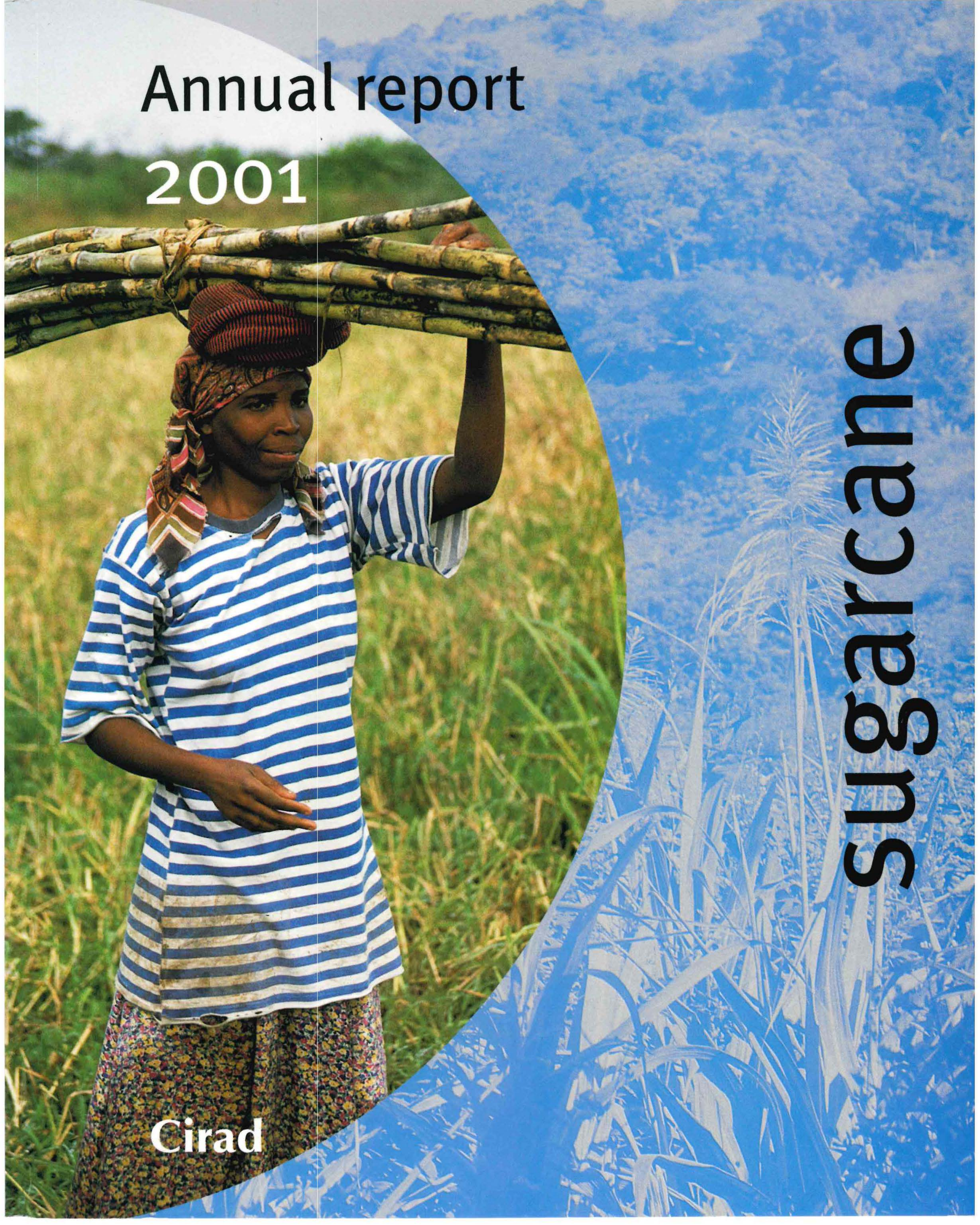
Annual report 2001

sugarcane



Cirad

Annual Report 2001
Sugarcane

Centre
de coopération
internationale
en recherche
agronomique
pour le
développement

Annual Crops
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scientifique et technique, CIRAD
English translation
D. Manley
Layout: Crayon & cie, 34560 Montbazin

Printing CIRAD

Cover photos
Carrying sugarcane
in South Africa
Photo: R. Gœbel
Flowering sugarcane
Photo: CIRAD-CA

ISBN 2-87614-524-3

Foreword

With a view to responding efficiently to challenges facing the sugarcane sector—namely improving crop yields at a reduced cost to guarantee income for growers—our research aims at coming up with solutions that will meet the specific needs of all stakeholders. This includes upstream research in the fields of genome analysis, genetics, plant functioning within the ecosystem, and crop protection, in addition to downstream research on agronomic practices and the structural organization of production. Studies are carried out in favourable conditions that foster innovations and multidisciplinary interactions between scientists based in Montpellier, Guadeloupe and Réunion. This research benefits from strong scientific support, many local and regional partnerships, and it has a regional and international scope through research networks in the French overseas departments.

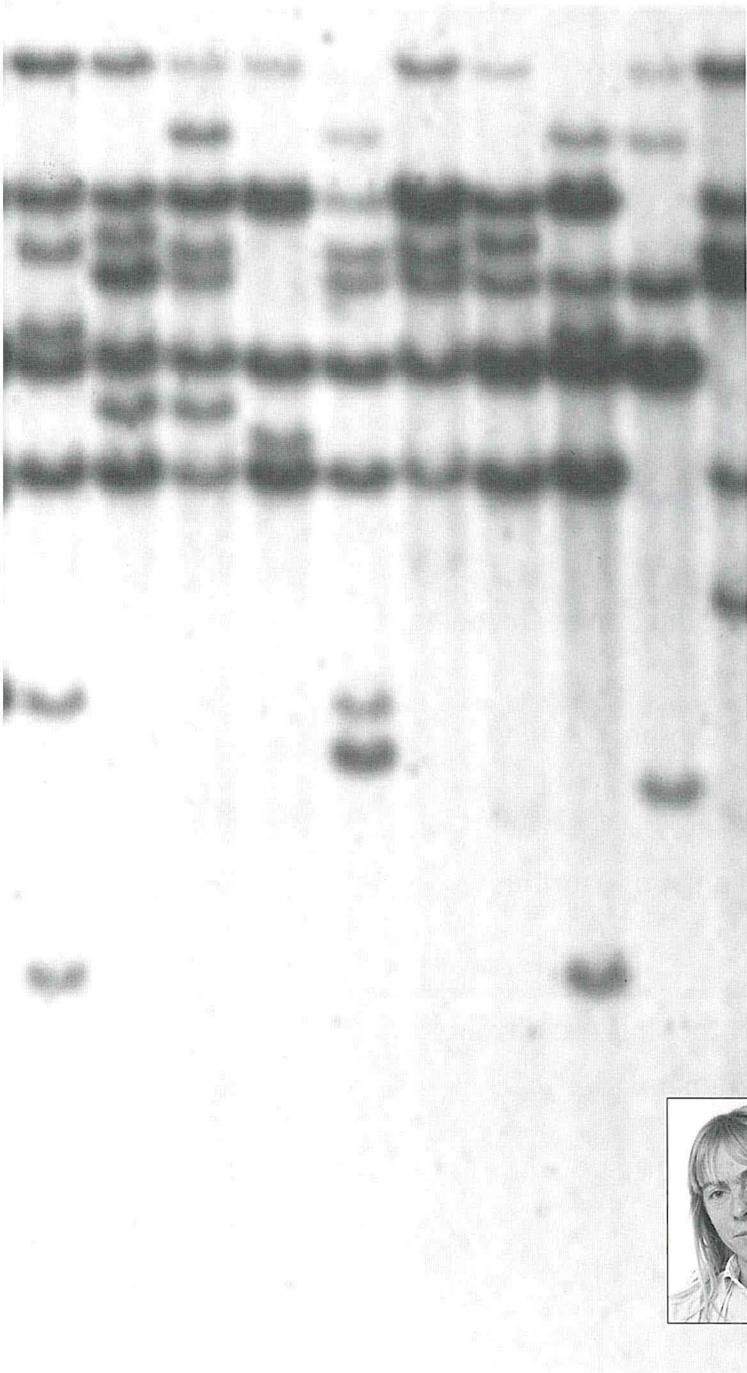
In 2001, several sugarcane research projects and support initiatives were launched through the posting of CIRAD scientists in regional research stations. In Réunion, research initiatives aim at improving water management for sugarcane fields and irrigated cropping areas and organizing production systems. In Guadeloupe, sugarcane/banana rotations were investigated with the aim of increasing sugar production. In southern Africa, sugarcane stemborer control was a major focal point, especially on small farms.

New varietal improvement strategies were adopted in Guadeloupe, thus broadening the international scope of this project. The goal is now to more accurately direct genetic improvement and varietal production so as to meet the expectations of farmers and stakeholders of the sugar industry. Backed by upstream research, this opens up new avenues of research and possibilities of working on new products.

A review of the Programme—undertaken as part of an external review of CIRAD's Annual Crops department in 2001—assessed the current research in terms of acquired knowledge and skills, and activities carried out in different environments and locations in collaboration with growers and partners. The outcome of the review will be examined within the framework of CIRAD's global objectives to determine the research programme and strategies to be implemented as of 2002.

Robert Domaingue
Head of the CIRAD Sugarcane Programme

Annual Report 2001 Sugarcane



Genome analysis

In the Genome analysis project, molecular marker techniques are utilised with the ultimate goal of helping sugarcane breeders enhance the efficiency of their breeding programme, through:

- analysis of genetic diversity;
- mapping of the sugarcane genome;
- genetic analysis of agronomic and disease resistance traits;
- development of molecular tools.

The Genome analysis project is coordinated by Angélique D'Hont.

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Sugarcane genome structure

Modern sugarcane varieties have a very complex genetic structure. They are highly polyploid and aneuploid and result from interspecific crosses between the domesticated sugar-producing species *Saccharum officinarum* (2n = 8x = 80) and the wild species *Saccharum spontaneum* (2n = 5x to 16x = 40 to 128). They have 100-130 chromosomes, around 15-25% of which are derived from the wild species (Figure 1). Molecular markers are used to unravel the structure and function of this complex genome and to generate information and tools that help sugarcane breeders tap the benefits of the available genetic diversity.

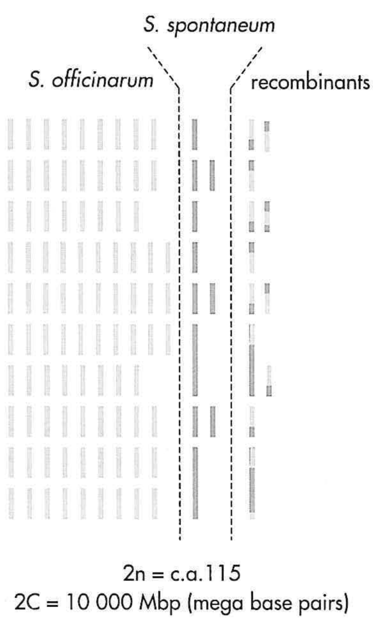


Figure 1. The sugarcane genome.

Genome mapping

Mapping microsatellite markers on the cv R 570 genome

A. D'Hont, C. Hui (Yunnan Sugar Research Institute, China), F. Paulet

Microsatellites are tandem repeats of a short DNA sequence (2-6 bp). Microsatellite markers are obtained by PCR (polymerase chain reaction) amplification with primers corresponding to sequences flanking the repeat units. They highlight polymorphism linked with variations in the number of repeat units that have appeared during evolution.

As part of a project undertaken with Genoscope, a French national gene sequencing centre based in Evry, 64 sequenced microsatellite loci are currently being mapped on two cv R 570 gene maps, with one based on RFLP (restriction fragment length polymorphism) markers and the other on AFLP (amplified fragment length polymorphism) markers. The aim of this mapping project is to analyse the distribution of these microsatellite loci on the sugarcane genome, assess their polymorphism and compare maps obtained with RFLP and AFLP markers. These microsatellite markers should also facilitate comparisons with QTL (quantitative trait locus) detection results and maps obtained by other laboratories.

In each mapped population, 256 polymorphic markers have been revealed, including 175 single-dose markers that are currently being mapped.

Mapping resistance gene analogs on the cv R 570 genome

A. D'Hont, M. Rossi (University of São Paolo, Brazil), F. Paulet, O. Garsmeur

Gene sequence comparisons led to the identification of 55 resistance gene analogs from some 300 000 partial gene sequences, or ESTs (expressed sequence tags), obtained by the SUCEST (Sugarcane Expressed Sequence Tag) project in Brazil. RFLP analyses were performed to investigate their distribution in 112 selfed cv R 570 individuals. In these studies, 52 resistance gene analogs revealed 272 polymorphic markers, including 177 single-dose markers that are currently being mapped.

Detection of sequence polymorphism

L. Grivet

Research is under way at the University of Campinas in Brazil on sequence polymorphism, especially SNP (single nucleotide polymorphism), in SUCEST sugarcane partial gene sequence databases generated by a consortium of Brazilian university laboratories. This sequence polymorphism could theoretically provide a basis for future automated molecular marking techniques.

Detailed analyses similar to those conducted last year on two gene families, i.e. 6-phosphogluconate dehydrogenases and alcohol dehydrogenases, were initiated to study around 50 other genes (or gene families). These gene families were chosen since their sequences are already established and mapped in sorghum. Sorghum (diploid) is an excellent model to estimate the number of genes in sugarcane (polyploid). The aim of this detailed analysis is to make the results obtained with 6-phosphogluconate dehydrogenases and alcohol dehydrogenases a standard for subsequent general use.

Initiatives have been taken to develop a bioinformatics tool for automatic SNP detection in all SUCEST databases, and to set up an SNP genotyping project to assess the potential of applying SNPs as molecular markers in specific studies on sugarcane.

Genetic analysis of disease resistance

Positional cloning of a major rust resistance gene in cv R 570: utilising synteny between sugarcane and sorghum

A. D'Hont, L.-M. Raboin, L. Le Cunff , O. Garsmeur, H. Telismart

Synteny between grass species was utilised in previous studies to locate a major rust resistance gene identified in cv R 570. It was pinpointed at the terminal end of a cosegregation group belonging to linkage group VII on the R 570 gene map. Based on comparative AFLP (amplified fragment length polymorphism) analysis of DNA pools derived from susceptible and resistant plants, the gene has been surrounded within a 10 cM interval by eight mapped AFLP markers, with the two closest located 2 cM (centimorgan) on each side of the gene.

A study was undertaken in 2001 using markers surrounding the rust resistance gene to enhance the utilisation of synteny between sugarcane and sorghum by using a recently accessible high density gene map for sorghum, and also by BACs (bacterial artificial chromosomes, i.e. large DNA fragments of around 100 kb — kilobase) from sorghum.

An inversed target zone (homologous to the fragment carrying the sugarcane rust resistance gene) was detected on the sequence when AFLP markers were cloned and mapped in sorghum. Four markers were mapped, with the two closest ones located 0.3 and 0.6 cM on

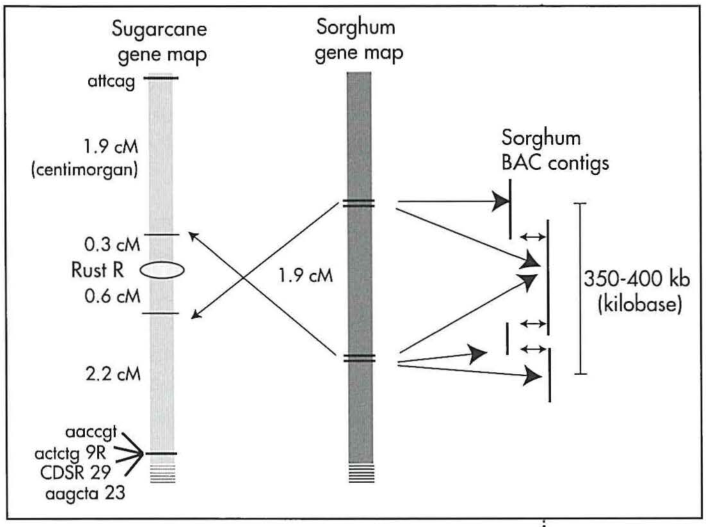


Figure 2. Sorghum molecular resources used to accelerate chromosome walking towards the rust resistance gene in sugarcane.

each side of the gene. These two markers are 1.9 cM apart in sorghum (Figure 2).

Four RFLP loci are located in the inversed target zone in sorghum. These four loci were used to screen the BAC library for sorghum available at Clemson University, USA. Four locus-specific BAC contigs were identified on the basis of BACs detected through this screening process and via partial ordering of the library into contigs (carried out at Clemson University).

Terminal ends of BACs located outside of these contigs were cloned and used to rescreen the BAC library for sorghum. These four BAC contigs were thus found to partially overlap and actually belong to a single contig of around 350-400 kb. This sorghum contig will now be tapped to identify corresponding contigs in sugarcane.

Diversity in sources of rust resistance

L.-M. Raboin, H. Telismart, I. Promi, M. Hoarau

A study to assess segregation of the rust resistance trait in hybrids bred by CERF (Centre d'essai, de recherche et de formation, Réunion) was launched in collaboration with CERF breeders. The goal is to pinpoint sources of rust resistance in parents used for sugarcane breeding in Réunion. More than 100 crosses were screened in 2000 and 2001. This method is efficient for detecting hybrids that display Mendelian segregation of interest with respect to rust resistance. Molecular analyses will be carried out on leaf samples from susceptible and resistant plants to determine whether the resistance gene involved is the same as that in cv R 570 or whether it is another allele or even another locus.

Genetic mechanisms of smut resistance

L.-M. Raboin, H. Telismart, I. Promi, M. Hoarau

The aim of this initiative is to use genetic mapping and QTL detection to gain insight into genetic mechanisms that control smut resistance and to try to locate and identify the genes involved.

Two hundred progeny of a R 570 x MQ 76/53 cross were screened for smut resistance at two sites in Réunion, i.e. Ligne Paradis research station (Saint-Pierre) and CERF's Gol research station (Etang Salé). Other traits were also assessed in these tests, including Brix, tillering and rust resistance, with the aim of making efficient use of the results of molecular marking initiatives.

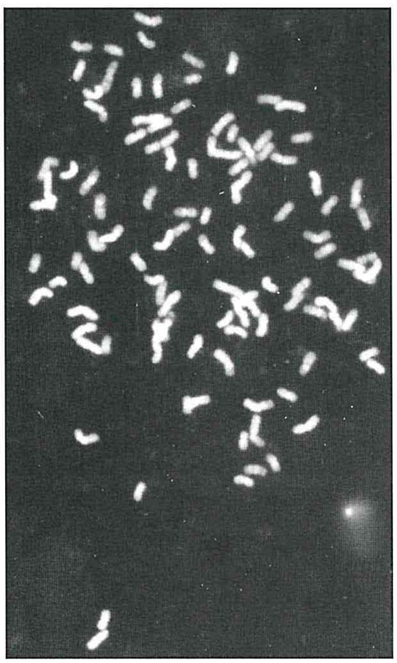
AFLP genotyping of this population is under way and 22 primer pairs have already been analysed. A preliminary analysis to detect associations between markers and measured characters was conducted on an initial set of molecular data available for 100 individuals. Interesting markers were revealed for the different characters (Table 1). One marker was found for smut resistance—it was inherited from cv R 570, i.e. the parental source of resistance. These preliminary results only concerned 100 individuals and must now be confirmed with a larger test population.

Microsatellite markers have also been developed to analyse the causal agent of smut. A microsatellite-enriched library was developed for this fungus in Montpellier and the clones were sequenced. Thirty-eight of them contain microsatellite repeat motifs. Primers were obtained, synthesised and tested for the 20 most interesting microsatellites. A genetic diversity analysis will be carried out with this tool to assess isolates from Réunion relative to those sampled elsewhere in the world.

Table 1. Marker-character associations detected in R 570 x MQ 76/53 progeny.

Markers	Segregation		Number of whips			Number of stalks		
	A	P	sig	mA	mP	sig	mA	mP
R 570 specific								
aagctg_r4	47	50	****	10.13	5.38			
aacctg_r10	40	58						
actcag_rx2	6	92						
accctc_r4	46	47						
aaccac_r6	59	39						
MQ 76/53 specific								
actcat_m14	52	46						
actcat_m3	54	43				***	35.97	31.03
accctc_m8	17	77				****	39.85	32.32
actcac_m14	47	50						
actcac_m2	46	44						
common								
aagctg_rm5	27	69	***	13.37	5.51			
acacta_rm9	11	87	***	18.32	6.30			
actcag_rm9	18	79						
accctg_rm6	9	30						

A : number of clones without markers
P : number of clones with markers
Sig : significance level according to the Kruskal - Wallis test *** : 0.01 **** : 0.005
mA : mean for clones without markers
mP : mean for clones with markers



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Sugarcane chromosomes.

Impact of breeding for high sugar content on molecular diversity

A. D'Hont, S. Alleyne (WICSCBS, Barbados)

Over the last decade, WICSCBS (West Indies Central Sugar Cane Breeding Station) has been conducting research to determine the peak sugar content that can be obtained by recurrent selection in sugarcane. After three breeding cycles, a population yielding very high sugar content was obtained, i.e. 27.6% Brix as compared to a mean 22.4% for the 37 source parents. Molecular markers were used to study genetic diversity in this population, and to assess the possibility of determining regions involved in the genetic determination of sugar content via this population.

The 37 parents and 144 progeny derived from the three recurrent selection cycles were analysed using four AFLP primer combinations. Around 1 200 polymorphic markers were thus generated. Only markers with clearly visible frequency differences between the parents and progeny were read, i.e. 356 markers. An analysis of their frequency distributions revealed significantly different frequencies in 200 of these markers when comparing parents and progeny. Statistical analyses highlighted that some markers were significantly linked with the Brix levels.

To test these candidate markers, a segregation analysis is under way to investigate two 100-individual populations derived from bi-parental crosses between a clone with high sugar content (obtained through a recurrent selection programme) and a clone with low sugar content.

Sugarcane genome database

L.-M. Raboin

This sugarcane genome database is managed with ACEDB software (ACEDB for Microsoft Windows, R. Durbin, J. Thierry Mieg and R. Bruskiewich). It contains general descriptive information on sugarcane varieties used in breeding programmes as well as sugarcane molecular genetics data.

In 2001, the database was supplemented with smut resistance data derived from varietal screening trials conducted by SOSUCO (Société sucrière de la Comoé, Burkina Faso) and data collected in a world survey (Tew, 2000) on varieties most commonly cropped in different sugarcane-growing countries. A small database user's manual was also published.

) P. Rott

Crop protection

In the Crop protection project, pathogens, pests and their environments are studied with the ultimate goal of developing efficient crop protection procedures, through:

- detection of pathogens;
- analysis of pathogen diversity and genetic variability;
- monitoring of the pest and disease status of sugarcane plantations;
- analysis of the impact of pathogens and predators on sugarcane production;
- varietal screening for disease resistance;
- quarantine and sanitization of sugarcane varieties.

The Crop protection project is coordinated by Philippe Rott.

Sugarcane quarantine unit in Montpellier

CIRAD's sugarcane quarantine unit in Montpellier has a leading role in the transfer of sugarcane varieties worldwide. This quarantine service is used by many sugar producers and known research institutes and centres because it offers numerous advantages as regards varietal cleanliness-enhanced by the fact that it is not located within any sugarcane growing area.

The goal of the quarantine unit is to provide a supply of certified disease-free plant material. Work is under way in three main areas: disease elimination in sugarcane by *in vitro* culture, growing varieties in quarantine glasshouses, and disease diagnosis and detection.

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A sugarcane meristem after 3 months of culture.

Disease elimination in sugarcane by *in vitro* culture

J.-C. Girard, M. Chatenet, P. Rott, J.-F. Bousquet, M.-J. Darroussat, R. Habas, M. Muller

In 1998, meristem culture was found to be efficient for eliminating the *Sugarcane yellow leaf virus* (SCYLV) in sugarcane varieties infected with this disease. A systematic disease-elimination process is now implemented in CIRAD's sugarcane quarantine unit in Montpellier to eradicate SCYLV in elite sugarcane varieties. In 2001, 31 SCYLV-infected varieties from Guadeloupe and 80 infected varieties from other geographical areas were cleaned by meristem culture; 13 varieties were planted in pots and transferred to quarantine glasshouses.

Varieties grown in quarantine glasshouses

J.-C. Girard, M. Chatenet, P. Rott, J.-F. Bousquet, M.-J. Darroussat, R. Habas, M. Muller

Two hundred sugarcane varieties were grown in quarantine glasshouses, including 100 in the first cycle and around 100 in the second.

One hundred and nine sugarcane varieties were released from quarantine during the 2000-2001 season: 14 international varieties, 46 FR varieties produced and supplied by CIRAD-CA in Guadeloupe, 44 varieties supplied by the West Indies Central Sugar Cane Breeding Station (WICSCBS) in Barbados and 5 varieties for limited circulation. The sugarcane cuttings were mainly distributed in Africa (Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Mali, Uganda, Senegal, Sudan, Chad), but also in the West Indies (Barbados, Guadeloupe, Martinique), the Mascarene Islands (Madagascar, Réunion), Australia and South America (Brazil) (Table 2).

Table 2. Number of sugarcane varieties received and released by the CIRAD sugarcane quarantine unit in Montpellier in 2001.

Region (Organization)	Introduction	Release
Australia (BSES)	-	5
Barbados (WICSCBS)	30	11
Brazil (COPERSUCAR)	-	13
Burkina Faso (SN-SOSUCO)	-	54
Cameroon (SOSUCAM)	-	91
Congo (SARIS)	-	103
Côte d'Ivoire (CNRA)	-	60
Florida (USDA-ARS-SAA)	12	-
Guadeloupe (CIRAD)	60	58
Madagascar (CMCS)	-	9
Mali (SUKALA SA)	-	50
Martinique (CTICS)	-	99
Uganda (USCTA)	-	49
Philippines (PHILSURIN)	32	46
Réunion (CERF)	-	8
Senegal (CSS)	-	60
Sudan (Kenana Sugar Co. Ltd.)	-	60
Chad (SONASUT)	-	99

Disease diagnosis and detection in quarantine glasshouses

J.-C. Girard, M. Chatenet, P. Rott, J.-F. Bousquet, M.-J. Darroussat, R. Habas, M. Muller

Sugarcane varieties grown in the quarantine glasshouses are tested to detect the presence of serious sugarcane diseases. In first-year quarantine, they were systematically screened in the laboratory to detect leaf scald *(Xanthomonas albilineans)*, ratoon stunting *(Clavibacter xyli* subsp. *xyli)*, *Sugarcane mosaic virus* (SCMV), *Sorghum mosaic virus* (SrMV) and *Sugarcane yellow leaf virus* (SCYLV).

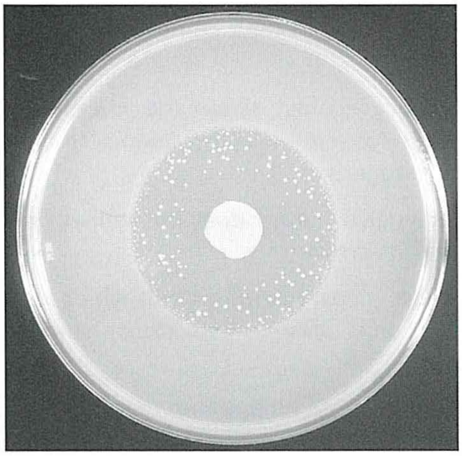
Varieties grown in second-year quarantine were screened again for the presence of SCYLV. Some varieties were also tested for *Fidji disease virus* (FDV) and phytoplasms.

No cases of leaf scald or mosaic virus infection were detected in the quarantine glasshouses. The causal agent of ratoon stunting was identified in two varieties from China. SCYLV was detected in 58 of the 138 varieties in first-cycle quarantine by a molecular RT-PCR (reverse transcription - polymerase chain reaction) test and immunoprinting on nitrocellulose membrane. However, no cases of SCYLV were detected in the 23 varieties derived from meristem cultures using material from infected plants. The results of screening tests for phytoplasms and FDV were negative.

Pathological and epidemiological studies

Analysis of genes involved in the biosynthesis of toxic albicidin produced by leaf scald

P. Rott, M. Royer, D. Pitorre



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Production of albicidin toxin by *Xanthomonas albilineans*.

Sugarcane leaf scald *Xanthomonas albilineans* is the focus of the main phytopathological study of the CIRAD Sugarcane Programme. This pathogen produces a toxin complex, with albicidin as the main component. Albicidin is involved in the pathogenicity of *X. albilineans*, which varies according to the bacterial strain involved. Research that began at the University of Florida in 1993 is being continued at CIRAD in Montpellier to investigate the genetics of albicidin. Genes involved in the production of this toxin have been cloned and sequenced. In 2001, an analysis of the nucleotide sequences of these genes revealed that the metabolic pathways of albicidin involve several megaproteins of the polyketide synthase (PKS) family and nonribosomal polypeptide synthetases (NRPSs). *X. albilineans* megaproteins differ markedly from those described in other microorganisms.

These results enhance the prospects of research on albicidin biosynthesis pathways and biochemical characterisation of this molecule. These studies should generate key information concerning the action of albicidin in the pathogenicity of *X. albilineans* and enhance the overall understanding of polyketide biosynthesis pathways in microorganisms.

Genetic diversity of *Xanthomonas* pathogens in sugarcane

L. Costet, L. Gagnevin, J. Notaise, H. Lombard, J.-C. Ribotte, G. Gauvin , Y. Houdeau

© L. Costet

Symptoms caused by different *Xanthomonas* species in sugarcane.

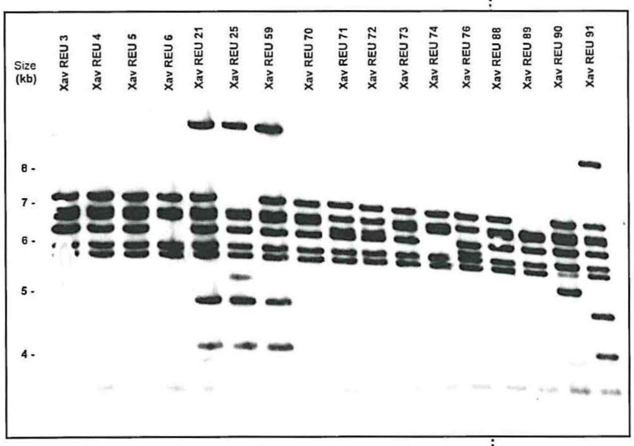
Several *Xanthomonas* species infect sugarcane and induce often similar leaf symptoms (necrosis, streaks, blanching, etc.): *X. albilineans* (Xa), the causal agent of leaf scald; *X. axonopodis* pv. *vasculorum* (Xav), the agent of sugarcane gumming disease; *X. vasicola* pv. *holcicola* (Xvh), the agent of sorghum bacterial leaf streak disease; and *Xanthomonas* sp. (Xsp), the agent of false red stripe in Brazil.

Sugarcane bacterial diseases are primarily controlled through preventive measures. Strict selection of resistant cultivars in sugarcane breeding programmes is thus essential. Thorough knowledge on the diversity and variability of the pathogens should enhance selection efficacy. A collection of *Xanthomonas* pathogen strains from Réunion and other geographical areas was established to evaluate their diversity. The causal agent of sugarcane gumming disease was also assessed in detail. Overall, a hundred strains were obtained and some 30 strains of *X. axonopodis* pv. *vasculorum* and *X. vasicola* pv. *holcicola* have already been biochemically characterised.

Isolation of *Xanthomonas* strains

The development of new semi-selective media to isolate *Xanthomonas* pathogens of sugarcane and the study of their colonisation potential led to the identification of:

- seven antibiotics with efficacy against sugarcane microflora in Réunion that can be added to semi–selective media to enable isolation of *Xanthomonas* pathogens;
- five antibiotics with efficacy against microflora but which do not inhibit *Xanthomonas albilineans* growth;
- three antibiotics with efficacy against microflora but which do not inhibit growth of *Xanthomonas* strains that cause sugarcane gumming disease;
- antibiotics that facilitate the separation of *Xanthomonas* species into four groups on the basis of their resistance to these antibiotics (*X. albilineans*, *X. axonopodis* pv. *vasculorum* and *X. vasicola* pv. *holcicola*, *Xanthomonas* sp. from Brazil, and *X. sacchari*).



Genetic polymorphism of 17 *X.axonopodis* pv. *vasculorum* isolates from Réunion identified by an *avr* probe.

Variability in the pathogenicity of *Xanthomonas* strains

Genetic diversity of *Xanthomonas* pathogens in sugarcane was assessed using specific tools (molecular markers of pathogenicity and neutral molecular markers). Techniques involving RFLP (restriction fragment length polymorphism) and probes derived from genes involved in the pathogenicity of bacteria, i.e. *hrp* (hypersensitive response and pathogenicity) and *avr* (avirulence), were used. Several haplotypes were thus identified in some species.

The *hrp* probe hybridizes with genomic DNA from all *Xanthomonas* species that are pathogenic in sugarcane, except for *X. albilineans* and *X. sacchari*. The different species can be differentiated on the basis of their gene profiles. The *avr* probe did not hybridize with DNA from *X. albilineans* and *X. vasicola* pv. *holcicola*. However, 11 haplotypes were identified in the pathovar *X. axonopodis* pv. *vasculorum* (sugarcane gumming disease), which includes 41 strains, i.e. 30 strains from Réunion and 11 strains from various other geographical areas. After phylogenetic analysis, these 11 haplotypes were assigned to three separate groups.

Leaf scald on cv B 69566 infected by aerial dissemination.

Aerial dissemination of *Xanthomonas albilineans* in Guadeloupe

J.-H. Daugrois, P. Champoiseau, S. Bonotto, R. Boisne-Noc, S. Joseph

In 1993 and then in 1996, atypical leaf scald symptoms were observed in mother nurseries. The *X. albilineans* bacterial causal agent was isolated. For about 10 years, it has been suspected that leaf scald contamination of sugarcane fields occurs via aerial dissemination. The aim of this study was to assess and gain insight into the dissemination mechanisms involved.

A first series of *X. albilineans* bacteria were isolated from dewdrops 4-5 weeks prior to the appearance of disease symptoms. Contamination of three test plots did not, however, occur at the same time. Depending on the location of the plots, the first bacteria were isolated on the surface of leaves 8-22 weeks after planting. The speed of contamination seemed to depend on the proximity of contaminated sugarcane plants and on climatic factors.

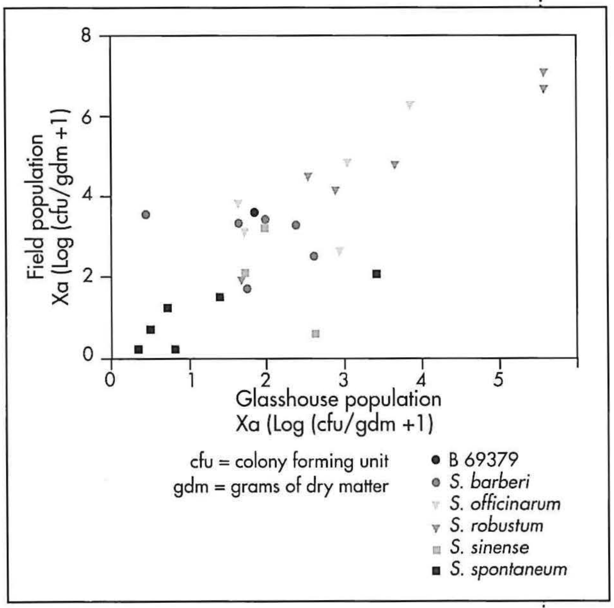


Figure 3. Correlation between *Xanthomonas albilineans* populations on sugarcane stalks under field and glasshouse conditions.

Several million *X. albilineans* bacteria per ml of water were sometimes detected. In the first ratoon, epiphytic bacterial populations varied substantially between the test plots. Population levels were higher in humid areas. Stalk contamination was associated with the earliness of *X. albilineans* infestation of the plot and with the density of epiphytic populations, and ranged from 2 to 18% of plant cane stalks and 1.4 to 7% in ratoons. The least contaminated plot was located in a dry area (Nord Grande-Terre), amidst commercial sugarcane plantation fields (Figure 3).

Study of the yellow leaf syndrome in Réunion

A new sugarcane disease called yellow leaf syndrome (YLS) was discovered in Brazil in the early 1990s, causing estimated yield losses of 30-40%. It is now found throughout the world and widespread in Réunion on the three main cultivars, with infection rates ranging from 10 to 100%, depending on the site and variety. Research is focused on four aspects of this disease: virus dynamics, economic impact, disease vectors and genetic variability of the pathogen.

Epidemiology of the *Sugarcane yellow leaf virus*

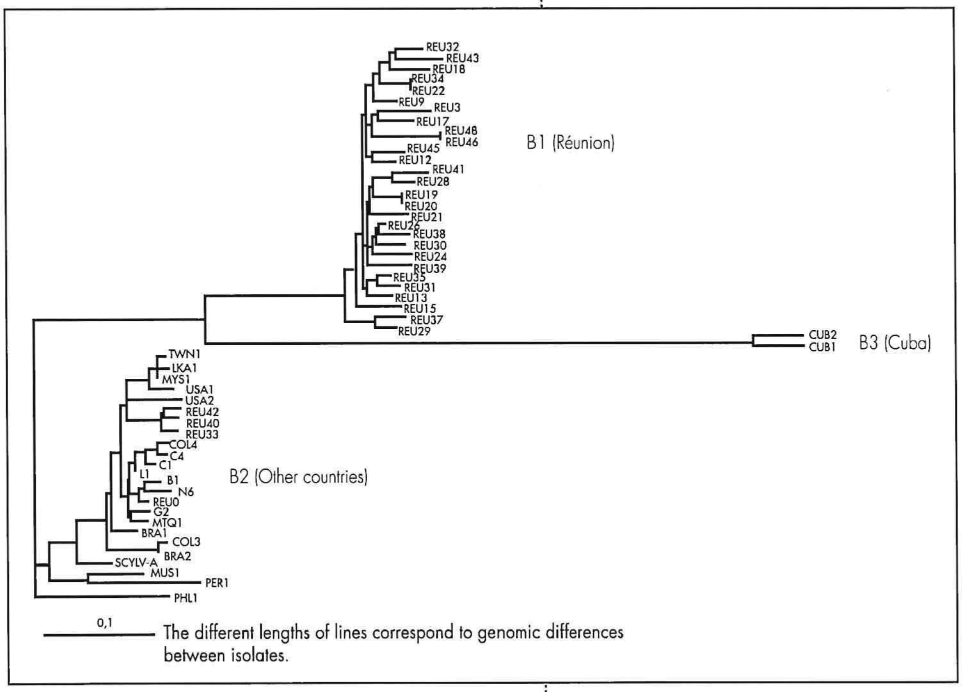
L. Rassaby, L. Costet, H. Lombard, J.-C. Ribotte, G. Gauvin, Y. Houdeau

A study was conducted in Réunion to assess the rate of sugarcane recontamination by the *Sugarcane yellow leaf virus* (SCYLV). For his purpose, SCYLV-free cv R 575 plantlets obtained by *in-vitro* and meristem culture were planted in the field. This cultivar was selected on the basis of studies on SCYLV dynamics, which showed that it always had a virus infection rate of around 100% in sugarcane cropfields, irrespective of the area considered. The virus was detected in 14% of the micropropagated plantlets 2 months after they had been planted in the field, and in 25% of these plantlets 6 months later.

Genetic diversity of the *Sugarcane yellow leaf virus*

L. Rassaby, P. Rott, M. Royer

Genetic variability of *Sugarcane yellow leaf virus* (SCYLV) was analysed with 48 virus isolates from Réunion and 24 isolates from other countries (Figure 4). Part of each of the six ORFs (open reading frames)—regions that each correspond to a genomic nucleotide sequence—was amplified by RT-PCR (reverse transcription - polymerase chain reaction), cloned and sequenced. Phylogenetic analysis of the resulting sequences showed that the most variable regions on the SCYLV genome are ORF1, encoding a multifunctional protein, and ORF2, encoding polymerase. ORF3, which codes for the capsid protein, was found to be the least variable region. The virus isolates were classified on the basis of their genomic regions into two to four phylogenetic groups. Based on their overall genomic variability, most of the isolates from Réunion differed from those of other origins. However, four isolates from Réunion closely resembled those from other geographical areas. This suggests that SCYLV was introduced in Réunion and that a specific genotype then became established and developed on this island.



	B1	B2	B3
B1	98.2-100		
B2	94.0-95.0	97.0-100	
B3	90.9-91.8	89.7-90.9	99.0

Percentage of intra- and inter-group homology.

Figure 4. Phylogenetic relationships between the different SCYLV isolates established on the basis of nucleotide fragment B.

Analysis of *Sugarcane mosaic virus* isolates from Africa and Asia

C. Mazarin, S. Garcia, M. Chatenet, J.-C. Girard, M. Muller, M.-J. Darroussat, P. Rott

The pathogenicity of six *Sugarcane mosaic virus* (SCMV) isolates from Cameroon and the Congo were characterised on sugarcane varieties

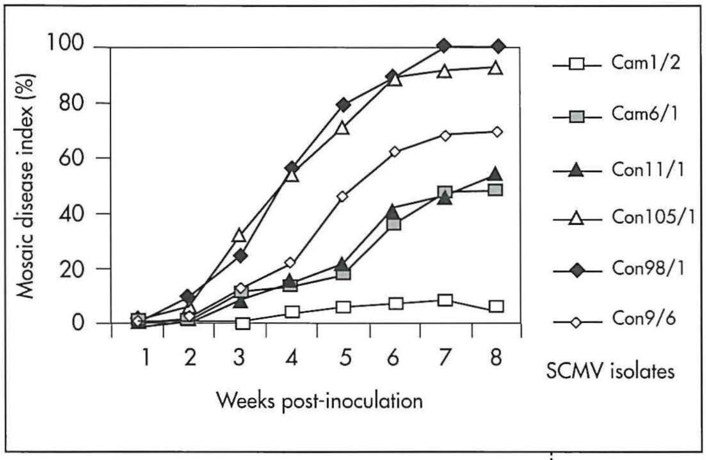
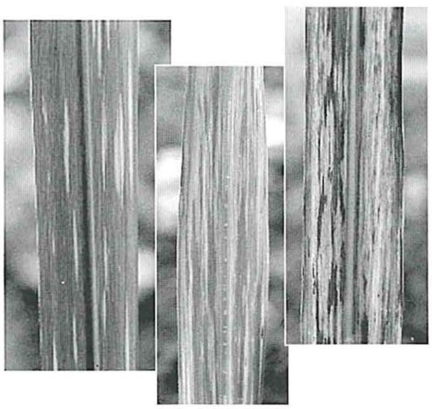


Figure 5. Mosaic disease progression in cv B 8008 inoculated with six SCMV isolates from Cameroon and the Congo.



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Mosaic disease symptoms of three phylogenetic subgroups.

B 8008 and R 570 (Figure 5). These six isolates belong to three different phylogenetic groups or subgroups and are representative of the genetic diversity of SCMV in these two African countries. The six isolates were pathogenic in all tests on cv B 8008, but the intensity and severity of symptoms varied according to the isolate, symptom monitoring date and trial. However, only one isolate (Con98/1) was highly pathogenic in cv R 570 and induced symptoms in all trials. There was a very close correlation between the appearance of symptoms and the presence of the virus on different leaves of the plant. In contrast, there was no clear correlation noted between any phylogenetic group or subgroup and qualitative or quantitative aspects of SCMV pathogenicity.

Six virus isolates that are agents of SCMV in Asia were found to induce symptoms in sugarcane, maize and sorghum after mechanical inoculation. Electronic microscope analyses revealed that they all have the same size of filamentous virus particles as members of the Potyviridae family. Pak155/1 was the only isolate that reacted to an anti-*Potyvirus* serum and an anti-SCMV serum. This was the only isolate with a genomic region encoding a capsid protein that could be amplified by RT-PCR using *Potyvirus*- and SCMV-specific primers. This isolate from Pakistan thus belonged to the SCMV species and the *Potyvirus* genus. The systematics of the five other isolates have yet to be determined.

Disease control

Phytosanitary status of sugarcane plantations in Réunion, Guadeloupe and the West Indies

P. Champoiseau, S. Bonotto, R. Boisne-Noc, S. Joseph, J.-H. Daugrois, L. Costet, P. Rott

Monitoring and forecasting phytosanitary status in sugarcane plantations revealed that there were no new pathological phenomena in Réunion and Guadeloupe in 2001. Very localised symptoms of Pokkah boeng, wilt and ratoon stunting disease (RSD) were noted in different diagnostic assessments carried out in Guadeloupe. Serious occasional stemborer attacks and smut-infected whips were observed on cv B 47258 in pre-nursery plots.

RSD diagnostic assessments were also conducted for WICSCBS in Barbados and for Central Romana in the Dominican Republic. The study carried out in collaboration with Central Romana highlighted the extent of RSD contamination locally.

Impact of diseases on yields of sugarcane varieties cultivated in Guadeloupe and Martinique

L. Rassaby, L. Costet, P. Champoiseau, S. Bonotto, R. Boisne-Noc, S. Joseph, P. Rott

A study on the impact of RSD on three varieties grown in Guadeloupe and Martinique (B 8008, R 570, B 5992) has been under way since 1998 because the causal agent of this disease, *Clavibacter xyli* subsp. *xyli*, is present on these two islands. Mean first- and second-ratoon cane yield losses due to RSD infection were 2.6% for cv B 8008, 10.1% for cv R 570 and 11.6% for cv B 5992. Regardless of the crop cycle, cv B 8008 was found to be less infected than cvs R 570 and B 5992, which had identical contamination rates. This decline seemed to be correlated with a decrease in stalk height.

In 2000, the impact of *Sugarcane yellow leaf virus* (SCYLV) was experimentally assessed on the three main varieties grown in Réunion (R 570, R 577, R 579). This virus had a depressive effect on some yield components as early as the plant cane stage only in cv R 577 that generally worsened in the first-ratoon phase. For cv R 577, cane yields (t/ha) dropped by 37% and sugar levels decreased by 12%, whereas a yield loss of 19% was recorded for cv R 579. Cane yields were not affected in cv R 570, but stalk heights and diameters were found to be reduced in SCYLV-infected cane.

Integrated control of sugarcane spotted stemborers

The spotted stemborer, *Chilo sacchariphagus* (Lepidoptera, Pyralidae), is a major sugarcane pest in Southeast Asia and the Indian Ocean region. In Réunion, it induces heavy sugarcane yield losses, especially in usually high-yielding cv R 579. Studies have shown that it causes 20-30% sugar losses in cv R 579, but only 3% in cv R 570. Varietal selection is thus an interesting alternative to efficiently control this stemborer. Moreover, physicochemical factors of varietal resistance are being investigated with the aim of developing reliable varietal breeding tools.

For several years, the entomology laboratory has been mobilising all of its resources to enhance integrated control of this pest. The population dynamics of *C. sacchariphagus* have been studied in these regions since 1997. This baseline study serves as an observatory that should help to pinpoint the factors that influence its dynamics. The information generated is essential for setting up efficient control procedures: cropping techniques (e.g. stopping burning), biological control, and planting of resistant or tolerant sugarcane varieties. A biological control programme involving inundative releases of *Trichogramma* flies was initiated in 2000 and represented the laboratory's main focus of activity 2001. In parallel, the potential use of stemborer-resistant varieties is being investigated specifically with respect to cv R 570.

Extent of spotted stemborer outbreaks in Réunion

R. Tibère, J.-C. Gauvin, J. Rochat, R. Goebel

A monitoring network was set up to assess sugarcane crop damage in around 35 pairs of plots representative of a broad range of typical climatic and cropping conditions. These plots are located in about 20 different geographical sites in Réunion, at elevations ranging from 20 to 700 m. Sugarcane varieties R 570 and R 579 (or R 575 and R 577 at high elevations) were grown on these paired plots and monitored once quarterly from 1997 to 2001.

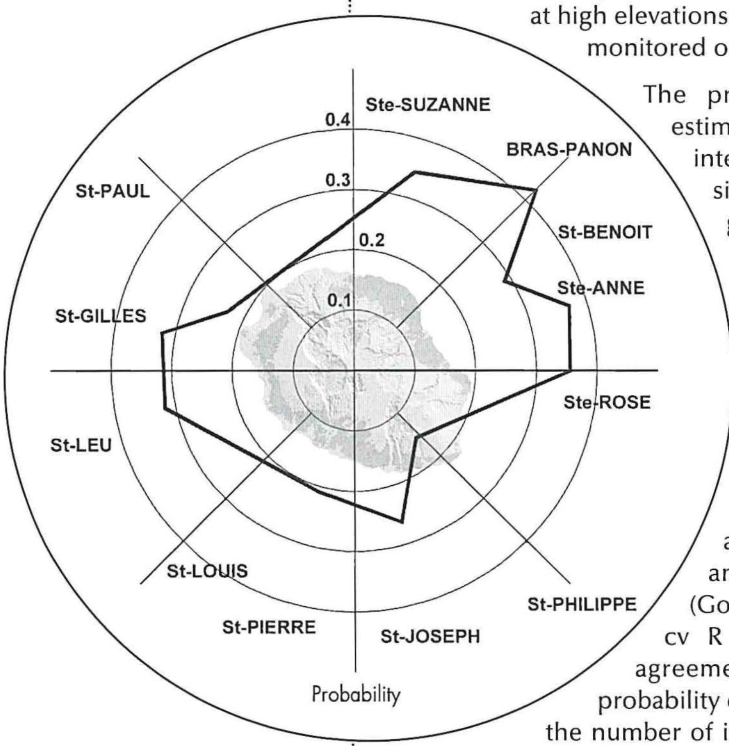


Figure 6. Probability of stemborer infestation in different geographical areas in Réunion.

The probability of stemborer infestation, estimated on the basis of the number of internodes attacked, was very significantly site specific, indicating clearly defined geographical structuring (Figure 6). Spotted stemborer infestation was twice as frequent in the northeastern part of the island than in the west, with the lowest infestation rates noted in the south. Infestation probability was highest at around 300 m elevation, and then sharply declined with elevation to reach the lowest rate at sea level. These results agree with the distribution of this pest and its optimal thermal conditions (Goebel, 1999). Stemborer attacks affected cv R 570 much less than cv R 579, in agreement with previous observations. The probability of infestation of cvs R 575 and R 577 and the number of internodes were in agreement with the results obtained for cv R 579. There were slightly fewer attacks on cane plants located along the edges of the plots, without any difference in the number of internodes attacked. Non-irrigated plots in the northeastern part of the island had higher infestation levels than drip irrigated plots, which in turn had higher infestation levels than sprinkler irrigated plots in the south. Plots that had been burnt—before or after cutting—had higher infestation rates than other plots, thus demonstrating that this cropping practice is detrimental to sugarcane crops. Finally, most spotted stemborer attacks occurred from January to March, and to a lesser extent from April to June.

Resistance of R 570 and R 579 sugarcane varieties to spotted stemborer infestation

J.-M. Bègue, J. Rochat, B. Vercambre

Several complementary strategies have been implemented to enhance integrated control of this pest and therefore reduce its impact on sugarcane crops. For instance, planting available varieties that are resistant to or tolerant of this pest is an efficient control technique that can be implemented alone or in conjunction with other methods such as biological control.

R 570 is less attacked by spotted stemborers than other sugarcane varieties (e.g. R 579) that are currently grown in Réunion. Hence, R 570, or another variety that has a similar level of resistance to stemborers, could be adopted within the framework of an integrated control strategy against this pest. Studies are under way to determine the origin of this resistance via different approaches: behavioural studies, choice tests, studies on the physical features of sugarcane stalks, and histological analyses (Goebel, 1999; Vercambre *et al.*, 2001).

Studies on rearing spotted stemborers in the laboratory have been conducted for several years with the aim of producing controlled biological material for potential use in different experiments. Stemborers are reared on semi-artificial medium supplemented with ground cane stalk tissues. In 2000, this rearing method was used to assess the impact of different sugarcane varieties and their properties on stemborer development. In 2001, these experiments were repeated to check the reliability of the method, but the results could not be replicated. Hence, this semi-artificial medium is not very reliable for biological screening aimed at identifying sugarcane varieties resistant to sugarcane spotted stemborers.

Rearing stemborers on semi-artificial medium to assess varietal resistance

J. Rochat , J.-M. Bègue, B. Vercambre

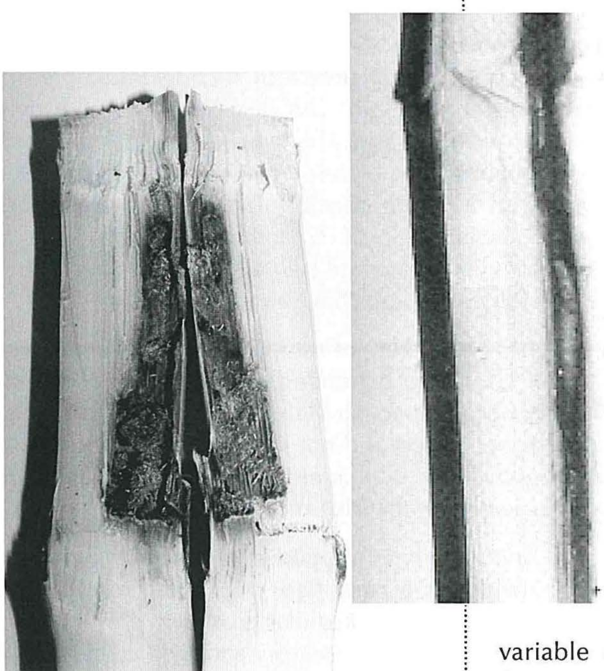
An assessment of the development of stemborers reared on powdered leaves from cvs R 570 and R 579 revealed identical survival rates when the caterpillars were reared on medium prepared with powdered healthy tissues from different plant parts of both varieties. Pupae reared on medium with powdered tissues from cv R 579 were heavier (+ 9.6%) and females that emerged were found to lay more eggs (+ 39%) than those reared on medium with powdered tissues from cv R 570-a difference of 4.8 more eggs per mg of powder. The results seemed to confirm the susceptibility of the top of cv R 570 stalks and the base of cv R 579 stalks. This was also demonstrated using the BING (beam identification by non-destructive grading) vibration analysis system.

Histological assessment of sugarcane stalk damage

I. Faure, J. Escoute, B. Vercambre

The feeding behaviour of the sugarcane spotted stemborer *C. sacchariphagus* was studied relative to stalk lignin contents in cvs R 570 and R 579. Histological cross-sections of these tissues were analysed to characterise the central part of internodes from four different positions on the stalk: bottom (lower 1/3), mid (middle1/3), top (upper 1/3), tip (eight topmost internodes, located under the last visible dewlap). 100 µm thick histological sections were cut with a vibratome (Micro-cut H 1200 from BIORAD) to assess the surface of tissues between the epidermis and pith. Lignin content was evaluated by image analysis (Leica Qwin® software) on the basis of its colour relative to the entire surface area.

The results highlighted a predictable lignification gradient associated with the different sections on the cane stalk—this gradient was very clear for the cortex region. The lignification rates were quantified. The tip always had very low lignification, with less than 8% of the area lignified, whereas the most lignified zones had levels of 35- 45%. Gradients between the cortex and the pith were measured and showed higher lignification around the base of the stalk, especially in young stalks. The pith showed very little or no lignification, and this was constant for all stalk parts and ages. There were no obvious differences between lignification rates on the surface of stalks when comparing cvs R 570 and R 579, even though the lignification rate in the zone close to the epidermis was 5-10% higher in cv R 579 as compared to the resistant cv R 570. These results will have to be confirmed because of the heterogeneity of the cane stalks tested and the low number of samples assessed.



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Damage caused by spotted stemborers on cvs R 570 (top) and R 579 (below).

Use of the Optima image analysis method to assess sugarcane damage

B. Vercambre, G. Gisors, J.-M. Méot

Optima is an image analysis method designed for assessing plant damage. Evidence of *C. sacchariphagus* infestation was very accurately assessed in comparable batches of cane stalks from cvs R 570 and R 579. The results were recorded at five sites in Réunion between April and December 2000. In 2001, the data were processed on the basis of around ten criteria and six infestation indices were estimated. The stability of resistance criteria in cv R 570 varied according to the homogeneity of the cane stalk batches studied. The stable citeria were: the number of independent galleries in an infested internode, the number of galleries between two consecutive internodes, the frequency of cane surface and core damage, the frequency of infestation of the top three to five internodes. The variable criteria were: the number of holes per internode, the frequency and severity of infestation. Stemborer entrance and exit holes were found on the stalk axes of the leaves and leaf sheaths.

Trichogramma chilonis females preying on a spotted stemborer egg mass.

The width of galleries relative to the total internode volume on the stalk was the most discriminating index.

Biological control of spotted stemborers using egg parasitoids

Inventory of egg parasitoids

J. Rochat, A. Ruttee, E. Fernandez, R. Goebel, E. Tabone (INRA-Antibes), B. Pintureau (INRA/INSA-Lyon)

In 2000 and 2001, an inventory of egg parasitoids that occur in sugarcane agrosystems was conducted at 10 chosen sites in preparation for biological control operations with *Trichogramma*. Parasitoids were captured in traps baited with eggs of *Galleria mellonella* (large wax moth), a laboratory substitute host for *Trichogramma*, or with stemborer eggs. *Trichogramma* were detected at all sites, but their frequencies and numbers varied. All individuals were identified as belonging to the species *Trichogramma chilonis* Ishii.

Population dynamics of egg parasitoids

J. Rochat, A. Ruttee, E. Fernandez, R. Goebel, E. Tabone (INRA-Antibes)

Egg parasitoid trapping tests were conducted in 35 plots (10 sites) cropped with two sugarcane varieties (R 570, R 579) of different ages and sizes and at different times of the year. Two types of trap (box, tube) were used and baited with different numbers of *G. mellonella* or *C. sacchariphagus* host eggs. The rate of *Trichogramma* parasitism of host eggs depended on the plot and decreased with the density of eggs in the trap. The capture probability was also highly dependent on the plot. This probability was higher when stemborer eggs were used as bait. It increased with the density of stemborer eggs, whereas it decreased with the density of *G. mellonella* eggs. This pattern indicates that either *Trichogramma* have a preference for their natural host, or the substitute host eggs have a repellent effect.

There was a higher probability of trapping *Trichogramma* on shorter cane (less than 2 m). It also depended on the period of the year, i.e. lower probability from January to March and higher from October to December. The other factors did not have a significant effect on this probability. The parasitism rate significantly decreased with the host egg density, irrespective of the plot and other factors.

The number of *Trichogramma* trapped by this strategy was still very low and the corresponding parasitism rates were much lower than rates obtained in previous studies carried out in the Indian Ocean region. Other complementary laboratory and field tests revealed that these low capture and parasitism rates were due to the type of traps used, which limit access to host eggs even though they do attract

Trichogramma. The parasitism rates obtained should thus not be taken as reference values, but the effects of the different factors studied seem reliable. The low probability of trapping *Trichogramma* from January to March (a period when stemborer densities are highest) could also be explained by competition between relatively inaccessible eggs in the traps and more abundant nearby eggs.

Studies should now be conducted on new and more efficient *Trichogramma* trapping systems.

Biological analysis of three *Trichogramma chilonis* strains from Réunion

F. Reay-Jones, J. Rochat, E. Fernandez

The aim of this study was to investigate biotypes (or geographical races) of *Trichogramma chilonis* adapted to different sugarcane cropping areas, and also to select the strain with the best potential for mass laboratory rearing and biological control in the field. Three *T. chilonis* strains studied were derived from Saint-Benoît, Saint-Pierre and Saint-Joseph characterised by hot humid, hot dry and cool humid climates, respectively.

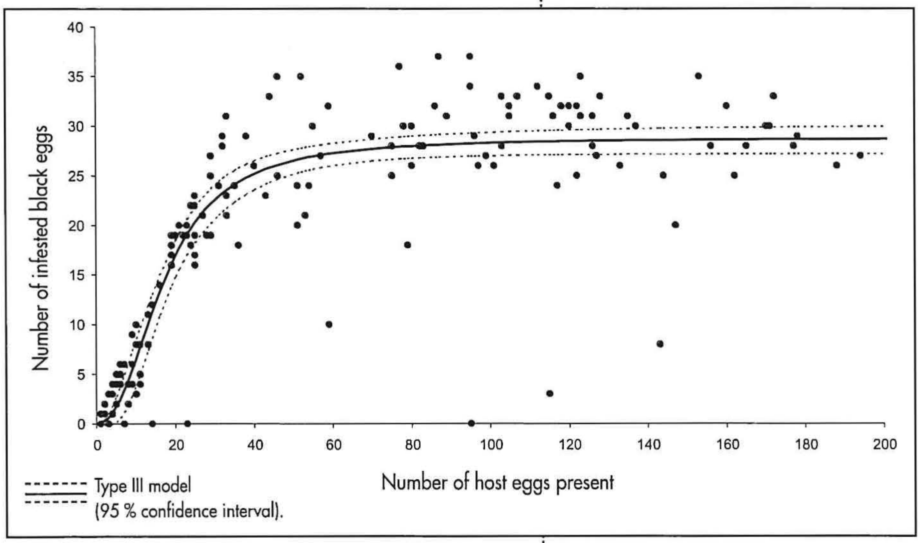
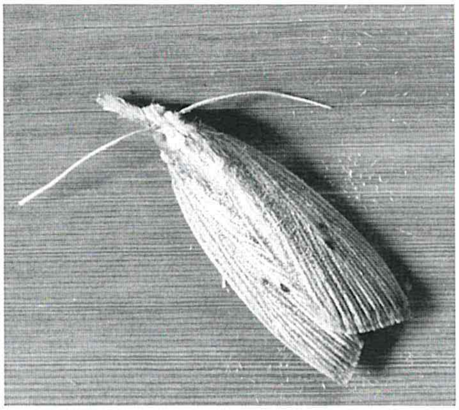


Figure 7. Functional response of females of the Saint-Benoît *T. chilonis* strain to the density of substitute *G. mellonella* host eggs at 25°C.

Females of the Saint-Benoît strain preyed on more *G. mellonella* or *C. sacchariphagus* eggs than the two other strains (Figure 7). Individuals of the three strains developed at different rates, i.e. more rapidly for the Saint-Benoît strain (11 days at 25°C), and less rapidly for the Saint-Joseph strain. This latter strain also had the lowest thermal threshold for development (9.5°C), while the Saint-Benoît strain had the highest (13°C). These results are in agreement with the climatic origin of the strains and the 13°C threshold measured for spotted stemborers (Goebel, 1999). At a constant temperature of 35°C, only the Saint-Benoît strain developed, but with difficulty (few adults and all wingless) and only in the natural host.

The Saint-Benoît strain-whose overall traits appeared suitable for mass rearing and potentially useful for biological control via inundative release-was handed over to FDGDEC (Fédération départementale des groupements de défense contre les ennemis des cultures), a professional agency responsible for development of the biological control technique in Réunion, in collaboration with CIRAD. Trials to assess the field efficacy of this *Trichogramma* strain against spotted stemborers are to be initiated in 2002.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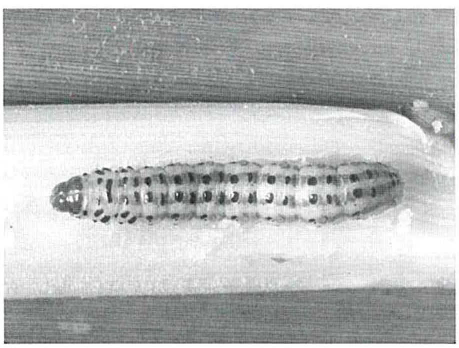
Adult *Chilo sacchariphagus.*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Chilo sacchariphagus larva.

Collaboration with southern African and Indian Ocean regions

R. Goebel

As part of an initiative to develop collaborations between CIRAD and the South African Experiment Station (SASEX) at Kwazulu-Natal (South Africa), studies have been under way since 2001 on pest control in relation to *Eldana saccharina* and *Chilo sacchariphagus* stemborers. This regional operation involves countries in southern Africa and the Indian Ocean region, with three main objectives:

- to provide scientific support for research under way on the African stemborer *Eldana saccharina*, as requested by the South African partners;
- to provide expertise and initiate regional collaboration on the sugarcane spotted stemborer *Chilo sacchariphagus*, because of the risks of infestations in Kwazulu-Natal and Mpumalanga provinces by stemborers migrating from Mozambique;
- to set up and strengthen bilateral cooperation between Kwazulu-Natal and Réunion with respect to pest monitoring and integrated control on smallholder sugarcane farms, through research, expertise and training activities.

Impact of the African stemborer *Eldana saccharina* on sugarcane yield in Kwazulu-Natal

R.Goebel, M. Way (SASEX, South Africa)

Knowledge acquired and methods developed in Réunion on the spotted stemborer *Chilo sacchariphagus* have facilitated studies on sugarcane yield loss caused by *Eldana saccharina* in southern Africa. A research project was set up in 2001 to evaluate yield losses. Tests are under way on protected plots (treated) with artificial infestation, and on unprotected plots (control). Loss of sugarcane quality (sugar, fibre, etc.), yield (cane and sugar) and yield components (stalk diameter and height) will be measured according to the extent of stemborer infestation. Complementary studies will be carried out on sugarcane populations to determine the impact of stemborer infestations on sugarcane growth.

Two tests were set up in SASEX experimental stations in Zululand (area with high *Eldana saccharina* infestation levels): Gingindlovu and Empengeni (north of Durban). These field experiments are complemented by a glasshouse trial under way Mount Edgecombe.

Resistance of sugarcane varieties to *Eldana saccharina*

R. Goebel, M. Keeping (SASEX, South Africa)

Studies on the resistance of sugarcane varieties to *Eldana saccharina* in South Africa are based on previous studies carried out by CIRAD.

Methods used to investigate *C. sacchariphagus* in the Indian Ocean region were adapted for studies on *E. saccharina* in Africa. The aims are:

- to detect variability in the responses of varieties to stemborer infestation;
- to characterise the damage (puncture points, analysis of stemborer pathways in the pith);
- to identify potential resistance factors that hamper stemborer penetration and feeding behaviour (stalk silica levels, pith and bark texture, the presence of organs that hinder penetration, etc.).

Initial tests on cut cane under artificial infestation conditions showed that young *E. saccharina* nymphs penetrate tender parts of the stalks—usually around buds and in the radicular area, between growth rings and leaf scars. Internodes were almost never penetrated. Differences were noted between commercial varieties (N11, N12, N21 et N30) with respect to penetration speed and internal damage, in agreement with other results obtained on an experimental farm. These tests are ongoing.

Extent of spotted stemborer *Chilo sacchariphagus* outbreaks in sugarcane-growing areas in Mozambique

R. Goebel, D. Conlong, M. Way (SASEX, South Africa)

Two years ago, SASEX launched an awareness campaign on spotted stemborers for the benefit of South African sugarcane growers. CIRAD was asked to implement preventive measures to overcome the current risk of outbreaks of stemborers migrating from Mozambique. This support includes:

- conducting scouting surveys on sugarcane farms close to the Mozambique border;
- analysing the stemborer infestation situation in Mozambican sugarcane plantations in collaboration with the South African commercial groups Tongaat Hulett Sugar and Illovo;
- collecting stemborer eggs, nymphs and pupae in order to identify the parasitoid complex and assess parasitism levels;
- organising parasitoid release operations in Mozambique, as proposed by SASEX, and participating in post-release assessments;
- coordinating a small discussion group on problems caused by *Chilo sacchariphagus* and organising seminars for South African sugarcane growers via the Pest and Disease committees.

Two joint CIRAD/SASEX missions were carried out in 2001 in sugarcane growing areas in Mozambique (Mafambisse and Marromeu) at the request of stakeholders. Stemborer infestations rates are rapidly progressing—but not yet to an alarming extent—due to the rapid extension of sugar production in these areas. Stakeholders requested support from SASEX and CIRAD to control this pest. A biological control operation involving the release of *Xanthopimpla stemmator*, a pupa parasitoid, was carried out by SASEX.

Survey of stemborer damage on smallholder plantations in Kwazulu-Natal and Réunion

R. Goebel, M. Way, G. Leslie (SASEX, South Africa)

A cooperative project was set up jointly by SASEX and CIRAD to manage stemborer control operations—these two research centres have skills and experience in this field. The Regional Council of Réunion is providing substantial funding for this project. Three types of initiative are planned:

- training, with field training sessions organised for students from Réunion;
- scientific visits to Kwazulu-Natal and Réunion;
- participation in the annual congress of the South African Sugar Technologist's Association (SASTA) in Durban.

The field initiatives include infestation surveys on smallholdings and an analysis of agricultural practices that hamper pest outbreaks. This will involve developing a reliable survey procedure and also enhancing recommendations issued by the sugar profession. The work will be conducted in collaboration with technicians of the South African Pest and Disease committees, FDGDEC and the Crop Protection Service of Réunion. The project will first focus on the most concerned areas where sugarcane growers' demand is high, i.e. regions near the southern coast (Sezela) and in Zululand (Empengeni). Moreover, farms (small, medium and commercial) in these regions have already been mapped on the basis of production criteria, soil characteristics and economic indices.

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Varietal improvement

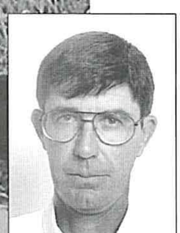
In the Varietal improvement project, sugarcane clones are bred from commercial parents by means of intergeneric and interspecific hybridization, while focusing on:

– increasing sugar yields;

– breeding adapted varieties;

– developing suitable assessment methodologies;

– producing pre-selected varieties.



The Varietal improvement project is based in Guadeloupe and coordinated by Philippe Oriol.

Varietal improvement strategies and research trends

P. Oriol, D. Roques, R. Domaingue

Sugarcane varietal improvement studies began in 1993 as a follow-up to breeding initiatives previously carried out by the Centre technique interprofessionnel de la canne et du sucre (CTICS) in Guadeloupe. The aim is to breed new high-yielding sugarcane varieties adapted to cropping conditions that prevail in commercial sugarcane and rum plantations in Guadeloupe and Marie-Galante.

Sugarcane breeding research is a continuous ever-progressing activity. This operation involves breeding a high number of new varieties (FR clones) every year, and then selecting them through a series of stages under local growing conditions. The sugarcane selection scheme adopted in Guadeloupe involves six stages extending over a period of around 12 years. This scheme is supplemented yearly with some 50 promising clones from the West Indies Sugarcane Breeding and Evaluation Network (WISBEN) in Barbados, along with varieties of various international origins, including the Centre d'essai de recherche et de formation (CERF) in Réunion, introduced after a 2-year quarantine in Montpellier. Every year, CIRAD supplies its foreign partners (in West and Central Africa, Vietnam, etc.) with around 50 selected FR clones.

Breeding operations currently under way in Guadeloupe include assessments of initial populations at the Roujol research station, and regionally-oriented selection to obtain varieties adapted to the different agroclimatic conditions of sugarcane-growing areas throughout Guadeloupe (Basse-Terre, Grande-Terre, Marie-Galante). The experiments are mainly carried out on sugarcane farms, whereas the new variety evaluation and dissemination phases are conducted in partnership with the different extension agencies of the sugar subsector, including CTICS, the Sociétés cannières d'intérêt collectif agricole (SICAs), the Service d'utilité agricole pour le développement (SUAD), and the Société d'aménagement foncier et d'établissement rural (SAFER).

CIRAD is constantly striving to improve the breeding scheme via targeted hybridization, the adoption of suitable assessment methods, experimental designs and conditions, and the development of early disease detection techniques. This breeding operation is supported by research carried out by other scientific teams of the Sugarcane Programme, with the aim of acquiring knowledge on the sugarcane genome, genetic resources, disease resistance and plant functioning under natural environmental conditions. The operation also benefits through a close collaboration with WISBEN. Information from foreign partners who have evaluated FR varieties under their own particular cropping conditions is taken into consideration to accurately target hybridization operations and potential releases of improved varieties.

In 2001, discussions were initiated on future varietal improvement strategies in Guadeloupe in response to the demand of local and foreign partners. A review of the different operations and activities undertaken revealed potential areas of development, including: strengthening the scientific structure; determining genetic factors linked with yields of cane, sugar and their components; developing varieties adapted to cropping conditions in Guadeloupe and elsewhere in the world; setting up a regionally-oriented early breeding programme in Guadeloupe; and increasing the size of the initial population to be evaluated. The aim of these proposals is to take the main selection criteria into fuller account, i.e. cane and sugar yields, technological quality, disease resistance and adaptations to local cropping conditions, including drought resistance and hardiness.

It was decided that the sugarcane breeding scheme should first be improved by testing plant material at stage 1 (seedling stage) in two contrasting regions of Guadeloupe (Basse-Terre and Grande-Terre). This operation presupposes boosting the breeding potential through the selection of higher yielding hybrids and rehabilitating the hybridization system. Selection of promising varieties in a greater number of environments (five or six) would be required at later breeding stages. Studies on "family x environment" and "variety x environment" interactions will also be carried out to determine specific environments in which selection could ultimately be conducted.

New varieties resulting from research carried out in Guadeloupe are currently being evaluated and developed through an official certification procedure involving all stakeholders of the sugar subsector. New varieties are compared with others grown in demonstration plots. However, there have been some problems in establishing these demonstration plots due a to lack of planting material, and because growers are reticent to plant newly proposed varieties without having any information on their agronomic features. A complementary pre-industrial selection stage and a new certification procedure are planned in 2002.

Sugarcane breeding in Guadeloupe

D. Roques, G. Gelabale, L. Toubi, M. Cadet, G. Algou

New adapted high-yielding sugarcane varieties obtained though directed breeding are required regularly to fulfil the needs of the sugar industry.

Germplasm management

Genetic diversity in CIRAD's sugarcane germplasm collection was further enhanced this year through the introduction of 57 new clones. The working collection is available for the varietal improvement programme and currently consists of more than 1 200 genotypes, commercial hybrids, F1 hybrids, wild and related species (Table 3).

In 2001, a relational database for sugarcane varietal improvement was created with Access software. Users can thus obtain information concerning different breeding and selection phases. This application will be further developed in 2002 to enable controlled data cross-tabulation in response to specific queries.

Table 3. Status of the CIRAD germplasm collection in Guadeloupe.

Variety/species	Number	Origin	Variety/species	Number	Origin
B	220	Barbados	N	15	South Africa
BJ	69	Barbados-Jamaica	NCO	3	South Africa
BR	30	Barbados-Romana	PHIL	4	Philippines
BT	39	Barbados-Trinidad	POJ	3	Java
C	5	Cuba	PR	9	Puerto Rico
CB	14	Brazil	PS	2	Indonesia
CL	1	USA, Clewiston	PT	1	Taiwan
Co	31	India	Q	38	Australia
CoS	2	India	R	30	Réunion
CP	50	USA, Florida	RB	17	Brazil
CR	3	Dominican Republic	RD	1	Dominican Republic
CRA	2	Dominican Republic	RK	1	Japan
D	4	Guyana	ROC	5	Taiwan
DB	39	Guyana	S	1	Saipan
F	9	Taiwan	SP	40	Brazil
FR	250	France-Guadeloupe	TUC	16	Argentina
H	12	Hawaii	WI	22	Barbados
HJ	1	Hawaii	Other hybrids	36	
IAC	5	Brazil	*S. officinarum*	38	
J	1	Jamaica	*S. spontaneum*	29	
JA	3	Cuba	*S. robustum*	13	
KWT	2	Sudan	*S. barberi*	5	
L	3	USA, Louisiana	*S. sinense*	6	
LF	33	Fiji	*S. edule*	1	
M	37	Mauritius	*Erianthus*	4	
MEX	15	Mexico	*Miscanthus*	1	
MQ	2	Australia	*S. officinarum x*		
MY	8	Cuba	*S. spontaneum*	40	

Seed maturation.

Crossing campaign

One hundred and fifty-one hybridizations were performed during the sugarcane crossing season, i.e. from October to December. Most of them were to be used in the sugarcane breeding scheme and the others were combinations of interest for subsequent genetic and heredity analyses. Hybridizations performed in 2001 will give rise to the FR 2003 series after selection (Table 4).

Table 4.Hybridizations performed in 2001 and fuzz production.

Type of crosses	Number of crosses
Bi-parental	139
Poly crosses	17
Open pollinisation	7
Selfing	7
Total	151
Total weight of fuzz produced (g)	3 207

Varietal selection in Guadeloupe

In the first three stages of the sugarcane selection scheme, some 50 (FR) clones are evaluated and pre-selected on the basis of low susceptibility to environmental constraints. The goal of the last three stages is to provide the Guadeloupe sugar industry with a regular supply of new varieties that are adapted to its needs.

Varietal pre-selection stages

D. Roques, G. Gelabale, L. Toubi, M. Cadet, G. Algou

Pre-selection involves the first three stages of the selection scheme currently under way at CIRAD's Roujol research station (Table 5).

Amongst the varieties in selection stage 1 (seedlings), 10% of the FR 2001 series and 11% of the FR 2000 series were kept for selection stage 2.

Table 5. Progress of the pre-selection stages in 2001.

Series N°	Stage	Number of clones evaluated	Number of clones chosen
FR 2002	Stage 1	6 680 seedlings (74 families)	To be selected in April-May 2002
FR 2001	Stage 2	507 clones	To be selected in June-July 2002
FR 2000	Stage 2	224 clones	To be selected in April-May 2002
FR 99	Stage 3	60 clones	60 clones being propagated
FR 98	Stage 3	64 clones	64 clones being propagated
FR 97	Release	50 pre-selected clones dispached for quarantine in Montpellier and included in a breeding scheme in Guadeloupe (stage 4)	

Sixty clones of the FR 99 series, representing 20% of the clones in selection stage 2, were promoted selection stage 3 in August 2001. Varieties assessed and selected in stage 3 were from the FR 98 and FR 97 series. They will be dispatched to the CIRAD quarantine unit in Montpellier for subsequent release to sugarcane growers in Martinique, West and Central Africa, and other countries in January 2002.

Final selection stages

P. Oriol, D. Roques, J.-H. Daugrois, M. Ragouton, J.-C. Efile, E. Nudol, E. Catan, M. Carbel, O. Calvados, M.-F. Al Rifai

In stage 4, the first step after pre-selection, varietal trials were carried out under short season conditions in sugarcane-growing areas in Basse-Terre and in long season conditions in Grande-Terre. In Basse-Terre, 115 varieties were evaluated in two trials conducted at the agricultural secondary school site of Baie-Mahault and at the Société coopérative d'exploitation agricole (SCEA) in Aiguebel (Table 6). At Grande-Terre, trials were carried out at the Gardel site (299 varieties tested).

In stage 5, which is the first stage involving replicated trials and recently set up with an incomplete experimental block design, varieties are evaluated over a 3-year period (plant cane, first and second ratoons). Eight variety trials set up on the same sites as stage 4 were continued until the second ratoon (Table 7). The six varieties chosen at Basse-Terre (FR 900306, FR 900840, FR 910384, FR 910486, FR 910699 and R 575) are being propagated (after sanitization by heat treatment) before assessing them in a pre-industrial trial. Other varieties gave interesting results in the first two harvest cycles. Hence, for second ratoons, the results will have to be confirmed for three varieties tested at Grande-Terre (FR 880196, FR 890423, FR 890746) and two other varieties at Basse-Terre (BJ 82119, B 8681). One trial that was planted in 1999 had to be abandoned due to the exceptionally harsh drought that occurred during the 1999-2000 season, which had a detrimental impact on stages 4 and 5.

Table 6. Progress of selection stage 4 trials in 2001.

Location	Harvest cycle	Number of clones tested	Number of clones chosen
Basse-Terre	First ratoon	47	11
	Plant cane	68	results in 2002
Grande-Terre	First ratoon	58	26
	Plant cane *	151	results in 2002
	Plant cane *	90	results in 2003

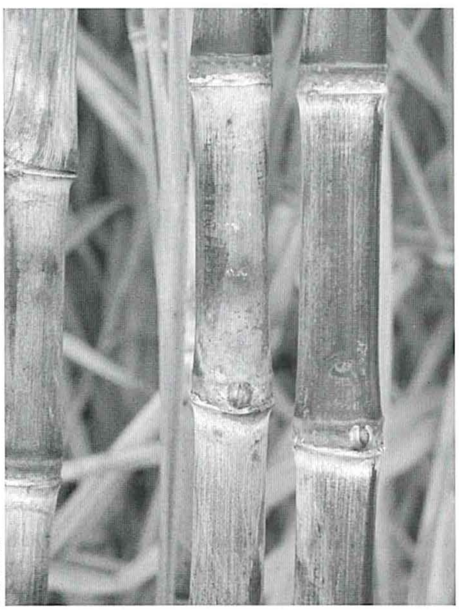
* 16-18 month old plant cane (long-season crop).

Table 7. Progress of selection stage 5 trials in 2001.

Location	Harvest cycle	Number of clones tested	Number of clones chosen
Basse-Terre	Second ratoon	23	6
	First ratoon	23	results in 2002
	Plant cane	26	results in 2003
	Plant cane	19	results in 2004
Grande-Terre	First ratoon	12	3
	Plant cane	64	trial abandoned(drought)
	Plant cane	26	results in 2003
	Plant cane	33	results in 2004

Pre-industrial trials and variety certification procedure

The variety certification procedure was adopted by the Commission paritaire interprofessionnelle de la canne et du sucre in 1999. The performance of new improved varieties can thus be evaluated under industrial plantation conditions. A network of demonstration plots is being set up in different sugarcane-growing areas, with the active participation of concerned growers, SICAs, CTICS, the Chamber of Agriculture and CIRAD. New recently improved varieties (B 80689 and B 82139) are compared with commercial varieties. The most promising varieties, i.e. R 579, FR 832035 and FR 832034, which are now being propagated in disease-free nurseries, will gradually be proposed to sugarcane growers. Ten other promising varieties are currently being sanitized prior to propagation: FR 880196, FR 890423, FR 890746, FR 900306, FR 900840, FR 910384, FR 910486, BJ 82119, B 8681 and R 575.



Stalks of cv FR 832034.

Assessment of varietal resistance to the main sugarcane diseases

One major thrust of the programme is to develop and implement screening tests to assess disease resistance in clones during the selection process. The aim is to avoid breeding highly susceptible varieties for subsequent distribution to partners and sugarcane growers.

Early screening method for smut resistance

D. Roques, G. Gelabale, L. Toubi, M. Cadet, G. Algou

In a conventional selection scheme, clones are screened for smut *(Ustilago scitaminea)* resistance by inoculating cuttings at stage 4. Research is under way to find a method whereby inoculations could be performed at an earlier selection stage (stage 1) in order to dispense with smut-susceptible clones as early as possible. A smut inoculation procedure for seedlings was thus developed (Roques *et al.*, 2000). Trials are being conducted to evaluate the efficacy of this technique in comparison to the standard method with cuttings. Results are expected in 2003.

Disease evaluation of varieties in Guadeloupe

P. Champoiseau, S. Bonotto, R. Boisne-Noc, S. Joseph, L. Toubi

Varieties bred for resistance to leaf scald, smut and ratoon stunting disease are being screened in Guadeloupe.

Four varietal series (FR 94, FR 95, FR 96 and FR 97) are assessed for resistance to smut and ratoon stunting disease, including 217 pre-selected clones, 13 clones at the end of the selection process, two commercial cultivars and six control cultivars. The two latter groups are also tested for leaf scald resistance. The results of tests that ended in 2001 highlighted the susceptibility of 16 FR 96 varieties to leaf scald and of 12 FR 94 to smut. These varieties will thus be excluded from the breeding process.

Disease evaluation of varieties in Réunion

L. Costet, H. Lombard, J.-C. Ribotte, G. Gauvin

CIRAD is evaluating varieties bred by CERF for their resistance to major sugarcane diseases (leaf scald, smut and gumming disease). Some 30 clones were assessed for resistance to leaf scald and gumming disease in 2001. The tested varieties showed different behaviours in response to infection by these two diseases, i.e. seven were highly susceptible to one of these diseases, while 10 others were tolerant of both diseases under the experimental conditions implemented. Some of these clones should, however, be reevaluated to confirm the results.

Responses of FR varieties to mosaic virus infection

P. Rott, M. Chatenet, J.-C. Girard, M. Muller

As *Sugarcane mosaic virus* (SCMV) and *Sorghum mosaic virus* (SrMV) are not present in Guadeloupe, the behaviour of FR varieties was assessed by CIRAD in Montpellier. Forty-six varieties of the FR 97 series were introduced in April 2001 and inoculated with SCMV (isolate from Cameroon) in a CIRAD glasshouse in Montpellier. The varieties were then classified in three groups on the basis of the appearance and severity of symptoms after inoculation: 31 resistant varieties (67%), nine moderately resistant varieties (20%) and six susceptible varieties (13%).

Leaf scald resistance in species related to sugarcane

P. Champoiseau, S. Bonotto, R. Boisne-Noc, S. Joseph, L. Toubi

Thirty-six clones belonging to six different *Saccharum* species (*S. barberi, S. edule, S. officinarum, S. robustum, S sinense* and *S. spontaneum*) were tested in glasshouse conditions to assess their resistance to leaf scald *Xanthomonas albilineans*. Clones of the wild species *S. spontaneum* were the most resistant to stalk colonisation by the pathogen after inoculation. In contrast, *S. robustum* clones were the most susceptible to stalk colonisation, and showed high disease symptom expression. These results confirmed previous field test results.

Varietal patterns in sugarcane plantations in Guadeloupe

P. Oriol, D. Roques

A study of sugarcane varietal patterns highlighted a substantial decrease in the area cropped with cv R 570, with a concomitant sharp increase in cv B 80689 (Figure 8). This trend differed when comparing the Basse-Terre region, where cv R 570 is still grown in more than 70% of plantations, and the drier regions of Grande-Terre and Marie-Galante, where cv B 80689 accounts for 60-90% of the area under sugarcane. The overwhelming use of cv R 570 in Basse-Terre and of cv B 80689 in Grande-Terre could ultimately lead to a single-variety monoculture situation in both of these areas. It is also clear that varieties that are well adapted to the cropping conditions of these regions must be planted. Hence, a major challenge for the varietal improvement programme is to enhance varietal diversification and targeting in these sugarcane-growing areas.

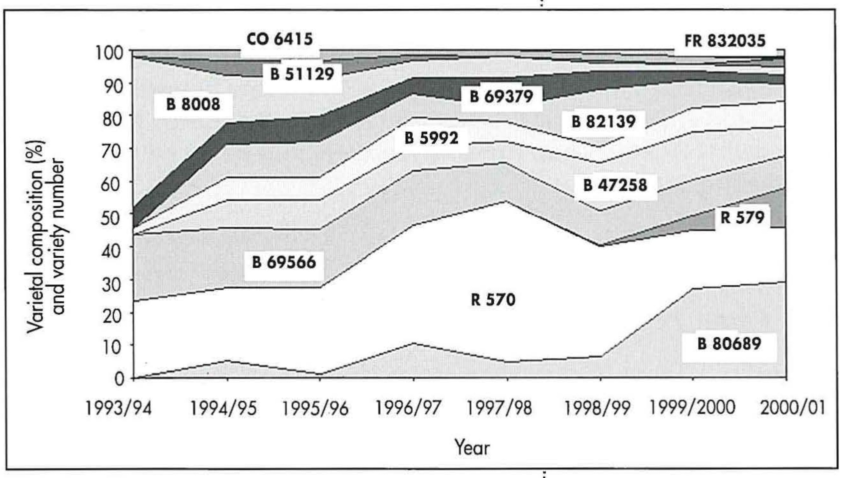


Figure 8. Sugarcane varietal patterns in mother nurseries in Guadeloupe since 1993.

Sugarcane nurseries

P. Oriol, D. Roques

The rapid spread of important sugarcane diseases in Guadeloupe since the 1970s prompted the Crop Protection Service, CTICS and CIRAD to set up a system of disease-free sugarcane nurseries. The current sugarcane nursery scheme in Guadeloupe was thus created in 1987 to control these diseases, including leaf scald (*Xanthomonas albilineans*).

This nursery system involves the production of healthy plant material propagated by tissue culture to obtain enough cuttings to fulfill annual planting needs in Guadeloupe and Marie-Galante (2 500 to 3 000 ha), and that have the best possible qualities (varietal purity, disease-free, germination vigour). Stock plants are sanitized in CIRAD's quarantine unit in Montpellier. Some plants are now sanitized locally, since a heat-treatment station was acquired in 2001 and thanks to the adoption of CIRAD's meristem culture technique.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Micropropagated plantlets.

Production of disease-free plant material

D. Roques, J. Sapotille, C. Guiougou, M.-C. Planchet, P. Navis, A. Joseph

Plants sanitized by heat treatment are micropropagated in the Roujol tissue culture laboratory in order to produce disease-free plants. After a hardening period of about 1 month, the micropropagated plantlets are transplanted in the field in the first "stock-plant nursery" stage.

Three groups of varieties were micropropagated in 2001:
– 11 varieties designated for sugarcane nurseries to meet an order from the sugar industry (CTICS), i.e. 20 000 micropropagated plantlets;
– 8 promising varieties (FR 91486, FR 90306, FR 91384, FR 90840, FR 91699, FR 90714, R 575, BJ 82119), sanitized by heat treatment and then micropropagated by shoot-tip culture;
– 3 500 micropropagated plantlets produced for use in various studies- aerial dissemination of leaf scald, yellow leaf virus epidemiology, and propagation of control varieties for breeding trials.

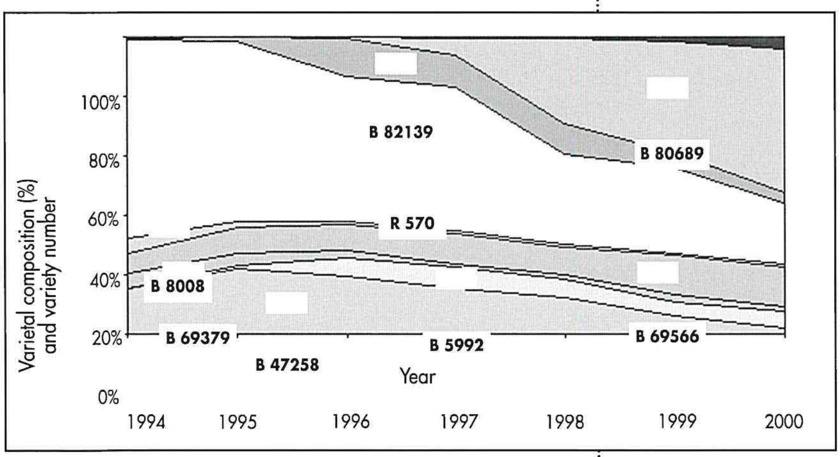

Figure 9. Varietal composition patterns in sugarcane plantations of Guadeloupe and Marie-Galante.

Production of sugarcane plants in mother nurseries

P. Oriol, D. Roques, J.-H. Daugrois, J.-C. Efile, J.-M. Coupan, R. Boisne-Noc, S. Joseph, E. Catan, M. Carbel, S. Carmel, O. Calvados, M.-F. Al Rifai

Mother nurseries cover a 2-ha area and include commercial varieties (B 47258, B 51129, B 5992, B 69379, B 69566, B 8008, B 80689, B 82139, Co 6415 and R 570), along with three new varieties (FR 832034, FR 832035 and R 579). B 80689 is the most commonly propagated variety (29%), whereas R 570 represents only 17% of all plants in the mother nurseries. In 2001, cv R 579 represented 12% of all plants in these nurseries. Varietal distribution patterns in mother nurseries have been analysed since 1993 (Figure 9).

Sugarcane breeding network in West and Central Africa

D. Marion, P. Oriol, D. Roques, J.-C. Girard, P. Letourmy, R. Domaingue

Sugar producers in West and Central Africa do not have direct access to any sugarcane breeding centre able to produce new improved plant material to meet their changing needs. These producers are thus obliged to regularly import varieties from different breeding centres (Barbados, Réunion, Guadeloupe, Mauritius, etc.), usually via CIRAD's quarantine unit in Montpellier.

During a first workshop, instigated by CIRAD, that was held in Yamoussoukro (Côte d'Ivoire) in October 1999, sugar industry operators decided to pool their resources to fund a regional network with the aim of gaining access to more varieties, setting up appropriate selection schemes and improving the efficiency of their current activities. CIRAD was asked to coordinate this network during the initial phase.

The network creation dynamics were confirmed at a workshop held in Yaoundé (Cameroon) in June 2001. This workshop mainly focused on the internal rules and regulations of the sugar producers' association involved in the network. A tentative agreement was reached on financing network activities on a pro rata basis of the sugar production levels of each network member. However, the conditions of plant material exchanges and the mode of transmission of collected data have yet to be determined and represent major topics for discussion to ensure the future of this network.

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Agronomy and crop modelling

The Agronomy and crop modelling project is involved in improving cropping systems and crop management sequences on the basis of local constraints and characteristics, while focusing on:

- improving agricultural practices;
- studying plant functioning;
- modelling sugarcane growth;
- managing the water balance in sugarcane;
- developing decision-making tools.

The Agronomy and crop modelling project is coordinated by Jean-François Martiné.

Pedoclimatic zoning to enhance sugarcane breeding in Guadeloupe and Marie-Galante

M. Brouwers

Guadeloupe has highly contrasting soil and climatic conditions because of its topography, geology, and exposure to trade winds and cyclones. A pedoclimatic zoning initiative was thus undertaken to enhance breeding research in the Sugarcane Programme, to in turn benefit growers in Guadeloupe and Marie-Galante. The main areas under sugarcane were zoned, along with the Capesterre and southeastern Basse-Terre regions. In this latter region, which is currently the main banana-growing area in Guadeloupe, sugarcane will soon be introduced in rotations with bananas.

Vertisols and brown soils developed on coral limestone are the main types of soil under sugarcane crops (Figure 10). These soil conditions are found on Grande-Terre east of a line extending from Port-Louis, in the northwest, to Sainte-Anne, in the south; and throughout Marie-Galante, especially in the middle and southern parts of the island which have the best rainfall patterns. Elevations range from 30 to 70 m in both of these areas. The other part of the sugarcane-growing area is located on ancient volcanic formations with ferrallitic soils that are friable—the most representative type-or compact (e.g. around Soufrière volcano), and sometimes on recent soils in the narrow colluvio-alluvial valleys and associated fluvio-marine plains. Elevations of sugarcane fields range from 0 to 200 m, and even higher in Basse-Terre.

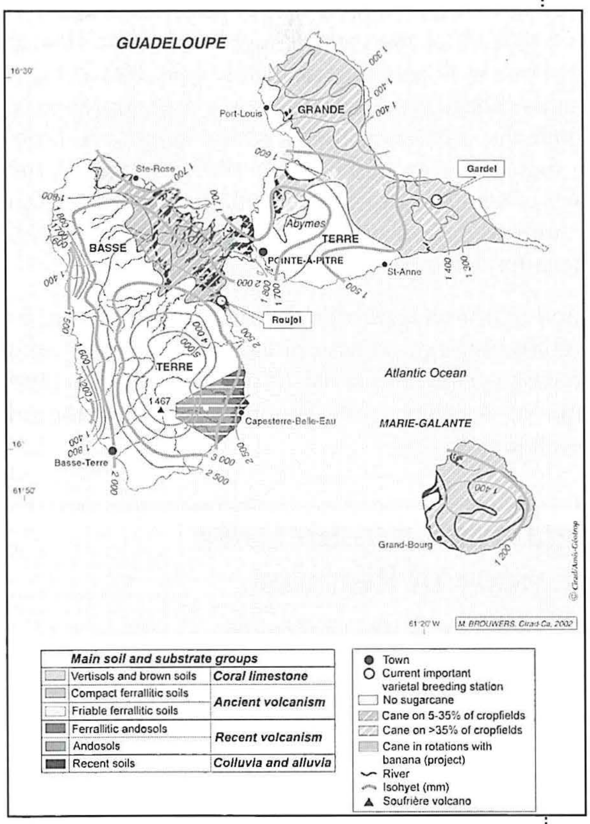

Figure 10. Pedoclimatic zoning map of the sugarcane-growing area in Guadeloupe.

A climatic analysis revealed three different zones with increasing annual rainfall patterns (1200-1500 mm; 1700-2000 mm and 2000-2500 mm), but decreasing potential evapotranspiration, solar radiation and dry-season length.

The main entities, by decreasing order of sugarcane area, are: vertisols and brown soils x 1200 -1500 mm rainfall; friable ferrallitic soils with 1700-2000 mm rainfall; friable ferrallitic soils with 2000-2250 mm rainfall; and compact ferrallitic soils with 1700-2000 mm rainfall. Two other entities from Capesterre could be added to this grouping-extending from the bottom towards the top of the slopes of Soufrière volcano, i.e. ferrallitic andosols on ash 2300-3000 mm rainfall and andosols on ash with 3000-4000 mm rainfall.

Characterising the ecophysiological factors that govern cultivar adaptation in such highly diversified soil-climate conditions substantially boosts the prospects for improving sugarcane breeding procedures. High-yielding cultivars that are potentially identified could be suitable for other sugarcane-growing areas, i.e. in island environments (Réunion, Martinique, etc.) and continental environments (West and Central Africa, Asia).

Recycling vinasse for agricultural use in Guadeloupe

G. Panon (INRA), Y.-M. Cabidoche (INRA), P. Guillaume, J.-P. Mauranyapin (Laboratoire professionnel régional d'analyses, LAPRA)

The resumption of operations at the Bonne-Mère distillery enabled CIRAD to continue monitoring vinasse degradation in sugarcane fields in Guadeloupe.

Physicochemical analyses of vinasse samples confirmed the absence of pathogens and the low metallic trace element and organic trace compound contents. The nutrient element content was 1.10 g/l nitrogen, 0.08 g/l phosphorus and 9.05 g/l potassium. The high organic matter content (34.5 g/l) in vinasse is a potential source of major pollution.

Carbon mineralisation was studied in an incubator with a stillage dose that was sufficient to cover the potassium needs of a sugarcane crop for a 12-month cycle (34 m^3/ha). Within 4 weeks, ferrallitic soils were able to degrade about 50% of this organic matter and vertisols about 30%. It was estimated that all of the carbon supplied by this stillage dose could be mineralised in 12 weeks on ferrallitic soils. However, as the nitrogen level in this stillage dose was very low, a urea supplement was necessary to fulfill the potassium needs of the sugarcane crop. The study showed that the urea supplement did not modify the mineralisation kinetics of vinasse-derived nitrogen. In contrast, carbon mineralisation was improved after this supplement, reaching 60% within 4 weeks on both ferrallitic soils and vertisols.

These results indicated that field application of distillery vinasse is an excellent way to mobilise enough potassium to meet the needs of a 12-month sugarcane crop cycle without risk of organic pollution. The potential acidification of ferrallitic soils should still be monitored in order to avoid aluminium toxicity.

Improving sugarcane productivity in highland regions of Réunion

D. Pouzet, A. Velle, M. Jeanette, R. De Larichaudy

Highland sugarcane yields are generally low, but this production is nevertheless essential for the sustainability of the sugar industry in Réunion. While awaiting new adapted cultivars, crop management sequences-involving reductions in inter-row spacing and increases the inter-harvest cycle-are being investigated with the aim of reducing the period during the production cycle when the canopy is not closed. These modifications can have an impact on sugarcane production, labour productivity and the environment (reduction in herbicide use, erosion risk and fertilizer loss by runoff).

The test results highlighted the importance of inter-row spacing on the crop coverage rate, and that this rate was very low in the highlands. The mean soil coverage by the crop was found to be 35% 3 months after plantation with 0.9 m inter-row spacing, as compared to 25% with standard 1.5 m spacing.

This inter-row adjustment technique is not, however, taken into account by operators responsible for furrowing the plantation, and growers also often overlook it. Some growers do modify inter-row spacing as a weed control strategy. In mechanised plantations, a participative approach is being considered whereby growers and operators would be involved in making decisions on modifying inter-row spacing. The aim is to plant the sugarcane crop with narrow inter-row spacing, but wide enough to allow free movement of farm machinery.

The risk of plant lodging and fire—which is often put forward by sugarcane growers-should be considered when deciding on extending the inter—harvest cycle.

Evaluation of crop residue in Réunion

D. Pouzet, A. Velle, A. Rassaby

Sugarcane harvesting conditions in Réunion have radically changed in recent years. Harvesting aerial parts after burning has generally been abandoned in favour of the widespread adoption of a green-crop harvesting strategy.

Burning is now only done when the field is being replanted, i.e. every 5-7 years, in order to get rid of excessive residual biomass that hampers tillage and furrowing operations. This biomass can also accumulate after harvests in drip-irrigated cropfields of dry regions, and part of it then has to be gathered and removed. In Réunion, where environmental problems are prevalent and sugarcane is a major crop, this residue is utilised as a carbon source that is well adapted for effluent cleansing and livestock management.

Crop-residue mulching has its benefits and drawbacks in terms of maintaining the ecological balance, i.e. it modifies the weed flora, soil biology (moisture, organic matter), subterranean fauna (e.g. earthworms) and above-ground fauna (e.g. worms, insects, birds), etc.

A new study was carried out to analyse correlations between crop residue and several other parameters: harvesting conditions, variety, crop age, climate, etc. The data obtained after the sample analysis are still too dispersed to determine accurate correlations (Figure 11). The biomass was found to

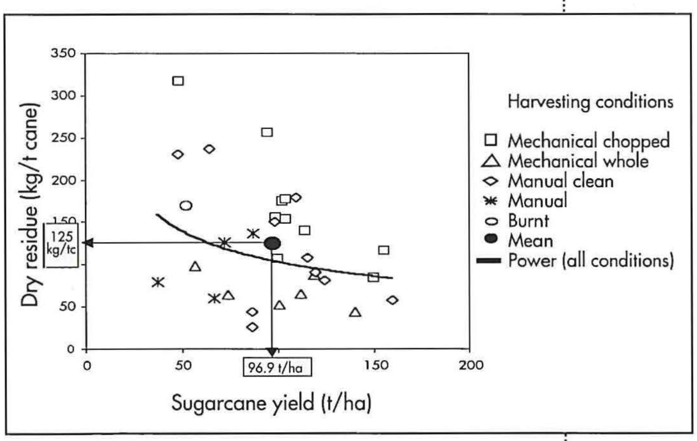

Figure 11. Dry residue, per tonne of delivered sugarcane, according to harvesting conditions.


© R. Domaingue

Complete mulch after a green crop harvest.

be distributed as follows: the foliar unit accounted for 87% of the residual biomass on average, including 67% leaf blades and 20% leaf sheaths; stalks accounted for 12% of the dry residue; levels of other organs (flowers, whips) in this biomass were insignificant. Quantities of mineral elements remaining in the field after harvesting 100 t of millable cane are presented in Table 8.

Table 8. Quantities of mineral elements derived from residue left in the field after harvesting 100 t/ha of millable sugarcane.

Mineral compound	Mean (units/ha)	SD (+/-)
N	68.1	23.2
P_2O_5	17.5	5.8
K_2O	171.7	79.4
CaO	44.8	12.8
MgO	26.3	8.6

Improving water management in Réunion

J.-L. Chopart, D. Tran Minh, L. Le Mézo, R. Nativel, B. Mouny, J.-L. Brossier, M. Mézino, J.-P. D'Export

In Réunion, an increase of around 7 000 ha in the irrigated cropping area is planned for the near future. Urbanisation will undoubtedly prompt increased competition between agricultural water supply and domestic and industrial supply. This study was designed to enhance management of agricultural supply water in order to ensure its sustainability and cost-effectiveness. There are two parts to the study: improving water efficiency, especially through controlled reductions in irrigation; and collecting agroclimatic remote sensing data, with the aim of providing personalised irrigation recommendations. The second part concerns sugarcane growers in Réunion, whereas the results (agronomic and management tools) of the first part are of interest for all rainfed and irrigated sugarcane cropping systems for which the water supply is a yield limiting or explanatory factor. Adjusting water supplies to satisfy actual needs can also reduce potentially polluting drainage water loss.

Optimising irrigation and water stress management

The effects of uncontrolled (irrigation cuts) or controlled (irrigation rationing) water stress on sugarcane growth and yield were monitored during the first third of the cropping cycle. One treatment was conducted at maximum evapotranspiration (T4). Three other treatments involved stopping or substantially reducing irrigation for varying periods (Figure 12, Table 9). Sugarcane growth monitoring results revealed that water stress had no effect on the earliest irrigation reduction treatment (T2). In treatments where irrigation was reduced later (T1 and T3), plant growth declined during the rationing phase, i.e.

115 days after the beginning of the ratoon stage (DABR). Differences were greater at the end of the growth period (315 DABR). At harvest, there were no significant differences between treatments. A reduction in water supplies relative to recommended doses was possible during the first third of the cycle (0-120 DABR) under the experimental conditions tested here.

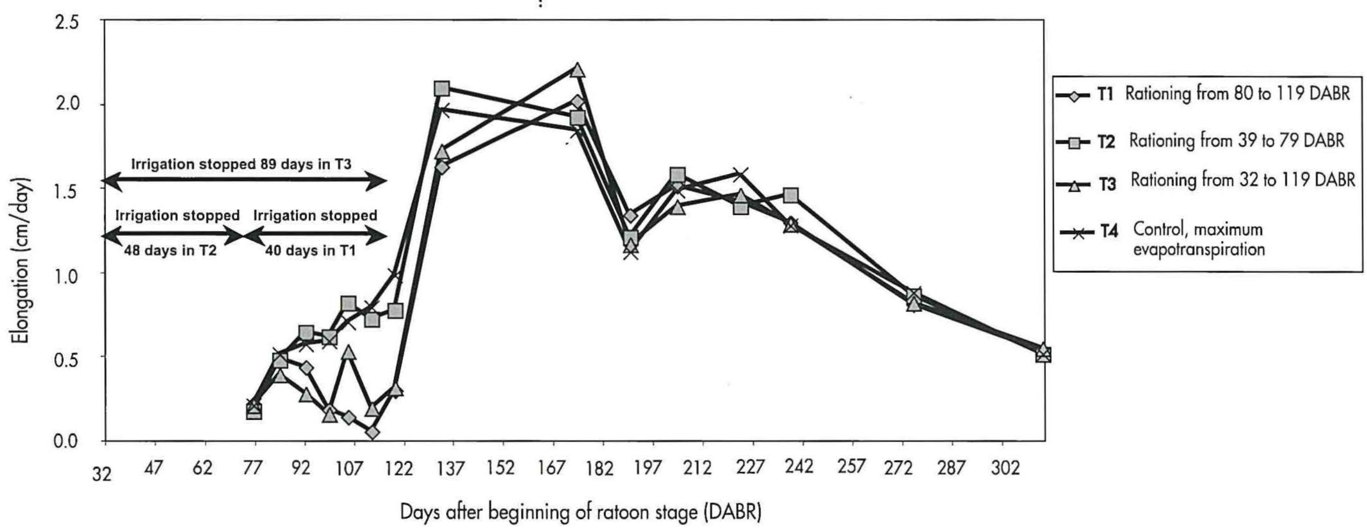

Figure 12. Effects of water stress at the beginning of the sugarcane cropping cycle (Ligne Paradis). Stalk elongation rates from 80 to 300 days after the beginning of the ratoon stage (DABR).

Table 9. Water stress: effects of irrigation on sugarcane stalk heights and yield components.

Treatment	T4 Control Maximum Evapotranspiration	T2 Rationing 32 to 79 DABR	T1 Rationing 80 to 119 DABR	T3 Rationing 32 to 119 DABR	Coefficient of variation (%)
Irrigation					
32 - 79 DABR (mm)	98	10	105	8	
80 - 119 DABR (mm)	116	130	29	46	
Stalk height (cm)					
115 DABR	36[b]	34[b]	24[a]	26[a]	6.2
315 DABR	287[a]	290[a]	273[a]	281[a]	2.9
Yield components					
Number of stalks per m^2	9.2[a]	10.0[a]	10.1[a]	10.1[a]	5.4
Mean stalk diameter (cm)	2.55[a]	2.46[a]	2.46[a]	2.45[a]	2.5
Millable stalk height (m)	3.03[a]	3.02[a]	2.90[a]	2.96[a]	2.5
Yield (t/ha)					
Millable stalk wet weight	144[a]	144[a]	139[a]	148[a]	6.8
Sugar weight	19.2[a]	20.2[a]	19.3[a]	20.3[a]	11.0

Results with the same attached letter (a,b) are not significantly different at the 0.05 threshold (Keuls-Newman test).
DABR = days after beginning of the ratoon stage.

Correlations between elevation and air temperature in western Réunion

The rugged terrain in Réunion is responsible for the marked thermal variations that occur over short distances. Temperature is, however, an important sugarcane growth factor. Correlations between monthly temperature and elevation (ranging from 0 to 1 200 m in the western part of the island) were investigated (Figure 13). For each month, a linear relationship between elevation and mean temperature was noted. The thermal gradient varied (from - 0.7 to - 0.8°C per 100 m) with elevation over the course of the year, according to a 3-degree polynomial function. This analysis provided a detailed estimate of local temperatures and confirmed the major impact of elevation on cane growth in Réunion. The gradients obtained were slightly higher than those reported previously (- 0.65°C per 100 m), which are still used for reference in Réunion.

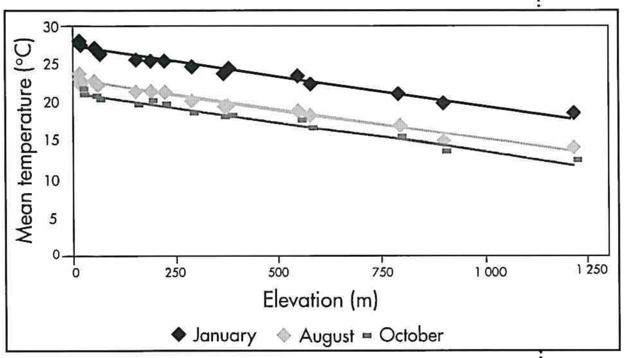

Figure 13. Correlations between mean daily temperature and elevation. Example for three contrasting periods of the year, i.e. January, August and October.

Agronomic diagnosis of sugarcane growth in drip irrigation conditions

An agronomic diagnosis was conducted at Saint-Paul in a drip-irrigated sugarcane field where growth was good in the lower elevation areas and poor on the higher ones. Joint measurement of soil moisture and rooting profiles highlighted the distribution of soil moisture and root densities and lengths in cm per cm^3 of soil. Although the soil was comparable at both sites, the extent of moisture and its distribution differed considerably (Figure 14). Differences between root distributions were less marked, but still visible. In the upper part of the field, soil wetting via drip irrigation was lower, which might have created a physical obstacle to root penetration. This poor soil wetting seemed to be linked with the drip flow rate. Since fertilizer was applied via irrigation water, the fact that less water was supplied than the volume planned likely led to insufficient fertilisation, and in turn poor crop growth.

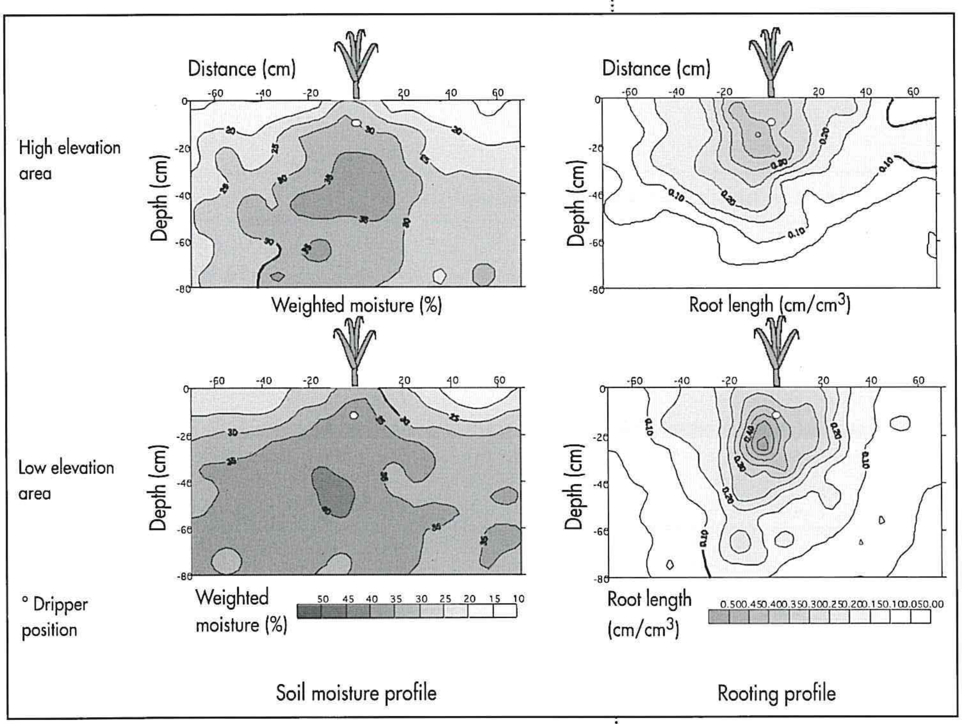

Figure 14. Soil moisture and rooting in low and high elevation areas of a sugarcane field 300 days after planting. Sugarcane status: high area = poor; low area = good.

Another diagnosis was carried out in a field located in the Gol plain region. The field had just been replanted and equipped for drip irrigation, with self-regulating drippers spaced 75 cm apart on the irrigation line. An abnormal delay in vegetation growth was noted. Pits were dug in the soil and it was found that the wet bulbs were not very wide, sometimes non-existent and especially that they did not meet along the line. Plant roots were short, not very developed, and many were dead.

Progress was noted when the dosage unit was doubled at the same watering frequency, i.e. root development improved, irrigation wet bulbs were more spread out, and the vegetation delay was overcome. More specific measures are now being taken.

Certification of herbicide products

P. Marnotte

An experiment designed for the certification of herbicide products was carried out in Réunion by the Service d'utilité agricole pour le développement (SUAD) in collaboration with the Service régional de protection des végétaux (SRPV) during the 2000-2001 season. CIRAD provided technical support. Herbicide efficacy tests were first set up at six locations according to an official method for biological testing. In order to take advantage of the agroecological variability that prevails in Réunion, the test sites were located in two different areas with contrasting environmental conditions: a humid area in the east with rainfed crops; and a dry area in the west with irrigated crops.

Persistence levels and action spectra were determined for about 10 herbicides: acetochlore, alachlore, alachlore + atrazine, isoxaflutole, metazachlore, metolachlor, metosulam + fluthiamide, metribuzine, and oxyfluorfene.


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Sugarcane stalk length measurement.

Modelling sugarcane growth

Development of a growth model

J.-F. Martiné, M.-P. Vesoul, P. Smith, S. Bouzouina, M. Jeannette, R. De La Richaudy

The aims of studies carried out to design a sugarcane growth model are:
- to gain further insight into sugarcane functioning;
- to predict the performance of varieties in the regions where they are to be grown, under highly varied pedoclimatic conditions;
- to develop decision-support tools that will be useful for other research and development applications.

Adaptation of the STICS model for sugarcane

J.-F. Martiné, P. Smith

A collaborative project was set up with the French Institut national de la recherche agronomique (INRA) in Avignon to design a sugarcane growth model on the basis of the "generic" (all plants) STICS growth model. The first aim was to adapt the "plant" parameters of the model for sugarcane.

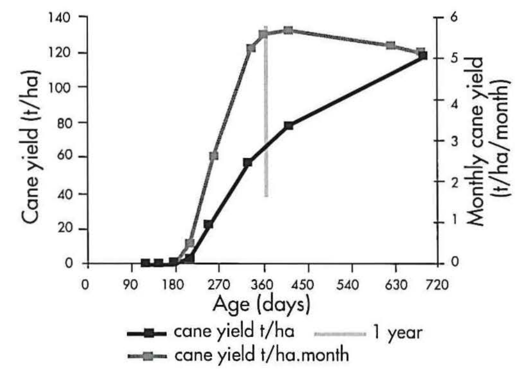


Figure 15. Cane yield patterns according to plant age.

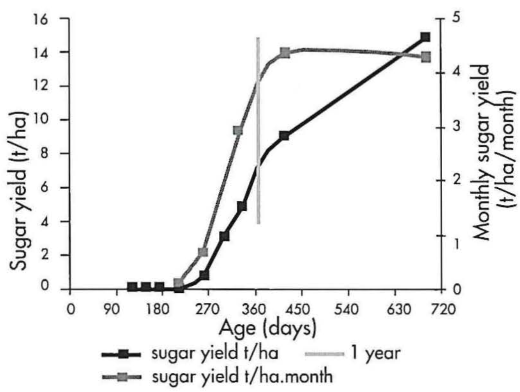


Figure 16. Sugar yield patterns according to plant age.

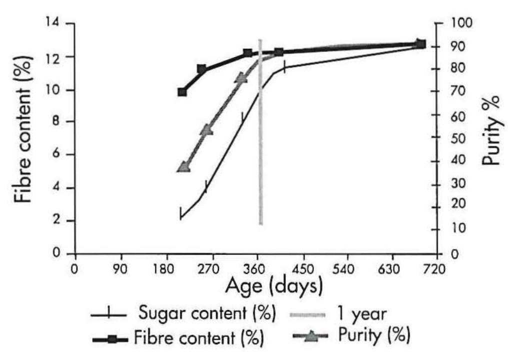


Figure 17. Variations in sugar and fibre contents and purity according to plant age.

The model was calibrated with two datasets in the absence of water stress. Under relatively optimal conditions, a set of "plant" parameters that characterise the functioning of aerial parts of cv R 570 was generated by the model.

Further studies are required to determine whether the adapted model can accurately simulate sugarcane yields under insufficient water supply and more varied temperature and solar radiation conditions.

Improvement of the MOSICAS model in Réunion

J.-F. Martiné

Initial results on long-season sugarcane cycles

To improve sugarcane crop management sequences in the highlands of Réunion, studies are required on the response of this crop to different plant spacings and cycle lengths (nitrogen nutrition likely would also have to be adjusted for this latter factor).

The initial results confirmed the very late appearance (7-8 months) of millable stalks and sugar in plants grown in highland cropfields. A decline in cane and sugar yields was noted after 12 months as compared to the previous period. The optimal cycle length can be estimated on the basis of cane and sugar yield patterns (expressed in t/ha/month). Other agronomic (practices), climatic (cyclones) and economic (cane payment conditions) criteria should also be taken into account. Cane yield (ha/month) was found to be optimal between the 12th and 13th month (Figure 15), with a subsequent decline, whereas sugar yield (ha/month) was optimal between the 14th and 24th month (Figure 16).

The increase in sugar yield between the 12 th and the 14 th month could be explained by the fact that sugar content was optimal at 14 months of age under these cropping conditions (Figure 17).

Potted plant studies on biomass component distribution

Studies geared towards adapting the MOSICAS model have so far focused on aerial biomass and components. However, this model requires more accurate information on partitioning between aerial and root biomass, since the current partitioning coefficient was gleaned from the literature. The results obtained for cv R 570 under irrigated conditions showed that the root biomass fraction relative to the total biomass was not stable and ranged from 10 to 30%.

Monitored traits of six commercial sugarcane varieties in Réunion

The MOSICAS model currently only applies to cv R 570. Other varieties grown in Réunion and Guadeloupe have also now been taken into account. A preliminary study was conducted on the main varieties grown in Réunion (R 570, R 572, R 573, R 575, R 577, R 579) in the plant

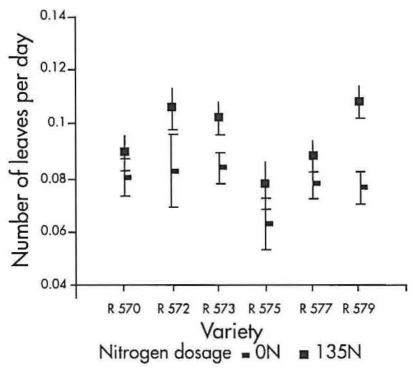


Figure 18. Number of leaves emitted daily according to the sugarcane variety and nitrogen dosage.

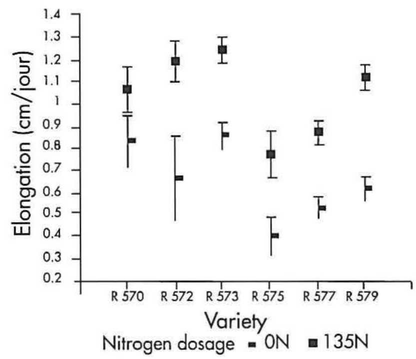


Figure 19. Stalk elongation according to the sugarcane variety and nitrogen dosage.

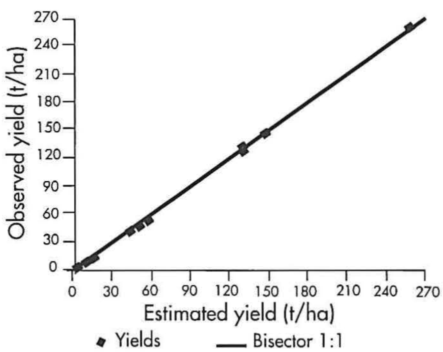


Figure 20. Comparison of yields estimated by the indirect method and actual observed yields.

cane crop, with three different levels of nitrogen fertilization. The results revealed varietal differences and the effects of nitrogen for two parameters, i.e. rate of leaf appearance, and rate of stalk elongation (Figures 18 and 19).

To confirm these results, similar measurements will be performed on sugarcane plants in the ratoon stage, supplemented with photosynthesis efficiency measurements.

Validation of an indirect biomass assessment method

Biomass levels used to calibrate the model in Réunion were measured using an indirect non-destructive method. This method involves monitoring biomass variations on sampling plots that are never harvested. At every date, the heights of all cane plants and correlations between height and biomass per stalk are estimated relative to a sample collected outside of the sampling plots. The results of the current study demonstrated that the method generated very satisfactory biomass estimates that were close to actual biomass levels (Figure 20).

Adaptation of the MOSICAS model to cropping conditions in Guadeloupe

P. Todoroff

The sugarcane ecophysiological growth model (MOSICAS)—which is currently being developed in Réunion—simulates the growth of a sugarcane crop on a daily time scale on the basis of biophysical data concerning the environment of the sugarcane plot (soil, meteorology) and the crop management sequence. It has been operational for water stress functions since late 1999. Simulations were calibrated and validated in Réunion for the R 570 sugarcane variety in the ratoon stage, with a 12-month cropping cycle at most.

The validity range of the model was extended to include Guadeloupe by supplementing the varietal database (R 570 and two varieties from Barbados), adding specific functions (e.g. water balance on vertisols) and validating it for two types of growth cycle. An initial trial was carried out to monitor "short season" crops (12 months with plant cane) in Basse-Terre, a humid tropical area on ferrallitic soils. A second trial was conducted to assess "long season" crops (16 months with plant cane) in Grande-Terre, a dry area on vertisols. For this latter trial, both rainfed conditions and optimal irrigated conditions were taken into consideration.

The Comité de prévision de récolte de la canne à sucre, to which CIRAD belongs, is already using this model. Yield simulations are performed for sugarcane-growing areas in Guadeloupe a few weeks prior to the beginning of the sugarcane harvest season. The figures are then updated regularly as the harvesting operations progress.

Development of decision-support tools

Geographical information system in Guadeloupe

P. Todoroff

An agronomic database is currently being developed for sugarcane in Guadeloupe (CASSIS, a sugarcane spatial information system) in collaboration with local sugar industry stakeholders. The aim is to develop a geographical information system (GIS) that pools the main cropping data from all sugarcane plots (planting dates, harvesting dates, yields, varieties, etc.). This database is also linked with the mapping coverage of agricultural land in Guadeloupe, i.e. a database which is compiled and updated yearly by CIRAD (Figure 21).

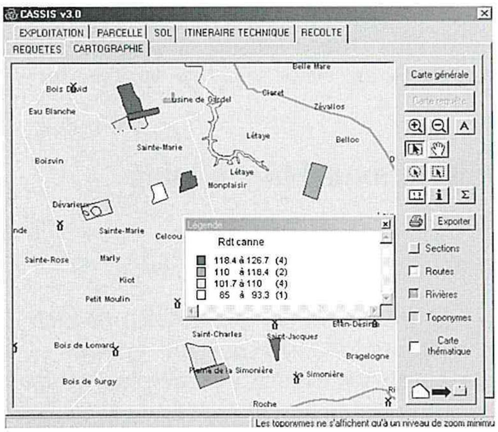


Figure 21. "Cartography" page of the CASSIS database.

The goal is to have access to data for validating the MOSICAS growth model on the basis of actual production, to test cropping scenarios, and to develop a GIS for use by operators in sugarcane-growing areas.

This GIS will also facilitate data storage, handling and analysis, along with descriptions of spatial variability in the data. Conversely, MOSICAS-like most crop functioning models-simulates the growth of a sugarcane crop on a daily time scale and a per-plot basis. It can thus explain and simulate temporal variability in biomass production for a specific homogeneous site. Interactions between spatial and temporal phenomena that determine regional crop production can be processed by interconnecting these two tools.

Beyond the scientific aspects, it is now essential to spatialise the simulation results in order to come up with relevant responses to technical, economic and strategic questions put forward by our local partners in the sugarcane sector—responses that are tailored to a range of different growth conditions that prevail in sugarcane-production areas.

Development of a sugarcane growth model and mapping its potential in Réunion

D. Pouzet, S. Cailliez, A. Velle

The sugarcane growth model will evolve from a research tool into a development-support tool by combining it with a GIS. Several steps are required to ensure the success of this transfer:

- developing a GIS interface that is integrated with the model, user-friendly and consistent (MapCanne);
- collecting climatic data, defining conditions for extrapolating data to interstation areas and assessing inaccuracies associated with existing meteorological systems;
- chemically and hydrologically characterising the main soil units;
- validating the results through dataset comparisons (real data versus simulations).

Only the first two steps have been completed so far.

Completion of MapCanne

The MapCanne software package is a modelling tool designed to map the results of the sugarcane growth model. The data utilised include maps, attribute data and a meteorological database. The inputs are geographical objects (dots, polygons). The software selects and weights the meteorological stations closest to target objects. It shuttles these data to the simulation program and recovers the calculated yields. The results are then mapped.

Development of MapCanne and SIMULEX meteorological databases

The MapCanne and SIMULEX meteorological databases were created in late 2001. This work involved supplementing the CIRAD database, which is limited to irrigated areas, through the acquisition of Météo-France data chosen on the basis of different criteria:

- stations located in the sugarcane-growing area or nearby, at elevations not higher than 1 200 m;
- only stations that are still open, with priority acquisition of data collected in the 1990s (late 1989 to late 2000), which are subsequently used to perform the simulations.

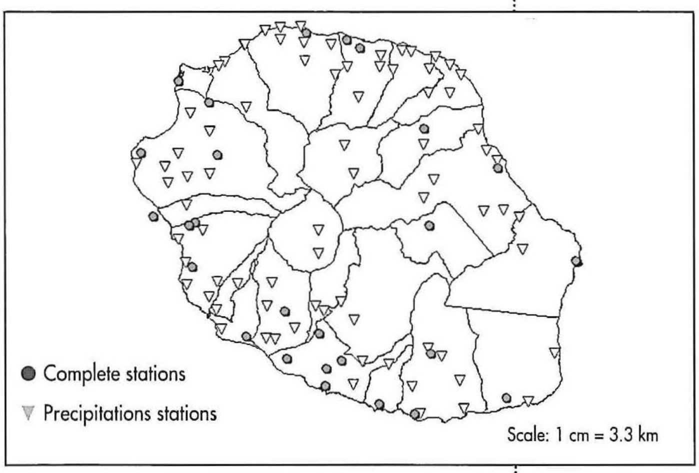
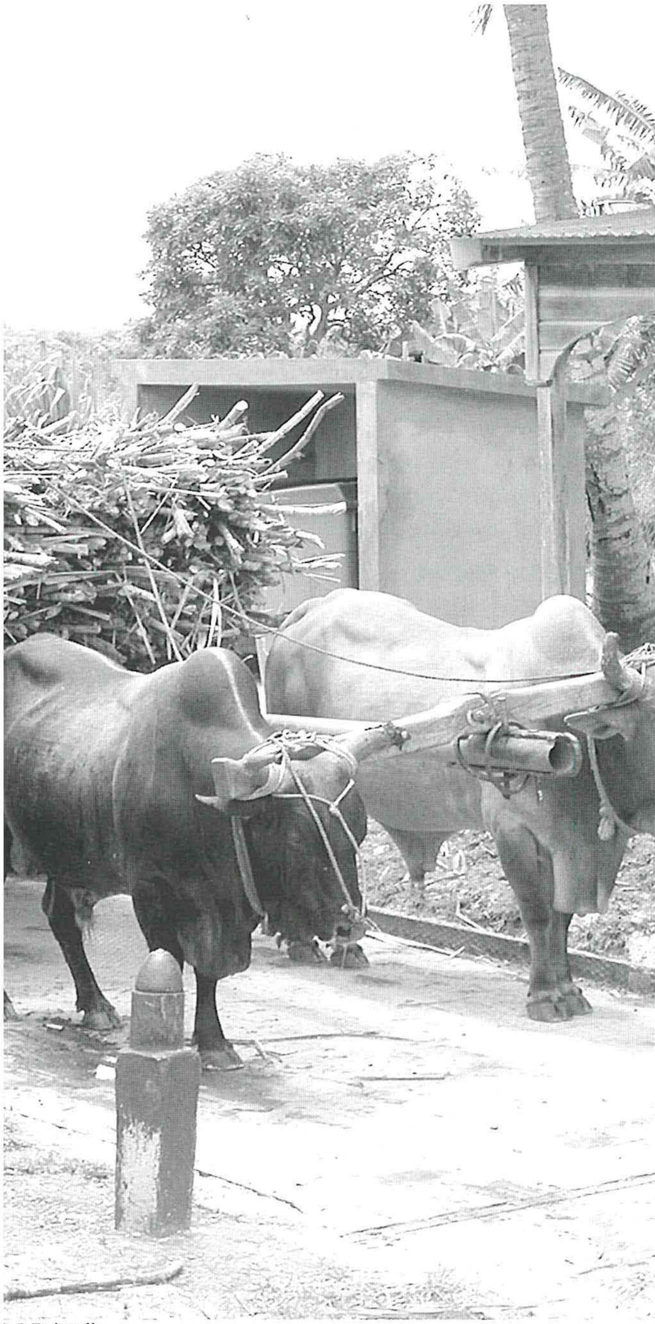


Figure 22. Map of current meteorological stations for the Mapcanne and SIMULEX tools.

The compiled database includes 26 complete stations and 80 precipitation stations (Figure 22). The oldest data in the database were collected in 1989.

The MapCanne database is now operational for Réunion. However, the impact of the climatic coverage and the rainfall and thermoradiative data extrapolation conditions on the simulation results must be assessed prior to mapping the potentials. A database was compiled for this purpose. It consists of 10 years of simulated yields and three simulated cycles (beginning, middle and end of the cropping season), first for complete stations and precipitation stations, and secondly for virtual stations substituted on the basis of several extrapolation conditions.



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Support to the sugarcane sector and producers

The Support to the sugarcane sector and producers project provides assistance to sugarcane growers and sugar producers on the basis of results obtained from the other research projects undertaken within the Programme:

- support to sugar producers in the French overseas departments (DOM), in Africa and Asia;
- validation and implementation of decision-making tools.

The Support to the sugarcane sector and producers project is coordinated by Pierre Langellier-Bellevue.

Socioeconomic approach to sugarcane production

M.-F. Zébus (INRA West Indies-French Guiana), P. Guillaume, E. Darie

This project, carried out jointly by the French Institut national de la recherche agronomique (INRA), the Université Antilles-Guyane and CIRAD, was set up to develop an agricultural production supply model to be used by government decision makers in Guadeloupe. The Modèle intégré pour les agricultures caribéennes (MICA) simulates growers' activity-choice processes through a linear programming procedure. The "test" grower chooses a certain number of activities that will maximise his/her gross margin per-hectare, with certain constraints taken into account, e.g. available family labour time or the grower's financial capacity.

Sugarcane-growing areas were accurately zoned according to agroclimatic, pedological and socioeconomic criteria that reflect the overall dynamics of the considered area. Nord-Nord Grande-Terre, Nord Grande-Terre, Abymes, Centre Grande-Terre and Nord Basse-Terre regions were differentiated. Some 20 typical "sugarcane activities" per area were determined prior to the modelling process.

Consistency tests were performed to evaluate how the model makes choices between all of the "sugarcane activities" and other speculations when the farm constraints vary. The modelling tool was unable to distinguish between certain sugarcane production modes (activities) that actually differ, but which are equivalent in terms of gross margin, production cost or labour time. Since "sugarcane activities" are necessarily clustered, only 10-15 can be considered per area.

The "sugarcane activities" matrix of the model is almost completed, and includes the following activities: rainfed sugarcane, irrigated sugarcane, sugarcane intercropped with watermelon, sugarcane cultivated using family labour, sugarcane cultivated with relatively high external service supply sourcing, and sugarcane cropped with different levels of inputs.

The model should ultimately be able to forecast the impact of technical (qualitative improvement of cutting and transport services, increased irrigation, investment in farming equipment, etc.), political (modification of subsidy schemes to benefit the sugarcane production sector, etc.) and economic (changing the per-tonnage price for sugarcane, and irrigation water fees, etc.) modifications on sugarcane supply in Guadeloupe, and over a longer term on all agriculture in Guadeloupe.

Agroenvironmental approach to forage sugarcane production in Guadeloupe

M.-F. Zébus (INRA West Indies-French Guiana), P. Guillaume, E. Darie

The main goal of this agroenvironmental approach, which is carried out within the framework of an environment-oriented territorial contract, is to promote the restoration of vertisol porosity in Grande-Terre, since it can be markedly reduced after several years of sugarcane cropping. Heavy harvesting machinery can even cause complete breakdown of porosity, especially if soil moisture is too high. However, sugarcane rooting systems-if they are not too damaged-can help restore the soil structure by enhancing soil aeration and water supplies for the crop. The recommended solution is to cultivate sugarcane fields for 2 years using manual labour whenever possible.

The method involves maintaining a standing ripe sugarcane crop of about 12-months-old and cutting enough cane daily to meet livestock needs. The planned management sequence would require farmers to pulverise the cane in a grinder when preparing the livestock feed ration. Farmers who decide to adopt this combined cropping-livestock production system will therefore need some technical and organizational skills. By this strategy, the field is left fallow for 2 years. The cane that is left standing at the end of the sugarcane forage cycle will have to be cut manually, followed by a light tillage prior to replantation in order to maintain the restructured soil.

One critical feature of this procedure is to ensure the soil porosity created by the sugarcane roots is preserved after they have died and decomposed. The stubble is destroyed by applying a non-persistent chemical herbicide treatment. This avoids the risk of breaking down the soil structure by detrimental ploughing and spraying operations.

This system would be most suitable for farmers with livestock production experience, and with at least 5-6 ha under sugarcane. The approach is also in line with the objectives of the sugarcane sectoral plan drawn up by the industry for the 2000-2006 period, i.e. to safeguard the total area currently under sugarcane. Indeed, much agricultural land in Guadeloupe is taken up by relatively unproductive natural rangelands. Growing sugarcane on part of these rangelands could boost per-hectare forage yields for feeding ruminants, while freeing some areas that would otherwise be cropped with sugarcane designated for the sugar factories.

Agricultural operations in Guadeloupe.

Introduction of sugarcane in banana production systems

C. Poser, T. Monsaingeon

In the Capesterre region, intensive mechanised banana cropping is responsible for physicochemical soil degradation (plough pan, compaction, anoxia, etc.) and outbreaks of soil-borne parasites (nematodes, weevils, etc.) that reduce crop yields and the longevity of the banana plantations. Moreover, standard pesticide treatments have to be avoided whenever possible to reduce already high environmental stress. The banana industry has also been weakened in Guadeloupe as a result of reduced investment under the current highly competitive market conditions.

Introducing sugarcane in banana production systems is an agronomically and economically interesting solution in Guadeloupe. Since 1998, banana-sugarcane-banana rotations have been tested on almost 200 ha of banana plantations with encouraging initial results.

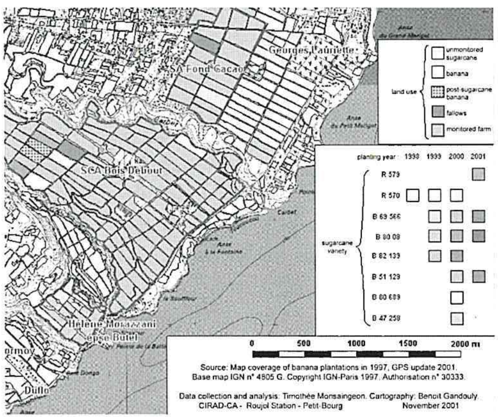

Figure 23. Map of sites where sugarcane has been replanted in Capesterre.

Introducing a short-season sugarcane crop with two to three ratoons has a sanitizing effect against soil-borne parasites (currently investigated by CIRAD-Flhor), so pollution loads due to pesticide treatments could thus be reduced by around 25%. Studies have also been initiated to assess the beneficial effect of sugarcane on the soil structure. This practice is also economically preferable to leaving the fields unproductively fallow and weed infested, i.e. the climatic conditions are suitable for sugarcane production for the distillery and sugar industries, and even for the production of top quality cuttings. The introduction of high-yielding sugarcane (around 110 t/ha on average) in a banana production system therefore seems promising for both agronomic and economic reasons (Figure 23).

Improved structural organization of production in Réunion

J.-C. Dagallier, D. Deurveilher, L. Gauvin, F. Mouniapin

Technical-economic recommendations for growers' groups

Companies involved in farming operations must adapt to increased production costs associated with production uncertainties and application of the obligatory 35-hour work week. They are obliged to look for solutions via new mechanisation management strategies in order to maintain their positive operating results. This implies diversifying their mechanised operations (harvesting, land development, etc.) because farmers—whose equipment is improving—are now often handling operations that they formerly contracted out to entrepreneurs. These latter agents are now only proposed a few operations that are too heavy for farmers to handle or located in areas where farmers hesitate to work for fear of damaging their equipment. Companies thus require information on their technical performances, operational sites, clients and resource availability in order to enhance their operational efficiency.

The aim is to develop a tailored database structure and guidelines. Techniques are first required to improve data retrieval, automated processing to generate dynamic trend charts, and storage capacities to facilitate drawing up historical reports. All of these elements are part of the Sadem Gestion system, which simulates the economic results for a service or the workload for specific equipment.

In addition to producing baseline reports, e.g. assessments of fuel consumption per machine or spare parts and supplies required per machine, the system generates detailed analyses that the company's accounting service otherwise cannot obtain. The Sadem Gestion database is not structured to be able to allocate costs according to specific operations, but it can perform more detailed analyses on a per-operation basis for decision support. It recalculates economic results that are found in specialised matrices, organization and target charts (Tables 10 and 11).

Table 10. Operational choices to enhance the economic return. Results derived from the Sadem Gestion database. Operations are classified in decreasing order of cost-effectiveness.

Operation code	Economic return in euros (1)	Cancelled operations (2)
Restoration with D6 = RE6	296 603	Chisel ploughing = CHS
Restoration = REA	226 458	Light Crop Master tillage = CM0
Restoration with D7 = RE7	208 778	Bush clearing = DBE
Cutting = CPE	145 712	Land clearing = DEF
Restoration with D8 = RE8	135 148	
Rough stone removal with D6 = EP6	100 809	Rough stone removal = EPI
Rough stone removal with D7 = EP7	59 182	Planting 0 = PL0
Crop Master tillage = CM	47 834	Planting 1 = PL1
Fine stone removal = EFE	41 880	Planting 3 = PL3
Tractor-dozer 1 = TP1	35 877	Towing = RMQ
Cane transport = TRP	34 123	Herbicide spraying = RUP
Harvest = REC	27 913	Various operations 2 = TD2
Fine stone removal preparation = EPT	22 732	Various operations 1 = TD1
Land clearing with D6 = DF6	21 386	Tractor-dozer 3 = TP3
Planting = PL	17 564	
Various operations = TD	15 882	
Various operations 3 = TD3	13 658	
Market gardening-type fine stone removal = EFC	12 723	

(1) The expected economic return was calculated on the basis of previous years, structural costs, strategies for the current year, etc. The expected return for each operation should be considered in order to meet a balanced global target for the company.
(2) In the cancelled operations, which are unprofitable for the company, PL0, PL1 and PL3 represent former planting options and techniques.
D6, D7 and D8 are categories of bulldozers of increasing power.

Table 11. Equipment recommended to help meet cost-effectiveness objectives according to the Sadem Gestion database.

Equipment code	260	263	264	265	268	271	272	280
Operation	EP6	RE6	REA	RE6	RE6	RE7	RE7	RE8
	RE6	EP6	RE6	REA	REA	EP7	REA	REA
	REA	REA	EP6	EP6	EP6	REA	TD3	EPT
	DF6	DF6	CH6	TD		TD	EP7	DF8
	EPR	TD1		DF6		TD3	DF7	EP8
	TD	TD3		TD1		CH7	RE6	
	RE7						CH7	

The operations are classified in decreasing order of cost-effectiveness according to associated equipment operating costs. It is thus better to conduct a restoration operation with D6 (RE6) with equipment 263, 265 or 268.

EPR, EP6, EP7, EP8 = rough stone removal
EPT= fine stone removal
REA, RE6, RE7, RE8 = restoration
DF6, DF7, DF8 = land clearing
TD, TD1, TD3 = various operations
CH6, CH7 = road works
D6, D7, and D8 are categories of bulldozers of increasing power.

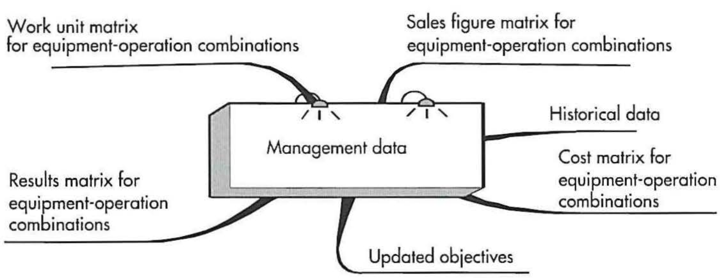

Figure 24. Sources of the management data.

These charts are used to adjust funding in order to achieve a given financial result. They integrate the operational cost history and can simulate the financial impact of choices concerning the structure of the equipment fleet and management service, or concerning technical operations required. An expected financial result can thus be determined by iteration.

Per-operation analyses—based on historical data, target charts and results matrices—recalculate the optimised individual objectives per machine, per operation, or both combined. The objectives are generated in several forms, i.e. in numbers of hours and hectares, or in sales figures per operation or per machine. Technicians overseeing the work operations thus have access to the objectives (and associated cost figures), and the secretariat of the operational service is able to regularly transmit updated result matrices to facilitate operational follow-up (Figure 24).

Mechanical harvesting in harsh conditions with the SIMON cane cutter

Many modifications were made to the cane cutter on the basis of an analysis of its performance in 2000. These modifications were chiefly aimed at reducing harvest stoppage due to a number of minor breakdowns and to facilitate quick adjustments to certain parts of the machine in response to changing harvesting conditions, and to reduce operating costs.

The cane cutter was also equipped with a more reliable data recorder to enable continuous long-term data recording. Cutter performance was thus measured over a 22-week harvesting period (Table 12). Cane yields (t/ha) of the fields were found to be very poor overall, except for one week (135.5 t/ha). Peak cane cutting yields were around 16-17 t/h. Machine performance remained stable. The time to shift between rows was still too high, and equivalent to the peak cutting time.

Table 12. Performances of the cane cutter over a 22-week harvesting period.

	Area (ha)	Time (h)	Cutting (h)	Handling (h)	Production (t)	Overall yield (t/h)	Cutting yield (t cut/h)	Cane yield (t/ha)
Total	28.91	284.97	130.95	106.47	1 978.50			
Mean	1.3	13.0	6.0	4.8	89.9	7.1	16.3	75.9
SD	0.8	6.2	3.3	2.4	43.6	1.8	4.9	22.6
Minimum	0.1	1.9	0.5	0.5	14.9	4.5	10.9	49.4
Maximum	3.7	28.5	15.3	11.1	189.6	11.3	31.7	135.5

The costs were compared with those recorded in 2000, and the machine modifications and field choices (technical specifications) were found to markedly reduce the direct costs.

Tractor and cane cutter maintenance and repair costs were 3 580 (23 484 F) in 2001, compared to 12 806 (84 000 F) in 2000 (cutter parts and supplies alone). Driver fees amounted to 9 147 (60 000 F) in 2001, as in 2000. Fuel consumption (2 000 l) cost 1 600 (10 500 F), exempt of tax. Total direct operational costs, including travelling expenses, were 14 614 (95 864 F) for 2001, compared to 31 448 (206 289 F) in 2000. The per-tonne cost was 7.31 /t (47.93 F/t) in 2001 and 9.23 /t (60.56 F/t) in 2000. The cutting fee proposed, i.e. between 7.62 /t (50 F/t) and 8.38 /t (55 F/t), was therefore warranted.

The machine adjustments led to a very substantial reduction in minor breakdowns during harvesting operations, which are now more regular. The field choices were found to be highly important, especially with respect to avoiding stony fields and therefore machine damage. The feed guides of the cutter are inefficient for gathering cane lying flat on the field. Cane is gathered better when the tractor is equipped with a scoop deflector ahead of the front wheels, on the side of the cane cutter. For very high cane densities, the tractor speed cannot be over 800 m/h, which is possible when the tractor is equipped with an optional "creep-speed" gearbox. When the field has not been tilled and the machine has no maneuvering room, the tractor has to back up to the head of each row, thus reducing machine performance by half, which explains the low overall yields presented in the performance chart.

Two important technical problems still have to be solved: the hopper should be improved in order to be more efficient on sloping fields; the rear steering-drive wheel unit (power wheel that moves the machine forward and reverse and steers it) should be designed to avoid all possibility of breakdown.


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Harvesting with a SIMON cane cutter.

Machine performances are still below the cane cutter's potential. This is linked with tillage conditions in the fields and with management logistics, not with the machine itself. In fact, no fields were tilled as formally requested, and it was not possible to conduct a harvesting operation for 2 full weeks without any breakdowns. Under these conditions, weekly tonnage yields of the cutter could not be calculated.

The cane cutter is currently only being used for harvesting fields that workers refuse to harvest manually—these fields are often relatively unsuitable for mechanical harvesting.

Sugarcane growers have asked to have the machine equipped with a trash catcher. Some farmers who have already tested the cutter would like to use it again for their 2002 harvests.

Organization of supplies to sugar factories in Réunion and Mauritius

C. Lejars

In Réunion and Mauritius, the sugarcane sector is hampered by many problems, further compounded by the high inherent challenges to improve productivity and lower production costs. It is therefore essential to pinpoint areas of potential improvement so as to enhance the overall efficiency of the industry. The productivity of this sector could be boosted, while making it more competitive and sustainable, by improving sugarcane supply management and organization.

Logistics and supplies to sugar factories

A project focused on the structural and functional reorganization of the whole supply system has been under way since 1997 in collaboration with the Mauritius Sugar Producers' Association (MSPA) and four sugar industry groups in Réunion and Mauritius. Since late 2001, this regional cooperation has been extended to South Africa, and a partnership is being established with the South African Experiment Station (SASEX) and the Sezela sugar factory.

The study addresses the following objectives:
- to assess-in collaboration with different partners in the sugarcane sector-the impact of supply strategy modifications on the functioning of the entire sector;
- to compare different potential organizational scenarios with the aim of coming up with a decision-support tool to benefit stakeholders.

The scenarios will take the objectives and constraints of each stakeholder into account. For farms, a broad range of different farm operation and growers' strategies will be integrated. Concerning interactions between industrial operators and growers, agreements between stakeholders will be analysed, especially with respect to payment conditions. Finally, logistic requirements should be taken into account.

Based on field surveys, two software models are being developed to obtain answers to question concerning the reorganization of sugarcane supplies.

A global supply model that was initially programmed in Excel is currently being reformatted for Access. It can be applied to test potential scenarios for whole sugarcane-growing areas and to determine the overall value for the sector. The simulations apply to separate campaigns and focus on weekly management of sugarcane flows from the field to the factory.

A logistic model is currently being developed. It will enhance evaluations on the impact of different scenarios in terms of resizing agroindustrial equipment. Moreover, it will operate on a daily time scale and include an economic approach.

Enhancement of production quality

The overall aim is to develop sugarcane production and supply organization strategies that take into account qualitative and quantitative variations in sugarcane produced during a season.

Implementation of these strategies should be compatible with the current system of interactions between stakeholders in the sector, and with producers' strategies concerning quality. This will initially involve investigating the effects of global sugarcane quality variables on sugarcane production optimisation.

The first step is to identify quality variations according to geographical locations, varieties, irrigation management strategies and harvesting conditions in order to determine if this feature could potentially be tapped. This step—especially on a whole sugarcane-growing area scale—could highlight areas where the crop is homogeneously ripe and indicate whether differences in ripeness are significant and of potential use.

The second step is to assess and measure the total productivity gain resulting from this approach for all stakeholders in the sector.

After analysing sugarcane quality-building processes, the goal will be to develop them through stakeholders' groups within the sugarcane sector. The last step will therefore be to propose and test sugarcane production and supply organization innovations.

Two approaches are being developed:
- one involving simulation of quality variations according to geographical locations and treatments carried out using the MOSICAS growth model;

– another involving real data on sugarcane tonnage and sugar content obtained from sugarcane reception centres, farms, or homogeneous sites within the sugarcane-growing area.

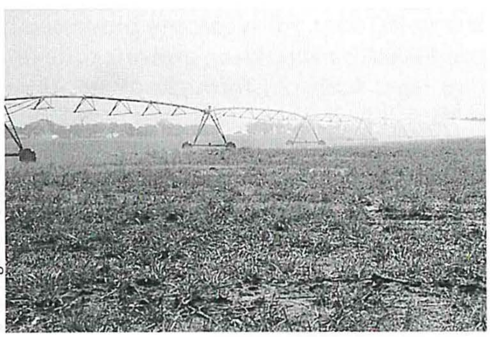
Development of an irrigation management-support tool in Côte d'Ivoire

P. Langellier-Bellevue

Initiatives begun in Côte d'Ivoire to develop decision-support tools—designed mainly for sugarcane field management and to optimise haulage vehicles—were continued in close collaboration with CIRAD-CA computer scientists. This project, however, is mainly focused on developing a water management software package.

The current aim is to continue developing this type of tool for subsequent dissemination to any interested stakeholders in the sugar industry. The decision to launch this initiative was prompted by the interest shown by the French Société d'organisation de management et de développement des industries agricoles et alimentaires (SOMDIAA) and the Sucrerie africaine de la Côte d'Ivoire (SUCAF-CI) in setting up a collaboration to develop an irrigation management support tool.

A blanket-coverage irrigation management module was developed on the basis of an analysis of operational constraints at the SUCAF-CI Ferkessedougou site. The module uses a two-reservoir water balance model derived from the SIMULEX meteorological database. The technical specifications were drawn up in close collaboration with users and takes specific operational constraints into account, especially water volumes available at the pumping stations.



Central pivot irrigation

The same approach was then used to analyse central pivot irrigation. The main water management principles were retained. However, management of this type of irrigation must be in line with the specific characteristics of the system and acceptable to the operator, and with the prevailing environmental and operational conditions. In this case, the hydrodynamic soil characteristics represent a key factor for calculating the water dose required, in order to limit runoff, subsequent erosion and deep percolation.

The aim is also to develop a tool that could, with suitable collaboration, be tailored to the specific needs of other types of farm.

The current blanket-coverage irrigation module hinges on two complementary elements, i.e. a software interface and a database. The database management program Microsoft Access 97 and the programming language Microsoft Visual Basic 6 were adopted to ensure that the management module could be easily run and maintained by users without any advanced computer training or equipment. The interface windows were also designed to be user-friendly. The main menu presents-in the form of a cycle-different

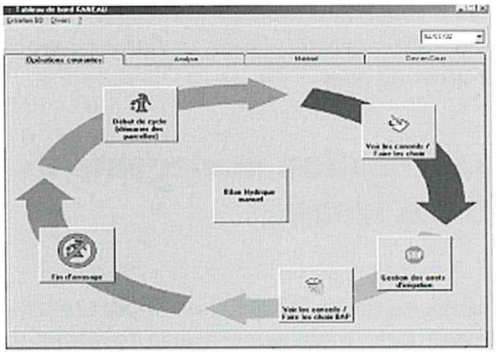


Figure 25. Main menu of the irrigation management module.

operations that can be accessed by clicking on a selected button (figure 25). The other tabs provide access to different functions. For instance, the "equipment" tab opens the "equipment installation" window, which displays the database contents at the top of the window, and modifications can be made at the bottom.

This software has several features:

- the adjustment of cropping coefficients according to users' choices and the extent of crop development;
- a proposed field watering plan based on available water volumes;
- a proposed sequence if rainfall occurs;
- the possibility of programming when irrigation should be halted and of drawing up a report at the end of the season;
- the possibility for the operator to switch to default values, as listed in the guidelines, for dosages, times, and flow rates.

The programme concerning blanket-coverage irrigation is now complete and will be validated. On the basis of a number of simple hypotheses, which will be explained in the instructions, a scalable product was developed, involving standard computer hardware and software, that could generate easy to implement decision-support recommendations on water management.

Support for the Quang Ngai sugar corporation in Vietnam

S. Volper

The Agence française de développement (AFD) granted a loan to the Quang Ngai Sugar Company (QNSC) to enable it to double its annual sugar production from 50 000 to 100 000 t. All sugarcane processed by QNSC is obtained from some 100 000 smallholders, growing cane on a field area of 1 500 m^2 on average, scattered throughout an area of around 2 000 km^2. Cane yields will have to be increased markedly to reach the targeted objective.

Sugarcane production constraints were identified during several consultancy missions by scientific specialists of the CIRAD-CA Sugarcane Programme. They concern transportation logistics, fertilization, agricultural practices, pathology and entomology. In 1998, CIRAD proposed to support QNSC in creating a research station, training a scientific team, and designing and implementing an experimental programme at the station and in the field.

The main thrusts put forward by the specialists are:

- to adjust the cropping calendar to water supply conditions (possibility of supplementary irrigation, state of the water table);
- to identify varieties that could be harvested at different periods under specific cropping conditions (drought tolerance, water logging);

- to develop fertilizer recommendations for different types of soil, rectify mineral deficiencies, select types of fertilizer and split dressings, and assess the role of organic matter;
- to improve ratoon crop management conditions, through different planting procedures, management of crop residue, improvement of drainage conditions;
- to protect crops from stemborer and white grub infestations, and develop efficient control procedures.

Because of the low number of personnel assigned to the experimental programme and the minor financial commitment of the host structure (QNSC), only the varietal introduction and assessment programme was implemented between April 1999 and December 2001.

Since March 1997, on a yearly basis, CIRAD-via its quarantine unit in Montpellier-has been supplying batches of new sugarcane varieties that were bred in Guadeloupe, Réunion and the Barbados network in the West Indies. QNSC thus now has a collection of more than 100 varieties.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Weighing operations in experimental plots in Vietnam.

Of all varieties that have been introduced since 1997, an experiment carried out in 2001 revealed five varieties of interest for cropping in Quang Ngai province. These varieties will be screened in 2002 through a series of tests carried out in the station and within a network outside of the station. The plan is that QNSC extension agents will be involved in managing this network, which is essential for conducting the follow-up experiments, and that sugarcane growers will also actively participate.

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Chopart J.L., Cameroun, juin 2001. Participation à la 3e Rencontre internationale en langue française de la canne à sucre organisée par l'Afcas et le Gps à Yaoundé.

Chopart J.L., Japon, novembre 2001. Participation au 6e symposium de l'Isrr (International Society of Root Research) à Nagoya.

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D'Hont A., Etats-Unis, janvier 2001. Participation au congrès Issct, à l'atelier Biologie moléculaire à San Diego.

D'Hont A., Etats-Unis, janvier 2001. Réunion annuelle de l'Icsb (International Consortium for Sugarcane Biotechnology) à San Diego.

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D'Hont A., France, juillet 2001. Participation à l'European cytogenetic conference à Paris. Investigating the genome structure of polyploid crops by GISH and FISH.

D'Hont A., Australie, septembre 2001. Participation au 24e congrès de l'International Society of Sugar Cane Technologists à Brisbane.

D'Hont A., France, octobre 2001. Participation au congrès Génoplante à Poitiers.

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Dagallier J.C., France, juin 2001. Participation au séminaire Third European conference on precision agriculture à Montpellier.

Daugrois J.H., Guadeloupe, mars 2001. Rédaction du Contrat de plan Etat-Région 2000, encadrement VAT, programmation des travaux pour 2001.

Daugrois J., Etats-Unis, juin 2001. Séminaire Assct, 31 annual joint meeting, Florida & Louisiana à la New Orleans en Louisiane.

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Domaingue R., Chine, avril 2001. Participation au sommet international sur l'industrie sucrière et rencontre avec les responsables de l'industrie sucrière à Pékin.

Domaingue R., Cameroun, juin 2001. Participation à l'atelier de travail du réseau d'amélioration variétale de la canne à sucre pour l'Afrique de l'Ouest et du Centre et à la 3e Rencontre internationale en langue française de la canne à sucre organisée par l'Afcas et le Gps à Yaoundé.

Domaingue R., Réunion, Maurice, juin 2001. Suivi du projet Protection des plantes et montage du pôle 3P ; suivi des projets analyse du génome, agronomie, modélisation. Discussions avec le Cerf (Réunion) sur des projets de collaborations, ainsi qu'avec des usiniers mauriciens.

Domaingue R., Australie, septembre 2001. Participation au 24e congrès de l'International Society of Sugar Cane Technologists à Brisbane.

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Goebel R., Réunion, avril 2001. Mission avec Elisabeth Tabone, Inra. Programme de lutte biologique contre les foreurs de la canne à sucre.

Goebel R., Afrique du Sud, juillet 2001. Participation au 13e congrès de l'Essa (Entomological Society of Southern Africa) à l'université du Natal.

Goebel R., Afrique du Sud, août 2001. Participation au 75e congrès de la Sasta à Durban.

Goebel R., Afrique du Sud, octobre 2001. Intervention à la réunion annuelle des comités Pest & Disease, à la Sasa, Mount Edgecombe.

Goebel R., Afrique du Sud, novembre 2001. Participation au workshop Burn/Harvest to crush delays & crop estimating in the South African sugar industry, Sasa, Mount Edgecombe.

Grivet L., Etats-Unis, janvier 2001. Participation à la conférence Plant, animal & microbe genomes à San Diego, Californie.

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Langellier P., Cameroun, juin 2001. Participation à l'atelier de travail du réseau d'amélioration variétale de la canne à sucre pour l'Afrique de l'Ouest et du Centre et à la 3e Rencontre internationale en langue française de la canne à sucre organisée par l'Afcas et le Gps à Yaoundé.

Langellier P., Tchad, décembre 2001. Complexe sucrier de la Cst. Mission d'évaluation de la faisabilité d'un logiciel de gestion de l'eau à N'djamena.

Marion D., Côte d'Ivoire, mai 2001. Participation à l'atelier annuel de restitution des résultats de la recherche des programmes de la direction régionale du Cnra à Korhogo.

Marion D., Cameroun, juin 2001. Participation à l'atelier de travail du réseau d'amélioration variétale de la canne à sucre pour l'Afrique de l'Ouest et du Centre et à la 3e Rencontre internationale en langue française de la canne à sucre, organisée par l'Afcas et le Gps à Yaoundé.

Marion D., Guadeloupe, novembre 2001. Formation à la sélection variétale de la canne à sucre à partir du fuzz à la station Cirad de Roujol.

Martiné J.F., Guadeloupe, mai 2001. Appui au projet modélisation du programme canne à sucre.

Martiné J.F., Afrique du Sud, juillet 2001. Participation au 75e congrès de la Sasta à Durban.

Martiné J.F., Australie, septembre 2001. Participation au 24e congrès de l'International Society of Sugar Cane Technologists à Brisbane.

Oriol P., Cameroun, juin 2001. Participation à l'atelier de travail du réseau d'amélioration variétale de la canne à sucre pour l'Afrique de l'Ouest et du Centre et à la 3e Rencontre internationale en langue française de la canne à sucre organisée par l'Afcas et le Gps à Yaoundé.

Oriol P., Caraïbe, octobre 2001. Participation à l'atelier de travail annuel du réseau d'amélioration variétale de la canne à sucre (Wisben) à Saint-Kitts.

Pouzet D., Maurice, août 2001. Offsite movement of agrochemicals in tropical sugar cane production. International extension workshop Msiri à Réduit.

Pouzet D., Australie, septembre 2001. Participation au 24e congrès de l'International Society of Sugar Cane Technologists à Brisbane.

Raboin L.M., Afrique du sud, juillet 2001. Participation au 75e congrès de la Sasta à Durban.

Rassaby L., Australie, septembre 2001. Participation au 24e congrès de l'International Society of Sugar Cane Technologists à Brisbane.

Rochat J., Afrique du Sud, juillet 2001. Participation au 75[e] congrès de la Sasta à Durban.

Roques D., Maurice, mai 2001. Visite du dispositif d'hybridation du Msiri.

Roques D., Caraïbe, octobre 2001. Participation à l'atelier de travail annuel du réseau d'amélioration variétale de la canne à sucre (Wisben) à Saint-Kitts.

Rott P., Brésil, mars 2001. Projet de collaboration avec l'université de São Carlos (Dr. Eder Giglioti), mission en pathologie de la canne à sucre.

Rott P., Australie, septembre 2001. Participation au 24[e] congrès de l'International Society of Sugar Cane Technologists à Brisbane.

Rott P., Réunion, novembre 2001. Mission en pathologie de la canne à sucre.

Siegmund B., Maurice, août 2001. Offsite movement of agrochemicals in tropical sugar cane production. International extension workshop Msiri à Réduit.

Todoroff P., Guadeloupe, juin 2001. Mesures de profils hydriques par réflectométrie temporelle. Communication au séminaire Inra-Cirad, intérêt des propriétés électriques de systèmes biophysiques pour la caractérisation de leur fonctionnement, Inra Duclos.

Vercambre B., Réunion, juin 2001. Programmation de l'opération vers blancs. Démarche compilibre.

Vercambre B., Afrique du Sud, juillet 2001. Participation au 75[e] congrès de la Sasta à Durban.

Vercambre B., Réunion, novembre 2001. Suivi de l'opération vers blancs.

Volper S., Vietnam, mars 2001. Mission d'appui à la Quang Ngai Sugar Corporation, dans le cadre de la convention Agence française de développement - Cirad : suivi de l'expérimentation, plantations d'essais, prospections de nouveaux sites à Quang Ngai.

Volper S., Vietnam, juin 2001 puis septembre 2001. Mission d'appui à la Quang Ngai Sugar Corporation, dans le cadre de la convention Agence française de développement - Cirad : poursuite du suivi de l'expérimentation, plantations d'essais, prospections de nouveaux sites à Quang Ngai.

Visiting scientists and trainees hosted by the Sugarcane programme

Genome analysis

Alleyne S. (c/o A. D'Hont). Analyse de l'impact de la sélection pour la richesse en sucre sur la diversité moléculaire de la canne à sucre. Université des West Indies, Barbade, thèse, 8 mois.

Bègue M. (c/o L.M. Raboin). Etude du déterminisme génétique de la résistance au charbon de la canne à sucre. Université de la Réunion, licence biologie des organismes, 1 mois.

Chen Hui (c/o A. D'Hont). Cartographie de marqueurs microsatellite sur le génome du cultivar R 570. Yunnan Sugarcane Research Institute, Chine, 4 mois.

Jaunoo Nazeema (c/o A. D'Hont). Collaboration Fapesp-Cirad sur l'analyse du génome de la canne à sucre. Fapesp, Brésil, 3 mois.

Le Cunff L. (c/o A. D'Hont). Contribution au clonage positionnel d'un gène de résistance à la rouille chez le cultivar de canne à sucre R 570. Université Paris VII, Dess, 8 mois.

Reffay N. (c/o A. D'Hont). Etudes des facteurs génétiques contrôlant l'accumulation du sucre et de la teneur en fibre dans les variétés de canne cultivées à la Réunion et en Australie. Université de la Réunion, thèse, 12 mois.

Rossi M. (c/o A. D'Hont). Cartographie d'analogues de gènes de résistance sur le génome du cultivar R 570. Université de São Paulo, Brésil, 6 mois.

Crop protection

Amodjee F. (c/o J. Rochat). Lutte biologique contre le foreur ponctué de la canne à sucre à l'aide de trichogrammes sur l'île de la Réunion. Lycée agricole Saint-Paul, la Réunion, Terminale Stae, 6 semaines.

Bouffier L. (c/o J.C. Girard, M.L. Caruana). Relations agents pathogènes/symptômes. Ina-Pg, stage deuxième année, 2 jours.

Cao Anh Duong (c/o B. Vercambre). Méthodologie d'évaluation de la résistance variétale vis-à-vis des chenilles mineuses des tiges de canne à sucre à la Réunion. Institute of Sugar Cane Research, Vietnam, 2 mois.

Caron D. (c/o R. Tibère, J. Rochat). Etude des nouveaux périmètres canniers de la zone d'antenne 4. Lycée agricole Saint-Paul, la Réunion, terminale Stae, 2 semaines.

Faure I. (c/o B. Vercambre). Etude de la nature physique de la résistance de la canne à sucre au foreur des tiges *Chilo sacchariphagus* (Lepidoptera : Pyralidae). Application aux variétés R 570 et R 579. Université des sciences et techniques, Lyon, maîtrise, 4 mois.

Garcia S. (c/o M. Chatenet, P . Rott). Pouvoir pathogène et détection d'isolats asiatiques de la mosaïque de la canne à sucre. Université Montpellier III, 4 mois.

Gisors G. (c/o B. Vercambre). Techniques d'analyse des données concernant une nouvelle méthodologie d'évaluation de la résistance variétale des tiges de canne à sucre vis-à-vis des chenilles mineuses. Université Montpellier II, maîtrise, 3 mois.

Grondin S. (c/o J. Rochat). Lutte biologique à l'aide de trichogrammes : étude des possibilités de stockage au froid des trichogrammes. Lycée agricole Saint-Paul, la Réunion, 6 semaines.

Houdeau Y. (c/o L. Costet). Caractérisation du pouvoir pathogène des *Xanthomonas* de la canne à sucre à la Réunion. Lycée agricole de Saint-Benoît/Centre de formation agricole pour adulte de Moissac, Bta, 1 mois.

Mazarin C. (c/o M. Chatenet, J.C. Girard, P. Rott). Variabilité du pouvoir pathogène du *Sugarcane mosaic virus* (SCMV) en Afrique et caractérisation d'isolats asiatiques de la mosaïque de la canne à sucre. Université de Montpellier II/Ensa de Montpellier, Dea, 8 mois.

Pittore D. (c/o M. Royer, P. Rott). Développement d'un système d'expression hétérologue de l'albicidine, phytotoxine produite par une bactérie pathogène de la canne à sucre, *Xanthomonas albilineans*. Université de Perpignan, maîtrise sciences et techniques, 4 mois.

Reay-Jones F. (c/o J. Rochat). Caractérisation bio-écologique de *Trichogramma chilonis* Ishii (Hymenoptera : Trichogrammatidae), implications pour la lutte biologique sur la canne à sucre contre *Chilo sacchariphagus* Bojer (Lepidoptera : Pyralidae). Université d'Angers, Dess technologies du végétal, 6 mois.

Tabone E. (c/o R. Goebel). Programme de lutte biologique à la Réunion contre les foreurs de la canne à l'aide de trichogrammes. Inra, Antibes, 4 jours.

Varietal improvement

Celestine-Myrtil-Marlin D., directeur régional de la recherche et de la technologie, et A. Bon, directeur de l'environnement, recherche et technologie innovantes du Conseil régional (c/o D. Roques, P. Oriol), 1 jour.

Chidiac A., directeur du service de la protection des végétaux de Guadeloupe (c/o D. Roques, P. Oriol), 2 jours .

Chiron M., responsable de l'enseignement agricole de l'Afpag (Association pour la formation professionnelle adulte de Guadeloupe), accompagné de 30 visiteurs (c/o D. Roques), 1 jour.

Humeau L. (c/o D. Roques, P. Oriol). Création d'une base de données relationnelle pour l'amélioration variétale de la canne à sucre. Iup Informatique, Montpellier, maîtrise, 4 mois.

Parfait A., directeur de recherche Inra, unité de recherche en technologie des produits végétaux, (c/o D. Roques, P. Oriol). Guadeloupe, 1 jour.

Piral G., technicien du Ctics accompagné de 6 agriculteurs (c/o D. Roques), 1 jour.

Sioussaram J. (c/o P. Oriol). Participation à l'amélioration variétale de la canne à sucre à la Guadeloupe. Lycée agricole, Bts agronomie tropicale, 6 semaines.

Urbino A., directeur du Ctics (c/o D. Roques, P. Oriol), 1 jour.

Agronomy and crop modelling

Baron H. (c/o P. Jouve, D. Tran Minh). Etude des conditions de durabilité de la filière canne à sucre à la Martinique : ancrage, produits – territoire. Université de Toulouse, thèse, 11 mois.

Bouzouina S. (c/o J.F. Martiné). Calage et validation de Ceres-Canne. Inra-Grignon, Dea mathématiques appliquées, 6 mois.

Hoarau M. (c/o J.L. Chopart, D. Tran Minh). Caractérisation des paramètres de l'irrigation en goutte à goutte à Savannah et des modalités d'humectation du sol. Comparaison avec une irrigation par aspersion. Lycée agricole Saint-Paul, la Réunion, Bts, 2 mois.

Monsemptes A., agent du développement en irrigation, (c/o J.L. Chopart). Suivi d'une expérimentation de rationnement en eau de la canne à sucre. Cfppa, Saint-Leu, la Réunion, 1 mois.

Papillon J. (c/o J.L. Chopart). Etude de l'humectation du sol et de l'accès à l'eau par les racines de canne dans un champ de canne irrigué en goutte à goutte en vue d'une recherche des causes d'un problème de croissance. Lycée agricole Saint-Paul, la Réunion, Bts, 2 mois

Smith P. (c/o J.F. Martiné). Etablissement de correspondances entre le fonctionnement physiologique de la canne à sucre et les concepts du modèle Stics. Ensa Rennes, Daa d'agronomie, 2 mois.

Support to the sugarcane sector and producers

Actim (c/o B. Siegmund). Visite de l'industrie sucrière de la Réunion organisé par l'Actim avec des représentants de sociétés françaises et des représentants du Mexique, de Cuba et d'Indonésie, 4 jours.

Angama (c/o J.C. Dagallier). Electronique, centrales embarquées Sadem. Lycée d'enseignement professionnel J. Perrin, la Réunion, Bac Pro, 1 mois.

Bamba Moussa (c/o P. Langellier). Formation en Sig et validation des données de la dernière campagne de récolte, Sucaf-ci, Côte d'Ivoire, 2 mois.

Barret P. (c/o J.C. Dagallier). Suivi de chantiers de coupe mécanique de la canne, coupeuse Simon. Lycée agricole Saint-Paul, 2 mois.

Bernard H. (c/o B. Siegmund, P. Marnotte). Dégradation des produits phytosanitaires herbicides dans leurs zones d'application au champ, risques de transfert et d'altération de la qualité des eaux dans la zone ouest de l'île de la Réunion. Ecole supérieure d'Ingénieurs, Poitiers, 11 mois.

Monsaingeon T. (c/o C. Poser). Rotation banane-canne-banane à la Guadeloupe : un système de production prometteur sur la région de Capesterre. Stage de fin d'études Istom, 4 mois.

Serin F. (c/o P. Langellier). Mise au point d'un logiciel de pilotage d'irrigation en couverture intégrale. Dess Iup informatique, 5 mois.

Vauclin M., directeur du laboratoire d'étude des transferts en hydrologie et environnement (c/o B. Siegmund). Appui scientifique au programme de gestion de l'eau ; exposé sur les travaux menés par son laboratoire. 1 semaine.

Participation of Sugarcane programme scientists in training courses

Chopart J.L. : cours sur l'alimentation hydrique des cultures, dans le cadre de la maîtrise de biologie physiologie de l'université de la Réunion.

Chopart J.L. : intervention dans le cadre de la formation d'agriculteurs sur les systèmes irrigués, avec la Chambre d'agriculture de la Réunion.

Chopart J.L. : intervention dans le cadre de la formation Amis-Agronomie sur les méthodes en écophysiologie. Montpellier (10-14 décembre 2001).

Daugrois J.H. : cours sur les maladies de la canne à sucre, dans le cadre de la maîtrise de sciences et techniques en sciences agronomiques et développement rural. Université Antilles-Guyane, 2 heures.

D'Hont A. : intervention dans le cadre du Dea ressource phytogénétique et interaction biologique, et dans le cadre de l'Ecole doctorale du Muséum national d'histoire naturelle de Paris.

Girard J.C. : cours sur les bactéries phytopathogènes, dans le cadre du Dea ressources phytogénétiques et interactions biologiques. Université Montpellier II/Ensa Montpellier (4 décembre 2001), 1 heure.

Langellier P. : cours sur la culture de la canne à sucre. Ensiaa Montpellier.

Roques D. : stage de formation aux techniques de semis de semences de canne à sucre et de sevrage de seedlings de Daniel Marion (4 novembre – 1er décembre 2001).

Roques D. : stage sur la création d'une base de données relationnelle pour l'amélioration variétale de la canne à sucre, dans le cadre de l'Iup génie mathématique et informatique. Université de Montpellier II.

Roques D. : cours sur la gestion des ressources génétiques, dans le cadre du Dea environnement tropical et gestion de la biodiversité (13 novembre 2001), 3 heures.

Rott P. : cours sur l'échaudure des feuilles de la canne à sucre, étude de cas en pathologie tropicale, dans le cadre du Dea ressources phytogénétiques et interactions biologiques. Université Montpellier II/Ensa Montpellier (4 décembre 2001), 2 heures.

Todoroff P. : cours dans le cadre du Dea environnement tropical et gestion de la biodiversité. Université Antilles-Guyane, 6 heures.

Sugarcane programme team

- Head of the programme : Robert Domaingue — Montpellier
- Programme assistant : Roland Pirot — Montpellier

Cammal Janine	Montpellier
Héraud Dominique	Montpellier
Rémondat Catherine	Montpellier

Scientific team	*Location*	*Technical team*	*Location*
Project "Genome analysis"			
• Project leader: D'Hont Angélique	Montpellier		
Alleyne Sharron (PhD thesis)	Montpellier	Garsmeur Olivier	Montpellier
Grivet Laurent	Brésil	Hoareau Michel-Yves	Réunion
Raboin Louis-Marie	Réunion	Paulet Florence	Montpellier
Reffay Nathalie (PhD thesis)	Montpellier	Promi Iréné	Réunion
		Télismart Hugues	Réunion
Project "Crop protection"			
• Project leader: Rott Philippe	Montpellier		
Champoiseau Patrice (VAT)	Guadeloupe	Bègue Léon	Réunion
Chatenet Michèle	Montpellier	Boisné Noc Rosiane	Guadeloupe
Costet Laurent	Réunion	Bousquet Jean-François	Montpellier
Daugrois Jean-Heinrich	Guadeloupe	Calvados Jean-Louis	Guadeloupe
Girard Jean-Claude	Montpellier	Carmel Sylvere	Guadeloupe
Goebel Régis	Afrique du Sud	Daroussat Marie-Jo	Montpellier
Notaise Julien (PhD thesis)	Réunion	Fernandez Emmanuel	Réunion
Rassaby Laurence (PhD thesis)	Réunion	Gauvin Ginot	Réunion
Rochat Jacques (post-doc)	Réunion	Gauvin Jean-Claude	Réunion
Vercambre Bernard	Montpellier	Gauvin Marie-Charlyne	Réunion
		Habas Rémi	Montpellier
		Joseph Steeve	Guadeloupe
		Lombard Hugues	Réunion
		Muller Marc	Montpellier
		Ribotte Jean-Claude	Réunion
		Ruttee Abdoul	Réunion
		Tibere Richard	Réunion

Scientific team	*Location*	*Technical team*	*Location*

Project "Varietal improvement"

• Project leader: Oriol Philippe	Guadeloupe		
Al Rifai Mehdi (VAT)	Guadeloupe	Algou Gabriel	Guadeloupe
Roques Danièle	Guadeloupe	Cadet Murette	Guadeloupe
		Calvados Omer	Guadeloupe
		Carbel Martin	Guadeloupe
		Catan Eugène	Guadeloupe
		Coupan Jean-Marie	Guadeloupe
		Efile Jean-Claude	Guadeloupe
		Gelabale Georges	Guadeloupe
		Guiougou Chantal	Guadeloupe
		Joseph Antoinette	Guadeloupe
		Navis Patricia	Guadeloupe
		Perrot Sylvie	Guadeloupe
		Planchet Marie-Claire	Guadeloupe
		Ragouton Marc	Guadeloupe
		Sapotille Jocelyne	Guadeloupe
		Toubi Lyonel	Guadeloupe

Project "Agronomy and crop modelling"

• Project leader: Martiné Jean-François	Réunion		
Baron Hélène (PhD thesis)	Montpellier	Annette Annick	Guadeloupe
Brouwers Marinus	Montpellier	Brossier Jean-Luc	Réunion
Caillez Sophie (VAT)	Réunion	De Larichaudy Richard	Réunion
Caumont Benoît (VAT)	Réunion	D'Export Jean-Paul	Réunion
Chopart Jean-Louis	Réunion	Gauvin Lilian	Réunion
Combres Jean-Claude	Réunion	Jeannette Michel Rosaire	Réunion
Darie Estelle (VAT)	Guadeloupe	Kandassamy	Guadeloupe
Gandouly Benoît (VAT)	Guadeloupe	Le Mezo Lionel	Réunion
Guillaume Patrice	Guadeloupe	Lubin Nadia	Guadeloupe
Lecanu Guillaume (VAT)	Réunion	Mezino Mickaël	Réunion
Lejars Caroline	Réunion	Mouniapin Floris	Réunion
Pouzet Denis	Réunion	Mouny Latchimy Bernard	Réunion
Todoroff Pierre	Guadeloupe	Nativel Raymond	Réunion
Tran Minh Duc	Réunion	Velle Aurélien	Réunion
Vesoul Marie-Pierre	Réunion		

Project "Support to the sugarcane sector and producers"

• Project leader: Langellier Bellevue Pierre	Montpellier		
Dagallier Jean-Cyril	Réunion	Ango Catherine	Réunion
Marion Daniel	Côte d'Ivoire	Deurveilher Dany	Réunion
Poser Christophe	Guadeloupe		
Siegmund Bernard	Réunion		
Volper Serge	Montpellier		

Acronyms

AFCAS, Association française de la canne à sucre, France
AFD, Agence française de développement, France
AFLP, Amplified fragment length polymorphism
AFPAG, Association pour la formation professionnelle adulte de Guadeloupe, Guadeloupe
AFPP, Association française de protection des plantes, France
ASIC, Association internationale du café, France
AUF, Agence universitaire de la francophonie, Canada
BAC, Bacterial Artificial Chromosome
BING, Beam Identification by Non-destructive Grading
BSES, Bureau of Sugar Experiment Stations, Australia
CERAAS, Centre d'étude régional pour l'amélioration et l'adaptation à la sécheresse, Senegal
CERF, Centre d'essai, de recherche et de formation, Réunion
CMCS, Centre malgache de la canne à sucre, Madagascar
CNRA, Centre national de recherche agronomique, Côte d'Ivoire
CNRS, Centre national de la recherche scientifique, France
COLUMA, Comité de lutte contre les mauvaises herbes, France
CSS, Compagnie sucrière sénégalaise, Senegal
CST, Compagnie sucrière du Tchad, Chad
CTICS, Centre technique interprofessionnel de la canne et du sucre, Guadeloupe
EMBRAPA, Empresa Brasileira de Pesquisa Agropecuaria, Brazil
ENSA, Ecole nationale supérieure agronomique, France
ESSA, Entomological Society of Southern Africa, South Africa
EST, Expressed Sequence Tag
FAPESP, Fondaca de Amparo à Pesquisa do Estado de São Paulo, Brazil
FARC, Food and Agricultural Research Council, Mauritius
FDGDEC, Fédération départementale des groupements de défense contre les ennemis des cultures, Réunion
GIS, geographical information system
GPS, Groupement des professionnels du sucre, West Africa
ICIPE, International Centre of Insect Physiology and Ecology, Kenya
ICSB, International Consortium for Sugarcane Biotechnology
INRA, Institut national de la recherche agronomique, France
INSA, Institut national des sciences appliquées, France
IRAD, Institut de recherche abricole pour le développement, Cameroon
IRD, Institut de recherche pour le développement, France
ISSCT, International Society of Sugar Cane Technologists, Mauritius
ISTOM, Institut supérieur technique d'outre-mer, France
ISRR, International Society of Root Research, Japan
LAPRA, Laboratoire professionnel régional d'analyses, Guadeloupe
MSIRI, Mauritius Sugar Industry Research Institute, Mauritius
MSPA, Mauritius Sugar Producer's Association, Mauritius

ORF, open Reading Frame
PCR, polymerase Chain Reaction
QNSC, Quang Ngai Sugar Company, Vietnam
QTA, quantitative trait allele
QTL, quantitative trait locus
RFLP, restriction fragment length polymorphism
RT-PCR, reverse transcription - polymerase chain reaction
SAFER, Société d'aménagement foncier et d'établissement rural, France
SARIS, Société agricole et de raffinage industriel du sucre, Congo
SASA, South African Sugar Association, South Africa
SASEX, South African Experiment Station, South Africa
SASTA, South African Sugar Technologist's Association, South Africa
SFP, Société française de phytopathologie, France
SNP, single nucleotide polymorphism
SN-SOSUCO, Société sucrière de la Comoé, Burkina Faso
SOMDIAA, Société d'organisation, de management et de développement
des industries agricoles et alimentaires, France
SONASUT, Société nationale sucrière du Tchad, Chad
SOSUCAM, Société sucrière du Cameroun, Cameroon
SPV, Service de la protection des végétaux, France
SUCAF-CI, Sucrerie africaine de Côte d'Ivoire, Côte d'Ivoire
SUKALA SA, Complexe sucrier du Kala supérieur, Mali
USCTA, Uganda Sugarcane Technologists Association, Uganda
USDA-ARS-SAA, United States Department of Agriculture – Agriculture Research Service –
South Atlantic Area, Florida
WICSCBS, West Indies Central Sugar Cane Breeding Station, Barbados
WISBEN, West Indies Sugarcane Breeding and Evaluation Network, Barbados

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Centre
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**Annual Crops
Department
CIRAD-CA**

**Sugarcane
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