doubtless among the oldest on the African continent. On the other hand, the coconut palms south of Dar-es-Salaam would seem to have been mainly planted and cultivated from the beginning of the 20th century onwards, particularly by the Germans. Most of the seednuts in the South apparently came from the island of Mafia.

Studies conducted by MARI (NCDP at the time) in the 70s-80s, then with the Germans and Spanish in the 90s showed that substantial diversity existed, with currently at least 29 "populations" of "East African Tall" types and two "Dwarf" populations in Tanzania (Duran *et al.* 1997, A. Mpunami personal communication).

FIG.1 (F.Pilet)

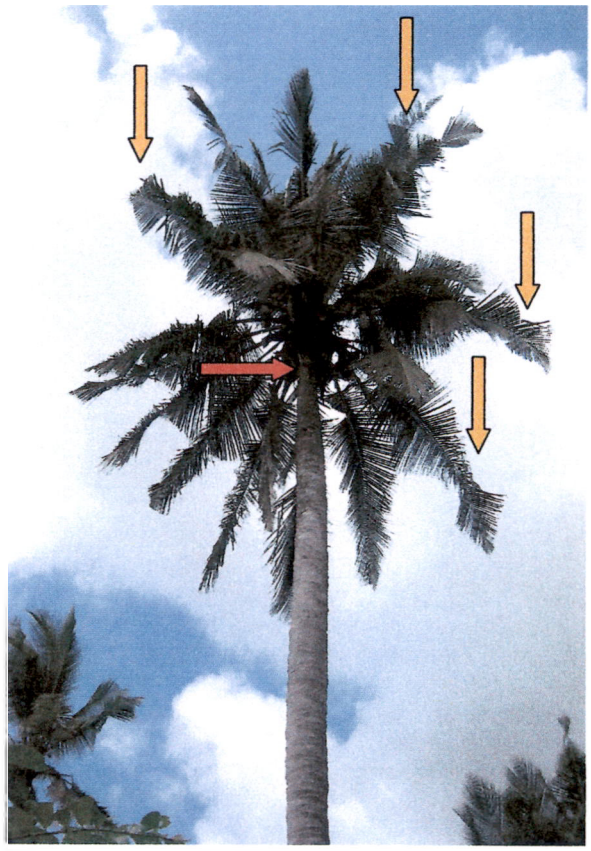

FIG.2 (M. Dollet)

Pencil point symptoms → *Oryctes* attacks →

FIG. 3 (M. Dollet) Old coconut palms near Dar-es-Salaam

1.2 MARI in Dar-es-Salaam

1.2.1. General

The Mikochini Agricultural Research Institute (MARI) in Dar-es-Salaam is an agricultural research centre that took over from the National Coconut Development Programme (NCDP) in the 80s. It is run by Dr Alois Kullaya. The NCDP was located at Tanga on the north coast. It benefited for several years running from subsidies provided by GTZ (Germany) and a Dutch researcher from the ex-Lethal Yellowing team in Jamaica spent several years working on coconut Lethal Decline in Tanzania (LDT) within that set-up. That project made it possible to establish the basis for a laboratory, run by Dr Anatolia Mpunami, which we were able to visit.

It has complete and operational equipment: PCR and electrophoresis instruments, an automatic Elisa reader, -20°C and -80°C freezers, centrifuges, along with power inverters and all the basic equipment. It is also worth noting that the centre has a liquid nitrogen supplier in Dar-es-Salaam.

However, since 2004, MARI has not had any funding for coconut research. No Tanzanian body took over from GTZ and, according to the information obtained, it would seem that the coconut supply chain has been somewhat forsaken by the Ministry of Agriculture.

1.2.2. Tour of the laboratories

a. *In vitro* culture laboratory

The laboratory is not intended for the production of *in vitro* plantlets, or to carry out any true fundamental IVC work. It is rather a practical work room for students. Among others, some of the plants used are; banana, cassava, vanilla and pineapple.

b. Crop protection - Pathology

Without funding to continue its LDT research, the laboratory has turned to other subjects for which it has received funding, such as Rice Yellow Mottle Virus -RYMV- (Rockfeller foundation) and a project on banana funded by the Bill Gates foundation. They are also working on African Cassava Mosaic with IITA, one of whose researchers is currently being hosted by the laboratory.

These two laboratories are under the authority of A. Mpunami, who worked on her thesis in the 1990s, partly at the University of Dar-es-Salaam, and partly at Rothamsted and Nottingham in the UK. There is a great deal of activity going on with numerous students: 2 PhD, 3 MSc and 5 BSc.

c. Entomology

Several trials on LDT transmission by insects - after an inventory of the entomofauna associated with coconut palms - were carried out over the GTZ period. The trials drew a blank.

A search for LDT phytoplasmas in the insects suspected of possible transmission has been carried out by the plant pathology laboratory. The DNAs of insects ground up in batches of five were tested using PCR with 16S rDNA primers by Rohde *et al.* (1993). Two species were found to carry phytoplasmas, one identified as *Meenoplus* senso latu and the other being a Derbidae of the genus *Diostrombus (D. mkurangai)*. The percentage of insects harbouring phytoplasmas was higher for the first species mentioned (28.6% of the batches of 5) (Mpunami *et al.* 2000). In fact, that species was apparently wrongly identified at the outset and is apparently a *Diostrombus*. However, no transmission trial in which those two species were released into cages resulted in the disease being reproduced. As regards the vector, the conclusion that always recurs in reports over the last 20 years seems to be that the vector insect cannot be a good flyer since:

1°) The disease spreads much more quickly in young plantations than in old plantations where the palms are tall.

2°) Disease spread sometimes seems to be slowed down by gaps without coconut palms, such as swamps or deltas.

At the moment, according to Dr. Seburu Seguni, an entomologist from MARI, the main entomological worries for coconut are:

c-1. Coreid bugs

This insect causes severe nut-fall on coconut palms and is now attacking cashew trees. Some interesting work has been undertaken to achieve integrated control combining insecticide treatments, ants and intercrops *(Citrus)* linking the *Citrus* trees to the coconut palms by a wire to facilitate the movement of ants. An extension brochure on this control method is supplied to farmers in Swahili (FIG. 4).

c-2. *Oryctes* (beetle)

Oryctes damage is worse in Tanzania due to the number of dead coconut palms killed either by LDT, drought, or old age. It is not rare to see coconut plantings in which more than a hundred palms display sometimes severe *Oryctes* damage on a large number of fronds (FIGs. 2, 3 and 4).

Several attempts at biological control with baculoviruses of various origins (Seychelles, Philippines and Western Samoa) have failed.

c-3. *Aceria guerreronis*

This mite is also considered as one of the major problems. However, we did not have an opportunity to verify that. MARI is working with APCC on the subject.

c-4. Whiteflies

Whiteflies, a new problem on coconut but also on other crops, are becoming increasingly serious. A large proportion of the lower fronds can now be completely covered with whiteflies. They hang down the stem (FIGs. 5 and 6). For the moment, there is not really any true research on this subject and control, where there is any, is somewhat by trial and error.

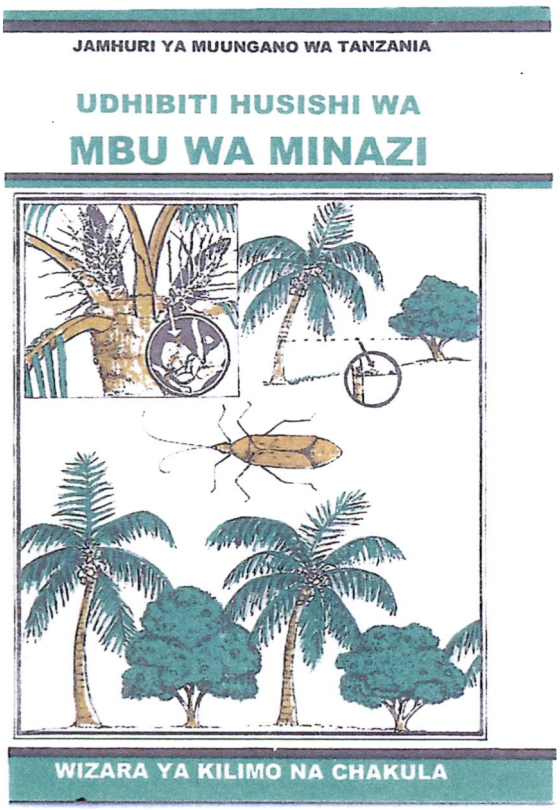

FIG.4
Brochure in Swahili published by MARI for Coreid bug control.

FIG.5
Coconut palm attacked by whiteflies (M. Dollet)

FIG. 6
Whitefly damage on lower fronds (M. Dollet).

1.2.3. Technology

Dr Tumu is in charge of coconut product matters and coconut supply chain marketing. MARI has embarked upon the production of virgin coconut oil, which it sells locally at 3,500 Tanzanian shillings (2 euros) per 250 ml. In their demonstration workshop there are 2 types of press, manual and hydraulic, along with a coconut grater working on the food shredder principle, which they have patented. However, the marketing and processing activities do not seem to be particularly aggressive.

1.2.4. Presentation by MARI researchers

On the afternoon of 27.06.2007, we attended a presentation of the results of MARI's work on LDT.

According to Dr Anatolia Mpunami, LDT has destroyed 40% of the coconut palms in Tanzania. That disease, like all "Lethal Yellowing" type diseases kills palms rapidly. Very little time passes between the first symptoms and the death of the palm.

MARI has discovered considerable diversity in coconut palms of the East African Tall (EAT) type using RAPD. That work has been continued by researchers at CIMA-Granja Modelo in Spain and at the Max Planck Institute in Cologne, Germany, which have analysed 48 EAT genotypes using microsatellite markers (Duran *et al.* 1997). MARI makes a distinction between 29 EAT populations and two varieties of Tanzanian Dwarf palms (Annex 1).

Different "exotic" varieties and hybrids have been tested for their reaction to LDT: 45 "Talls" and 10 "Dwarfs" and some hybrids, along with 29 EAT populations and 2 Tanzanian Dwarfs.

Five local EAT "sub-populations" are now classed as "LDT-tolerant": they are attacked less quickly than the others and die in smaller numbers. Those populations are known under the following code names:

- *"Vuo"*, from Tanga North region of the Tanzanian coast. Thirteen to 15 years after planting, this population remains, for the time being, attack-free at several sites, or only slightly attacked (2004 figures), whereas most of the other populations at the same sites exhibit losses of 19 to 100% (Table 1)
- *"LBS"* (Livestock Breeding Station near Tanga) (Table 1)
- *"Songosongo"* at Kilwa (south of Dar-es-Salaam)
- *Pate,* Chundwa in Kenya
- *Pate Siyu* (Kenya)
- *Msambweni* (Kenya)

The last populations display the same type of result as for the "Vuo" population.

However, it seems clear in any case that there are some highly susceptible populations – between 54 and 100% mortality depending on the site, over the same period.

Table 1: Comparison of losses recorded on the "Vuo EAT" palms and the LBS EAT" palms, and those recorded on other EAT populations or other exotic varieties and hybrids in the genetic collection at Chambezi in 2004.

Variety	Planting year	% losses in 2004
Vuo EAT - Block XI	1991	9.5
LBS EAT - Block XI	1991	0.0
LBS EAT - Block XII	1991	9.5
LBS EAT - Block X	1991	0.4
Boma EAT - Block II	1989	82. 9
Kilwa Singino EAT - Block II	1989	87.5
Laccadive micro -Block II	1991	100
"PB 121" - Block I MYD x WAT	1988	100

The Sri Lanka Green Dwarf (SGD) variety would also seem to be slightly less susceptible since, in a plantation where all the other varieties were rapidly and totally decimated (100%), 98% of the SGD palms apparently died much less quickly, and 6.7% of the SGD palms died in a plantation where the other varieties displayed 11 to 19% mortality. Unfortunately, those SGD palms do not grow well at all and give very low yields. Two other varieties would also seem to be less affected: "Catigan" and Papua New Guinea Brown Dwarf.

In terms of LDT spread, the disease has not spread on the island of Pemba. The hypothesis adopted is the beneficial effect of rapidly eradicating diseased palms.

Lastly, NCDP carried out some sustained research work on the vector insect. LDT phytoplasmas were detected by PCR in two species of insects, a Derbidae, *Diostrombus mikurangai* and a Menoplidae, "*Meenoplus* senso latu" (the latter probably being in fact another *Diostrombus).* However, transmission experiments failed to reproduce the disease (see above).

1.3. Meetings at the Ministry of Agriculture

Discussion with Dr A.M. Msabaha

Dr Msabaha could not but confirm for us the disinterest that has affected coconut growing in recent years. It is clear that the halt in GTZ assistance after several years of funding led to degree of inertia in this supply chain in Tanzania, by cutting off one of MARI's financial sources. However, he says he is convinced that this supply chain needs to be revitalized for the food security of the coastal populations, and as a possible source of new income for the new generations, provided diversified use of coconut products and their distribution in organized circuits is achieved very rapidly.

Dr Msabaha feels that, initially, MARI should draft a concept note on the condition of coconut plantations in Tanzania, referring first and foremost, of course, to LDT, but also the great age of the majority of the palms, drought, other pests and diseases, and organization of the supply chain (product diversification, organization of marketing circuits).

That concept note would be used to approach both the Tanzanian government and international donors. He pointed out again that the current Director of the Common Fund for Commodities (CFC) in the Netherlands is a Tanzanian who is very familiar with the problems in the coconut supply chain. He is highly in favour of a regional project including Mozambique and Kenya, because the three countries are having to cope with the same type of diseases. He even proposed that CIRAD act as coordinator.

Discussion with Dr Niakunga, Assistant Director for Plant Health Services

Dr Niakunga told us something very interesting: in 2004, the Minister of Agriculture said in a speech that he "no longer wanted to see a single diseased coconut palm". In fact, that amounted more to a pious wish than a programme, since apparently the minister was expecting farmers to eradicate them themselves. As they did not have the necessary resources, eradication did not take place.

However, the idea was not forgotten and a private company is currently felling diseased coconut palms and those that "no longer yield" (we were unable to find out whether this only concerned coconut palms with advanced typical LDT symptoms or also the oldest palms - 60 years old and over) for various uses of the wood: mainly charcoal. In government, the idea doing the rounds at the moment for replacing felled coconut palms is apparently to plant *Jatropha* to produce biodiesel.

According to him, other than LDT, the other recent problem that is acknowledged to be increasingly severe for coconut palms is whiteflies. This problem, which first occurred on the island of Zanzibar, reached the continent in Dar-es-Salaam, and now exists everywhere.

1.4. French Embassy in Tanzania

Meeting with: His Excellency Jacques Champagne de Labriolle, the French Ambassador, the Scientific Cooperation and Universities attaché, Raymond Lataste, and the Cooperation and Culture attaché, Patrick Thomas.

During this meeting, the Ambassador emphasized several key concepts - or "principles" - in his experience. A few are mentioned below:

- there are no good or bad projects, just good or bad management.
- the critical point, the time bomb for countries in the Southern Africa zone, is located around Lake Victoria and the great lakes. That is where population pressure is greatest, it is there that the greatest demand for food will occur in the coming years.
- for him, one should not expect many returns from any bilateral programme, since once French aid comes to an end, there is every chance that not much more will be done for lack of funding. However, the Embassy is ready to support a regional project including Kenya and Mozambique.

1.5. Field visits

1.5.1. Visit to the ex-varietal trial at Sotele

This trial is located near Dar-es-Salaam to the south of the city. NCDP researchers had to persuade the farmers to cut down their old EAT type coconut palms to set up a trial with new exotic varieties and hybrids, of which they promised that at least some would be more productive than the old local coconut palms, and more resistant to LDT. Some East African Tall (EAT) palms were also planted: yellow, green, bronze (more or less brown) EAT (FIG. 7). This trial was planted in 3 phases: 1981-83, 1985-87, then 1989. Several of the tested varieties and hybrids, including PB 121 (Malayan Yellow Dwarf x West African Tall) were soon killed by LDT.

Today, the land has been returned to the farmers who are angry with the NCDP researchers for "misleading" them in the negative trials, to the detriment of their old coconut palms which were not high-yielding, but some of which were still alive when the trials were set up.

They have turned to other crops, such as cashew nut, cassava, maize and banana. *Citrus,* groundnut, maize, banana and cowpea can also be seen between the surviving coconut palms (FIG. 8).

During the visit, we saw that some almost complete rows of EAT type coconut palms still remained, notably LBS-EAT (see above): 0% losses recorded in June 2004 - counting was halted after 2004 due to the end of funding.

Most of the surviving EAT palms have green or bronze nuts according to A. Mpunami. Nonetheless, some yellow type EAT palms can be found (FIG. 8).

The Sri Lanka Green Dwarf (SGD) palms would seem to have suffered very limited attacks (only 4,6% losses recorded in June 2004), but we were unable to locate them in the midst of regrowth or new plantings of cashew trees and others. However, according to A. Mpunami and J. Mugini, the SGD palms are growing very poorly; they are weak and apparently produce very few nuts.

FIG.7 (M.Dollet)
EAT palms with yellow nuts at Sotele

FIG.8 (F Pilet)
Intercrops at Sotele.

To the south of Sotele, towards the coast, near Kifumangao, some coconut palms display symptoms of decaying yellow fronds, but it can be seen that they have healthy young inflorescences (no browning, no necrosis) (FIGs. 9 and 10).

FIG.9 (M. Dollet)

Coconut palm probably suffering from drought, south of Sotele, towards Kifumangao

FIG.10 (M.Dollet)

Inflorescence No.9 with a healthy appearance on a palm probably suffering from drought south of Sotele, towards Kifumangao

These cases of yellowing might also be caused by drought. It is sure that, at the moment in Tanzania, it is not always easy to determine whether LDT or drought is to blame. On arriving somewhere and seeing crownless stems, they are not necessarily cases of LDT (see below, observations in the North). In this specific case near Kifumangao, the oldest fronds are hanging down, the fronds just above them are turning yellow, the lack of nuts suggests a case of LDT. However, in Lethal Yellowing type syndromes, young inflorescences display necrosis. It should also be noted that in the case of drought, necrosis can also be found on young inflorescences!... this inflorescence which has just opened does not make the diagnosis any easier. The most likely hypothesis is that the palm has suffered from drought, but is in the process of recovering.

At Kifumangao, in the old plantation of a German farmer, which was destroyed by LDT, some EAT palms were replanted in 2000, with seednuts from palms that had "resisted" (or had not been attacked?). For the moment, those 7-year-old palms remain disease-free.

1.5.2. Visit to the Chambezi station

This is a MARI research station (of the ex-NCDP) located around 50 km northwest of Dar-es-Salaam, established in an old coconut plantation planted in the 1950s. Of the 400 ha of coconut palms, 170 are currently bearing.

Some EAT and PB 121 palms were planted there in 1981 and 1982 respectively, for agronomy trials (fertilization). Since 1981, 1,826 coconut palms of different varieties have also been planted there, to assess their resistance to Lethal Yellowing: 7 Dwarf varieties, 13 Tall varieties and 17 hybrids. The EAT palms were included in the trial as a "susceptible control". These different varieties have given disappointing results, be it in agronomic terms or regarding their resistance to LDT. We saw a Cameroon Red Dwarf that was weak and highly susceptible to drought, like SGD elsewhere.

Due to the poor performance of the introduced varieties, a collection of EAT sub-populations was planted at the end of the 1980s. Those populations were selected using different criteria, including:

- EAT palms from locations where the disease existed but with a limited incidence on local Tall palms (the Kenyan EAT palms are included in this group),
- EAT palms from regions where the disease was very active but which survived the disease,
- EAT palms from disease-free regions,
- EAT palms producing yellow nuts, which are relatively rare,
- LBS-EAT palms from the Livestock Breeding Station, which have exhibited a very interesting reaction to the disease at Pongwe.

It has been possible to discriminate between some of the sub-populations with RAPD. In 2004, some of these sub-populations were still little affected by the disease. Up to 15 years old, the nuts of these palms were sold as edible nuts but are now used for replanting purposes. The EAT area now amounts to 54 ha.

Another collection, set up between 1988 and 1992, comprising 4 blocks, contains among other things: EAT, MYD, MRD, SGD and BGD palms, along with various hybrids.

Lastly, with funding from IPGRI, some EAT x EAT, EAT x Dwarf, and Dwarf x Dwarf hybrids were created in the 1990s using the EAT sub-populations that displayed the best reaction to the disease.

Many cases of LDT can be seen on this station. Unlike the other sites seen during our mission, large active LDT foci can be found, with all stages of the disease (FIGs. 11, 12, 13 and 14). The inoculum pressure there makes the results of the varietal performance trials all the more interesting (Table 2).

Table 2: LDT incidence on different EAT populations at Chambezi, in an EAT varietal performance trial. A few results as of June 2004

EAT population	Planting year	% losses due to LDT
EAT - Mafia	1981	72.3
EAT - Kilwa Singeno	1988	56.7
EAT - "yellow colour"	1986	31.6
EAT - Vuo	1990	28.6
EAT - LBS	1988	21.6

It can be seen (see also table 1) that at the same station, depending on the blocks and plots, the percentage losses attributable to LDT vary considerably. For example, for the Vuo palms, they range from 9.5% to 28.6% and for the LBS palms from 0 to 21.6%. This is a good example of the difficulty of interpreting figures from varietal performance trials, i.e. when the planting material is "naturally" exposed to the vector and the inoculum. Obviously, it would be very interesting to have the 2007 figures, but unfortunately, due to a lack of funds, these trials have not been monitored since 2004.

At Chambezi, we were surprised to find a cage used to test transmission by insects, of the same type as those we use in Ghana. Apparently, five coconut palms have been exposed to more than 3,000 *Meenoplus* (which in fact would appear to be a Derbidae) since 2003. The insects are collected once a fortnight from coconut palms and from "dumb palms" (an endemic palm species).
Four series of trials have been carried out at Chambezi and Kifumangao since 1984, in cages or under semi-controlled conditions. One coconut palm exposed to *Diostrombus mkurangai*, *Paraphenice* sp and *Lydda woodi* apparently developed disease symptoms 240 days after being removed from the cage, but it was not possible to check for the existence of phytoplasmas under the microscope.

Diostrombus mkurangai and *Mecnoplus sensu latu* both tested positive for LDT by PCR (Mpunami *et al*, 2000). As the frequency of positive *Mecnoplus* was much higher (4/14 as opposed to 8/1,270 for *D. mkurangai*), exposure to that species was continued despite the halt in funding.

As exposure began four years ago, it would probably be preferable to halt the trial and resume releases onto new coconut palms, assuming that the cage is still truly insect-proof.

FIGs.11, 12, 13, 14
(M. Dollet)

LDT at the Chambezi station

1.5.3 North Tanzania

North of Tanga, near the Kenyan border, we did not find any cases of LDT. However, at Vuo for example, there were some sites with many crownless stems. According to A. Mpunami those palms were killed by drought in the last two years (FIGs. 15 and 16)

FIG.15 and FIG.16

Damage attributed to drought north of Tanga (North Tanzania) (M. Dollet).

Immediately to the south of Tanga, towards Tongoni where a case of LDT had been seen in 1999, two or three cases of LDT were found by MARI researchers in 2003 at Mwambani. However, no cases were found in 2004, the final year of the survey. During our visit, we saw a likely case at the roadside, along with 2 or 3 other suspected cases near the village of Mwambani.

In the Vuo region, we saw several old EAT palms that had apparently been killed by drought, but no cases of LDT.

According to A. Mpunami, towards the end of the 1990s, the disease existed around twenty kilometres south of Tanga but, in general, there is not much LDT in the North of Tanzania (see Schuiling *et al.* 1992).

a. Livestock Breeding Station (LBS)

This station is located in Tanga region. EAT x Pamba Red Dwarf and EAT x Cameroon Red Dwarf hybrids are produced there.

Due to a lack of funding, fertilization and upkeep in the plots ended in 1981. However, some very productive EATx PRD (Pemba Red Dwarf) hybrids can be found.

In 2004, i.e. 23 years after planting 30.2% of the hybrids had disappeared, as opposed to 16.8% for the LBS-EAT population. However, by 1981 all the PB 121 palms had been killed by LTD, i.e. 5 years after planting.

b. Pongwe

The varietal trial at Pongwe is around 20 km southeast of Tanga. It was planted in 1981. All the EAT, Dwarf and hybrid palms from Chambezi were planted there. As at Chambezi and Sotele, several EAT palms seem to perform well with regard to LDT, whilst most of the hybrids have disappeared. The few surviving hybrids are in dreadful phytosanitary condition, with little leaves, pencil point stems and numerous *Oryctes* attacks. During our visit, an EAT was seen that was probably affected by Lethal Yellowing and the MARI researchers found that many palms had died since their last visit in 2004. However, after the fact, it is difficult to attribute that mortality to the disease or to the drought that has existed for some years.

Lastly, a brief visit was made to the former NCDP station where the first LDT research work was undertaken with M. Schuiling.

2. Kenya

2.1. Coconut and Lethal Yellowing

The coconut palm would seem to have been introduced into Kenya in the 16th century by the Portuguese and cultivated by Swahili tribes near Rabai and Ribe north of Mombasa, primarily for palm wine production. The coconut groves to the south of Mombasa were apparently planted by the Arabs between the 17th and 19th centuries, and some large plantations apparently still belong to them. The plantations located to the north of Mombasa are 1 to 2 ha in size, whereas to the south there exist some very large plantations.

Today, some coconut palms are found from Lamu in the North to the Tanzanian border, in the South. The great majority of cultivated palms are local EAT (East African Tall). A few Dwarf coconut palms can also be found, along with some scarce hybrids. A few hybrids were imported from Ivory Coast by KARI in 1978 and planted at Mtwapa (20 seedlings) and Msabaha (15 seedlings). Apparently they adapted very poorly and all ended up dying from lethal bole rot.

In 2007, the coconut population in Kenya was estimated at 7.4 million palms. Despite the existence of old coconut estates in Kwale district (south of Mombasa), Kenyan coconut plantings are relatively young (Tables 3 and 4). There has been regular replanting, unlike in Tanzania. Almost 40% of coconut plantings are apparently under 20 years old, and 71% of the coconut palms are under 40 years old (Gachanja *et al* 2007).

Table 3. Estimation of Kenyan coconut plantings (Gachanja *et al.* 2007)

District: North to South	Number of coconut palms
Lamu	434,105
Tana River	140,414
Malindi	986,997
Kilifi	2,831,978
Mombasa	136,938
Kwale	2,895,427
TOTAL	7,425,859

Table 4. Age of Kenyan coconut plantings -Percentages- (Gachanja *et al.*2007)

Age category	Kwale	Mombasa	Kilifi	Malindi	Tana	Lamu	Total
0-5 y	13.7	14.6	12.0	16.3	14.1	26.1	14.1
6-20 y	23.9	22.3	22.7	34.1	36.3	37.0	25.8
21-40 y	30.8	21.4	33.9	33.9	49.4	18.5	31.9
41-60 y	21.0	19.2	23.9	12.0	0.6	16.0	20.1
61 y and over	11.2	23.9	7.8	2.7	0.1	1.0	8.2

Copra is the main coconut product. In 1995, Kenya was seventh out of the eight African copra producing countries. A study carried out in 1988 showed copra production to be from 5 to 1,000 tonnes per year for a potential of 46,700.

Coconut is the main source of vegetable oil in Kenya. However, that oil is not earmarked for consumption but for cosmetics. For food purposes, Kenyans prefer to use coconut meat in the form of coconut milk which has a less stronger flavour. The main source of income derived from coconut today is toddy (palm wine). The other major products are fresh nuts (madafu, 15 to 20 KSh in Mombasa, i.e. around 20 euro cents), and fronds (makuti) (Table 5).

Table 5. On-farm value (in KSh) of the annual production of various coconut-based products in 2006.

District	Dry nuts	Unripe nuts	Palm wine	Foliage	Broom	Other	Total
Kwale	191.31	18.24	**248.47**	79.07	8.68	7.85	553.62
Kilifi	**234.77**	32.18	**1,177.30**	167.58	83.50	9.73	1,705.06
Malindi	133.75	28.70	**395.07**	87.52	3.26	2.13	650.43
Lamu	67.08	7.33	10.79	27.39	0.84	--	113.43
Tana River	2.68	0.18	--	2.53	0.17	--	5.56
Mombasa	26.56	10.92	66.43	15.03	6.34	11.3	136.58
Total	656.15	97.55	1,898.06	379.12	102.79	31.01	**3,164.68**

Research for coconut development in Kenya has always been weak compared to Mozambique and Tanzania, and little has been done since 1990.

Very little information is available on coconut Lethal Yellowing in Kenya. It is known that LDT affected northern Tanzania, not far from the Kenyan border in 1907 - first observation in that country in 1905 (Schuiling *et al.* 1992) - but we do not have any data for Kenya. Although numerous coconut palms were killed by the disease in the 1980s in the Matuga region, disease incidence remains low in Kenya. The analyses of a few scarce rRNA gene sequences of phytoplasmas associated with coconut Lethal Yellowing in Kenya have shown that it is the same phytoplasma as that associated with LDT in Tanzania (Mpunami *et al*, 1999).

2.2. KARI

2.2.1. General

KARI (Kenya Agricultural Research Institute) comprises 29 centres spread throughout the country. Around 500 scientists work for it in the different agricultural sectors. We had the opportunity of visiting the centres at Mtwapa and Matuga, and part of the one in Nairobi.

2.2.2. KARI centre, Mtwapa

We were received by Mr Muniu, head of the horticulture service. He organized our field visits, along with some meetings, and accompanied us for the two days in Mombasa. Mr Muniu is the only person met at KARI who partially takes care of coconut. However, his main centres of interest are tomato, cabbage, banana, mango, *Citrus* and papaya.

According to him, coconut is the main crop in the coastal region, especially south of Mombasa. In the vicinity of Mombasa, dried copra is bought directly on the farm by 4 or 5 small factories which extract oil from it. Toddy (fermented coconut sap) seems to have overtaken copra and is now the main coconut product sold in town. Another person from KARI at Mtwapa is working on coconut added value (coconut shells, fibres and husks) and organizes workshops with farmers. Those farmers have formed an association, dependent upon the Mombasa Coast Development Authority. The wood of old coconut palms is also used (construction, charcoal, etc.).

However, production is declining, mainly due to damage caused by insects such as *Oryctes*, *Pseudotheraptus*, coreid bugs and scale insects. At the moment, to our knowledge, no plant pathologist or entomologist is working on coconut. The rare work on coconut Lethal Yellowing in Kenya was carried out in the 1990s by Anatolia Mpunami from MARI in Dar-es-Salaam, who sequenced a few ribosomal genes of Kenyan isolates. The current Lethal Yellowing situation is therefore virtually unknown and undocumented, which does not mean that there is no problem.

Despite those constraints, coconut continues to be planted in Kenya and we saw some very handsome plantations. Seedlings are produced by smallholders themselves, or – though on a small scale from what we saw - by KARI, which has been producing East African Tall palms for the last ten years or so. There is apparently very strong demand at the moment, linked to tourism, for Dwarf coconut palms whose coconut water has more flavour than that of EAT nuts.

Mr Muniu brought up the very serious problem of *Citrus* greening in the highland regions of Kenya where *Citrus* plants survive no more than three years due to the disease. Apparently, a KARI-Insaba entomologist works on *Citrus*.

We met Dr R.W. Nwinga, Director of the Mtwapa centre. KARI's priorities for the coastal region are listed in her office:

1. Vegetables	4. Maize	7. Fruits	10. Sorghum and millet
2. Dairy	5. Cashew nut	8. Poultry	11. Sweet potato
3. Coconut	6. Cassava	9. Small ruminants	

Coconut comes third, but there is currently nobody at KARI working exclusively on coconut – only the two people already mentioned above. Consequently, very little work is undertaken on that crop.
However, Doctor Nwinga informed us of the existence of one of the most recent studies (March 2007), focusing on the coconut supply chain, funded by DANIDA (Danish International Development Agency). The purpose of that study was to assess the coconut supply chain as a whole and to estimate its potential. We were given a copy of the study, of which several tables are included in this report.

2.2.3. KARI centre-Matuga

The KARI centre-Matuga is dependent upon KARI-Mtwapa and is under the authority of Mr Powone. This centre preserves and assesses the varieties of a few tree crop species (coconut, mango, oil palm) and especially *Citrus*. They are in charge of *Citrus* phytosanitary matters, assess the adaptation of varieties to the coastal region and take care of seed production.
According to Mr Powone, the coconut palms in the district are almost 100 years old and have barely been replaced, or very slowly, which contradicts the DANIDA study which stated that coconut palms were regularly replanted.
We began the tour of the centre with a small plot of local coconut palms (EAT) planted around fifteen years ago to assess yields. Another small plot of coconuts was planted as genetic resources. Those palms, mostly bearing green nuts, are low-yielding and display symptoms of very severe nutritional deficiencies (FIG.17).
The largest collection at the centre involves *Citrus*. This collection was particularly established because of citrus greening, which has caused a lot of damage in Kenya. Several varieties were supplied by INRA in Corsica. Another plot of *Citrus* planted in 1985 is used for seed production.
Lastly, KARI would like to develop oil palm in Kenya. A few lines from West Africa (Ghana and Nigeria) were introduced in 1989 for assessment. Those palms are quite weak, with small chlorotic leaves and a very large number of aborted inflorescences.

FIG 17 Collection of EAT coconut palms at the KARI centre - Matuga (M. Dollet)

FIG 18. Possible cases of Lethal Yellowing just south of Mombasa (M. Dollet)

2.2.4. KARI centre-Nairobi

In Nairobi, we were received by Dr Lucike A. Wasilwa, Assistant Director, Horticultural and Industrial Crops Division. She was trained in the USA.

Like the previous people we met, she brought up the staffing problems at KARI, which are apparently linked to restructuring of the institute which began in 2004. This lack of resources has led to coconut being "put on the back burner". There is an entomologist (Vicente Kega) who has done some work on coconut, but he focuses more on *Citrus* and is now based at KARI-Katumani. A plant pathologist was requested for the coastal region two months ago.

Coconut Lethal Yellowing apparently caused very serious damage at the end of the 80s/beginning of the 90s near Matuga, but the disease does not currently seem to be a constraint. On the other hand, she spoke to us about several problems on *Citrus*: insects, *Phytophthora* and especially greening which caused considerable losses in the 80s. Substantial financial resources were provided from 1988 to 1993, and many new cultivars were introduced (from INRA in Corsica, among other places). There is strong demand from KARI for *Citrus* greening matters and the subject had already been discussed with H. de Bon during his recent mission to Kenya. However, the request is absolutely untargeted. As nobody is currently working on the subject, concrete requirements for greening matters have not been identified. KARI also wishes to organize the next generation of researchers and needs to train young people.

Lastly, we discussed KARI's laboratory facilities. There is a plant pathology laboratory and a biotechnology laboratory at KARI. A brief, unannounced visit was made to those two laboratories, but we met nobody. Lastly, there is another very new laboratory which is apparently to be equipped very shortly at KEPHIS, but we were unable to visit it.

2.3. Field visits

2.3.1. North of Mombasa: Kilifi district

After meeting our hosts, we visited a small demonstration workshop designed to add value to coconut by-products (husks and shells) located within the centre's perimeter. It is a workshop funded by DANIDA, and equipped with machines for spinning and weaving coconut fibres, for making doormats among other things. Handicrafts made from coconut shells (bracelets, earrings, maracas) are also made. However, nothing is done to extract virgin coconut oil like we saw in Dar-es-Salaam.

We then surveyed Kilifi district, north-northwest of Mombasa. On the way to Kaloleni, the coconut plantings appeared to be dense and relatively young on the whole, and in very good phytosanitary condition. Most of the coconut palms are only around thirty years old. Some groups of much older palms were seen, along with a few crownless stems.

We stopped at the Kaloleni office of the Ministry of Agriculture, where we met Mr Kalem Omundi, the head of the district. This new district, covering 909 km2, is home to 48,545 farming families, each having an average area of 7 acres. The main problem on coconut encountered in that district is *Oryctes monoceros*. There are apparently some problems with Lethal Yellowing and Lethal Bole Rot (attributed to the fungus *Marasmiellus cocophilus* in the 70s – Bock *et al.* 1970).

On the way back to Mombasa, we saw a palm with pale, drooping lower fronds and two dead palms in the village of Chonyi, but no obvious case of Lethal Yellowing was seen, despite the information received at Kaloleni.

2.3.2. South of Mombasa: Kwale district

Access south of Mombasa involves taking a ferry across the bay. Heading south, the coconut plantings are not dense like in the North, and some palms seem to be very old. Before reaching the few large coconut estates, there are mainly cashew nut trees, banana plants, mango trees, and especially maize sometimes intercropped with coconut either side of the road.

Around 7 km after the ferry, we saw from the road a suspect group of three coconut palms with very yellow fronds hanging down the stem (FIG. 18). Two of them had no nuts at all, the third one or two. Those palms were very old, but the yellowing did not appear to be a symptom of senility.

A coconut palm displaying very marked Lethal Yellowing symptoms (FIG. 19) was seen around 1½ kilometres after the Ukunda Youth Polytechnic (i.e. 22 km after the first). It was in a group of healthy roughly ten-year-old palms without any apparent nutritional deficiency, planted a few metres from a house. Inflorescence 9 was necrotic (FIG. 20) and there were no longer any nuts. According to the owner, Kibarani Mvindeni, three coconut palms had already died. Five hundred metres further on, three other cases were spotted either side of the road (FIGs. 21 and 22).

A total of seven coconut palms or groups of palms with Lethal Yellowing symptoms was seen along the roadside starting at Ukunda, over a distance of around 11 kilometres. In most of the cases, the coconut palms were isolated or in small numbers near dwellings. This visual diagnosis needs to be checked by PCR analyses, but it seems certain that these cases of decay observed are definitely of the "Lethal Yellowing" or "Lethal Decline Tanzania" type. Strangely, the disease would seem to disappear where the coconut palm density increases, with a succession of old coconut estates, including the one at Msambweni, which used to be the largest in Kenya and has now been abandoned. However, it has to be said that we did not have enough time to go through those estates, moreover the Msambweni estate was shut. We continued as far as the village of "Kinozini Funzi" located 3 km southeast of Ramisi. That village is only 26 km from the Tanzanian border and 70 km from Tanga (Tanzania) as the crow flies.

During this survey, we made two visits, firstly to KARI-Matuga (2.2.3.), then to the Ukunda Youth Polytechnic.

Ukunda Youth Polytechnic

The Ukunda Youth Polytechnic is a school in which general woodwork, and coconut woodwork in particular, is taught. This interest in coconut wood probably comes from subsidies provided by DANIDA which funded the equipment needed for woodwork, but also from the disappearance of high quality timbers in Kenya.

FIG. 19. Case of Lethal Yellowing south of Mombasa near the Ukunda Youth Polytechnic (M. Dollet)

FIG. 20. Inflorescence No. 9 on the coconut palm in figure 19. (M.Dollet)

FIG. 21. Case of Lethal Yellowing south of Mombasa (M. Dollet).

FIG 22. Case of Lethal Yellowing south of Mombasa, near the Ukunda Youth Polytechnic (M. Dollet)

A coconut stem has three different densities and colours depending on the quantity of fibres: a dark, high-density wood, very rich in fibres around the outer edge, a medium-density zone, and a pale low-density wood in the middle. Only high- and medium-density planks can be used for carpentry.

The wood comes from coconut palms that are usually over 60 years old with few fronds and which no longer produce any nuts. The palms are felled and cut up on site with a transportable circular saw. The planks are then taken to the polytechnic where they are dried to a moisture content of approximately 12.5 to 15% after 1½ weeks. The wood is then used to make very fine quality furniture sold by the school: chairs, armchairs, stools, tables (FiG. 23 and 24).

Figs.23-24. Folding stool and chair in coconut wood made at the Ukunda Youth Polytechnic (M. Dollet).

2.4. French Embassy in Kenya

We were received at the embassy by Cyrille Le Deaut, the cooperation attaché. Like the Ambassador in Tanzania, he encouraged us to draw up regional projects and is against bilateral projects. We also mentioned the possibilities of collaboration on molecular biology in Kenya. He spoke of the ICIPE laboratory which is to be equipped very soon (they had not responded to Denis Depommier's approaches).

Lastly, the Embassy has resources to fund shared theses to the tune of 6,000 euros per student per year over three years, and for the purchase of a laptop.

3. General Conclusions

3.1. The coconut supply chain

First impressions are that the coconut supply chain is far from flourishing. Undoubtedly, Lethal Decline in Tanzania since the beginning of the 20th century has not advantaged the sector. In Tanzania, LDT, when added to all the other problems (especially *Oryctes*) has somewhat dampened enthusiasm. To that has to be added the major drought problem for the last 3-4 years. But the limited interest generated by the coconut supply chain in the Ministries of Agriculture in recent years also has to be noted. As we saw, in Tanzania, there have been no researchers really working on coconut since 2004, be it for agronomy, entomology, breeding or plant pathology. The same applies in Kenya for even longer. It is difficult to understand such a situation and does not appear to be linked solely to discouragement caused by the existence of Lethal Yellowing in the region. That is all the more true in Kenya, where the disease has a negligible influence and does not appear to be a constraint for development of the coconut supply chain (Gachanja *et al.* 2007).

The disinterest of the ministries is all the more incomprehensible in that all along the coast, from southern Tanzania to northern Kenya, coconut lies at the heart of the culture and life of the populations. Coconut is ubiquitous, from 2 or 3 palms near dwellings to estates and including small blocks of 20 to 100 coconut palms. Coconut products are used daily. Coconut milk is an ingredient in numerous cooked dishes, palm wine is a very popular drink, roofs, even on new dwellings built with solid construction materials – including tourist hotels - are covered with coconut fronds, etc.

Several reasons probably lie behind this disinterest: among others, low copra prices in the 80s-90s; competition with the other supply chains; economic competition with copra from Southeast Asia; as in other countries, the poor image of coconut oil spread by countries producing soybean oil; poorly organized markets; lack of opportunities, funding, etc.

A positive point, common to both Kenya and Tanzania, is the existence of small projects to develop the coconut supply chain, and new products (copra, fresh nuts for coconut water, virgin oil, etc.) and by-products (use of wood, fibres, shells, development of handicrafts).

Development of these products might have a positive impact for coconut in these two countries. Collaboration, or at least exchanges between Tanzania and Kenya, particularly for high value-added products such as virgin oil or timber would be worthwhile.

The other positive point in Kenya lies in the study launched in 2006 by the Agricultural Business Development (ABD) programme of the Danish International Development Agency (DANIDA) in collaboration with the Coastal Development Authority on the coconut supply chain. The decision to carry out that study is the first encouraging fact. Then, the conclusions of that study regarding the potential of the supply chain are somewhat cause for optimism:

- In fact, the coconut sector in Kenya is much more important than generally acknowledged. That would seem to be due to estimation errors, but especially to the fact of limiting the supply chain to nut production for copra. That may have been done deliberately, in relation to palm wine sales for legal reasons in the recent past. For example, palm wine accounts for up to 60% of the 3.2 billion Kenyan Shillings derived from the coconut supply chain. (Table 3).
- Moreover, contrary to popular belief, the Kenyan coconut plantings are not in decline. On the contrary, farmers have regularly replanted. Only 8.2% of coconut plantings are over 60 years old and the number of coconut palms planted is increasing by 2.2% per year. The proportion of palms in full production is very good. The most dynamic districts in replanting terms are those that produce palm wine, Kilifi and Malindi near Mombasa!
- There are around 36 production zones (zones of 5 to 7 km with a high density of coconut palms) (production clusters) which have the potential for organized development of a supply chain activity (palm wine, or copra, or fresh nuts, etc.).
- Only 25% of the coconut sector potential is exploited! By improving production of the different products in the sector, the potential value of coconut would rise to 20 billion KSh i.e. 220 million euros (only 3.2 billion KSh at the moment).

This awareness of coconut potential has clearly not occurred in Tanzania. However, our contacts at the Ministry of Agriculture assured us of their wish to revive the coconut supply chain, in relation with MARI. It is true that LDT has a greater impact in Tanzania than in Kenya, but it would be in the interests of both countries to see how that coconut potential could be used to help the regions of the great lakes, with their galloping population growth.

3.2. Coconut and Lethal Decline

The results of Tanzanian variety trials have revealed an interesting performance for several Kenyan and Tanzanian East African Tall (EAT) palms distinguished between by RAPD and ISTR. A more in-depth study of EAT sub-populations with microsatellites depending on the updated results of the performance trials, could provide a great deal of information on the structure of the coconut populations in East Africa suitable for use in integrated protection against Lethal Yellowing type diseases. Indeed, these local coconut palms may appear to be more worthwhile than exotic varieties (Dwarf or Tall palms) or hybrids that are much more susceptible to drought, a not insubstantial factor in the region.

At least two phytoplasmas (and therefore two types of Lethal Yellowing) exist in East Africa. The few rare studies conducted on diversity-variability using the gene of the rRNA show to date that the phytoplasmas existing in Kenya and Tanzania (LDT) appear to be different from those characterized in Mozambique, themselves very similar to those encountered in Ghana (CSPW) (Tymon *et al*, 1998; Mpunami *et al*, 1999). It is therefore not certain that EAT palms displaying tolerance of the "Tanzanian pathotype" will provide resistance to or tolerance of the "Mozambican pathotype". However, as borders are only political, the existence of LDT phytoplasmas in Mozambique cannot be ruled out, at least near the Tanzanian border. A wider study of the phytoplasma populations responsible for coconut Lethal Yellowing in East Africa is therefore needed, along with their spatial distribution on a regional scale.

Lastly, the existence of two phytoplasmas may suggest the existence of at least two vectors. The transmission trials in Chambezi (Tanzania) did not result in disease transmission, but the conditions may not have been optimum. There too, much remains to be done.

3.3. Collaboration

1. International regional programme

The zone between southern Tanzania (south of Dar-es-Salaam) and northern Mozambique (from Zambezia to Cabo Delgado) currently seems to be the most interesting zone for a study on these Lethal Yellowing type syndromes. The MARI molecular biology laboratory is very well equipped and the necessary skills exist there. The work they published in the 1990s is a reference. The determination of the MARI researchers, who are attached to the LDT subject and to coconut, is also motivating. The MARI research centre in Dar-es-Salaam could therefore play a central role in a regional scale project, as there is no other such structure between Quelimane (Zambezia) and Dar-es-Salaam.

Collaboration between CIRAD research unit 29 and MARI can easily be considered on the different subjects already mentioned: in-depth analysis by microsatellites of the East African coconut populations, genetic analysis and mapping of the phytoplasma populations responsible for Lethal Yellowing diseases, epidemiology, entomology. CIRAD research unit 29 does not have any experience in Tanzania and Kenya, but has been working on Lethal Yellowing in Mozambique since 2000-2003, on the diversity-variability of phytoplasmas and on epidemiology. The two partners are therefore well prepared for working together in these fields. It would be worth integrating Kenya since, as we have seen, the disease is clearly present in the South of the country and some Kenyan cultivars tested in Tanzania would appear to be "tolerant" of LDT. We were unable to target any potential partners during this excessively short visit, but there is true potential with bodies such as ICIPE, KEPHIS, the universities and KARI.

The drafting of a concept note on the need for research into coconut Lethal Yellowing type diseases in East Africa has been envisaged with MARI management (A. Kullaya and A. Mpunami). The note could be submitted to CFC in Amsterdam, whose current chairman is a Tanzanian who is very familiar with coconut issues. Remember that CFC has a coconut Lethal Yellowing programme in the Caribbean. At the founding meeting for that programme, which was attended by Michel Dollet, a request was made to include the African countries concerned by this type of disease. It was solely for management reasons that the idea was rejected (too many countries for efficient management). It was envisaged that Africa would submit the same type of request once the CFC Caribbean programme was up and running. Our contacts at the Tanzanian Ministry of Agriculture showed considerable interest in this type of joint approach from MARI and CIRAD. For the Director of the Crop Research Department, CIRAD research unit 29 could be the Project Executing Agency (PEA) of a CFC programme involving Mozambique, Tanzania and Kenya. Extension of that project to West Africa has been considered, but the preference at the Ministry is for a project with a limited number of countries, with a regional vocation. The regional aspect (East Africa) is also favoured by the Cooperation and Cultural Services at the French Embassies in Tanzania and Kenya.
Neither should be forgotten the request from Tanzania for collaboration on whiteflies, and from Kenya on *Citrus* greening, two fields in which CIRAD has skills. Lastly, although no request has been submitted to us, it would be worth developing projects on coconut product technology in this zone.

2. Incentive actions by the Embassies

The Embassies express a preference for the establishment of regional rather than bilateral projects. They are ready to provide funding for young researcher training. This could be a good opportunity for hosting a Kenyan student in plant pathology to learn about the disease, as the necessary skills are sadly lacking. However, the "right" candidates need to be identified beforehand.

3. Short term

The researchers at MARI, notably Dr Mpunami and the Director, A. Kullaya, very clearly expressed their wish to work on coconut Lethal Yellowing diseases again. Providing that funding can be found, we could host Dr Mpunami in Montpellier in 2008 for a three-month training course. We have submitted a dossier for that purpose in connection with CIRAD Incentive Actions 2008, for A. Mpunami. This course in Montpellier would offer the advantage of really beginning to collaborate and lay the foundations for a future regional project. MARI already sent us some DNAs of diseased coconut palms in 2004, demonstrating their technical abilities and willingness to work together. During the course in Montpellier, she could complete the existing data on phytoplasma variability in Tanzania by cloning and sequencing, and produce a more exhaustive phylogenetic study than exists at the moment, based on a very limited number of isolates.

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Abbreviations

APCC: Asian Pacific Coconut Community

CFC: Common Fund for Commodities.

CSPW: Cape Saint Paul Wilt

COGENT: Coconut Genetic Resources Network

IPGRI: International Plant Genetic Resources Institute

ISTR: Inverse Sequence-Tagged Repeat

RAPD: Randomly Amplified Polymorphic DNA

Abbreviations used for coconut varieties

BGD: Brazilian Green Dwarf

EAT: East African Tall

WAT: West African Tall

MRD: Malayan Red Dwarf

MYD: Malayan Yellow Dwarf

PB 121: Port Bouet 121 (hybrid between the Malayan Yellow Dwarf and the West African Tall)

PRD: Pemba Red Dwarf

SGD: Sri Lanka Green Dwarf

Annex 1

East African Tall type coconut populations identified in Tanzania and Kenya by MARI.

EAT-Mafia
EAT-Chambezi
EAT-Kifumango
EAT-Kiembesamaki (Z)
EAT-Mazizini (Z)
EAT-Kinowe (Pemba)
EAT-Msuka (Pemba)
EAT-Yellow Colour
EAT-Pehepehe
EAT-LBS Tanga
EAT-LBS (All)
EAT-Kimanga (Tanga)
EAT-Mwambani (Tanga)
EAT-Boma (Tanga)
EAT-Boza (Pangani)
EAT-Bagamoyo
EAT-Mchukwi (Rufiji)
EAT-Kilwa Singino
EAT-Ng'apa (Lindi)
EAT-Mikindani (Mtwara)
EAT-Tumaini (DSM)
EAT-Mtoni (Kilwa)
EAT-Msangamkuu (Mtwara)
EAT-Vuo (Tanga)
EAT-Songomnara (Kilwa)
EAT-Lamu
EAT-Msambweni (Kenya)
EAT-Pate, Chundwa (Kenya)
EAT-Pate, Siyu(Kenya)
EAT-Songosongo (Kenya)