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Some of the papers presented at the September 1993 Symposium on Tropical Orchards, within the framework of "Journées CIRAD-FLHOR", are published in this special issue.
To address a wide readership, the articles are published in English and French, with key words in English, French and Spanish.
The English versions of the articles (text, illustrations, tables and bibliographical references) are published in full in the first half of the volume, while mentioning the paging of the French versions that are presented in the last half (colour pages).
Note that all papers presented at the Symposium on Tropical Orchards could not be covered in this limited 1994 special issue of FRUITS. However, on the last page there is a list of other complementary papers from the Symposium that have already been published (or are soon to be published). The reader will thus have access to all of the information conveyed at this special meeting on tropical orchards.
We hope that readers will find all information they are seeking in this document.

THE EDITORS

Ce numéro spécial « vergers tropicaux » permet de publier une partie des exposés qui ont été présentés à l'occasion des journées CIRAD-FLHOR de septembre 1993.
Pour que leur contenu soit accessible à tous nos lecteurs, les articles sont publiés en deux langues (anglais et français), et les mots clés sont trilingues (anglais, français et espagnol).
Les versions anglaises des documents (texte, illustrations, tableaux, bibliographie) sont publiées dans leur intégralité en début de volume, leur traduction en français (textes seuls) est reportée dans la deuxième partie de l'ouvrage (pages de couleur).
Cependant, du fait du grand nombre, et du volume, des communications qui avaient été présentées à l'occasion de ces journées CIRAD-FLHOR « vergers tropicaux », toutes n'ont pu être incluses dans ce numéro spécial 1994 de la revue *Fruits*. Afin que le lecteur puisse avoir, malgré tout, une connaissance exhaustive du contenu global de la manifestation, une liste des publications (déjà parues ou à paraître), complémentaires de ce numéro spécial, est présentée à la dernière page.
Nous espérons que chacun pourra trouver, à la lecture de ce document, l'information qu'il recherche.

LA RÉDACTION

FRUITS

Productions fruitières et horticoles des régions tropicales et méditerranéennes

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vol. 49, n°5-6, septembre-octobre-novembre-décembre 1994

editorial

tropical orchards: the exotic implications

Hot region orchards customarily evoke exoticism, rare and festive pleasurable commodities. According to this image, the orchards are often pictured as flourishing in special enclosures where growers bring together a few bountiful plant species producing a wide range of nutritional and appealing fruits that strike the imagination.

This hedonistic "18th century Rousseauistic" viewpoint is no longer relevant, despite the fact that tropical fruit consumption is booming (partly based on the traditional image), and presently higher than that of temperate fruits and even other prestigious produce. Tropical fruit consumption is not always clearly linked with daily energy needs, since the fruit is often eaten between meals, but some species are now widely consumed on a regular basis, e.g. oranges, mandarins and dates. Beyond their novel attraction, other tropical fruits (grapefruits, avocados, lemons, papayas, etc.) meet a need for dietetic and health foods. Some other fruits, e.g. litchis, mangos, mangosteens and rambutans, still have an emotional and symbolic impact, thus explaining their market success.

The wide spectrum of vitamins and flavours offered by tropical orchards is a prime attraction for modern adventurous societies seeking original products.

tropical fruit production controlled by market economy laws

Tropical and exotic fruit production is affected by mass consumption patterns, irrespective of the nutrient status. Producers therefore have to come up with pertinent responses to this situation: regular supplies and quality control, careful packaging and competitive pricing. CIRAD-FLHOR scientists are involved, through their research, in promoting tropical fruit products. Consumers often underestimate how much effort is required to reinforce and stabilize this production sector:
– surveying market trends to forecast market demand,
– perfecting horticultural techniques,
– rational management of genetic resources,
– efficient, low-input disease and pest protection.

This special issue of FRUITS includes some of the papers presented at the symposium on Tropical Orchards held from 30 August to 5 September 1993 in Montpellier (France). A wide range of technical and scientific information that could interest both research scientists and people involved in the tropical fruit industry is reviewed. This information is

presented as short updates (new cropping strategies, propagation techniques), and as clear and detailed summaries (germplasm management, hybridization and selection projects, genetic analyses, identification and control of new parasites and pests).

As an introduction, main trends and consumer requirements are considered from an economic perspective.

There was too much information presented at the Symposium on Tropical Orchards to be covered in a single special issue, even in a double issue. Some of the symposium papers were thus published in FRUITS vol. 49 (1994), and others are to be included in the next issue (vol. 50, 1995).

We would like to express our gratitude to all people who helped with this special issue, which was aimed at promoting the development of a sector that is involved in many rural tropical areas.

BERNARD AUBERT
Head of the Citrus and Orchard Fruit Programme

éditorial

le verger tropical : un terme hautement évocateur

Le verger des régions chaudes a traditionnellement évoqué l'exotisme, les produits rares, pour tout dire les aliments de fête et de plaisir. On l'a souvent imaginé sous forme d'enclos où l'homme aurait rassemblé quelques espèces végétales généreuses lui offrant une gamme de fruits utiles à sa santé, propres aussi à le réjouir et à le faire rêver.

Cette vision « dix-huitième siècle », hédoniste et « rousseauiste », n'est plus guère de mise, même si l'accroissement de la consommation de fruits tropicaux, du fait même d'une certaine réminiscence de cette image, reste aujourd'hui supérieur à celui des fruits tempérés, voire à celui d'autres denrées de prestige. Sans nécessairement présenter de liens directs avec le besoin énergétique journalier puisqu'ils sont souvent pris en dehors des repas, certains de ces fruits sont néanmoins définitivement entrés dans nos habitudes de consommation : oranges, mandarines, dattes, etc. D'autres, outre l'attrait de la nouveauté, ressortissent également à un souci de diététique et d'hygiène alimentaire : pamplemousses, avocats, citrons, papayes, etc. Pour certains enfin : le litchi, la mangue, le mangoustan ou le ramboutan, la charge émotionnelle et la symbolique prédominent dans l'acte d'achat.

La large palette de vitamines et d'arômes que le verger tropical est susceptible d'offrir, constitue, il est vrai, un atout majeur pour nos sociétés toujours plus avides de nouveautés et d'évasion.

des productions confrontées aux lois de l'économie de marché

Quel que soit leur rang dans la gamme des nutriments, les productions fruitières tropicales ou exotiques n'échappent pas aux problèmes soulevés par la consommation de masse, et vis-à-vis desquels le producteur doit trouver des réponses pertinentes : régularité des approvisionnements, surveillance constante de la qualité, soins apportés au conditionnement, prix compétitifs. Les chercheurs du CIRAD-FLHOR contribuent, grâce à leurs travaux, à promouvoir ces produits fruitiers des tropiques. Le consommateur sous estime d'ailleurs souvent la somme d'efforts à déployer pour conforter et stabiliser cette filière :

– suivi de la tendance des marchés pour anticiper l'évolution de la demande,

– perfectionnement des techniques horticoles,

– gestion rationnelle des ressources génétiques,

– protection phytosanitaire efficace et économe en intrants.

Ce numéro spécial de la revue FRUITS, regroupe une partie des communications du colloque Vergers Tropicaux tenu à Montpellier du 30 août au 5 septembre 1993. Il passe en revue un ensemble d'informations techniques et scientifiques susceptibles d'intéresser à la fois le monde des professionnels et celui des chercheurs. Certaines de ces informations constituent de courtes notes de mise au point (nouvelles approches culturales, techniques de propagation), d'autres se présentent sous forme de synthèses claires mais suffisamment détaillées (gestion du germplasme, travaux d'hybridation et de sélection, études génétiques, identification et maîtrise de nouveaux parasites et ravageurs).

En introduction des considérations d'ordre économique font état des principales tendances, voire exigences posées par le consommateur.

Le volume des informations collectées lors de ce colloque « Vergers tropicaux » dépasse malheureusement le cadre d'un simple numéro spécial, fut-il double. En conséquence, certaines des communications qui y ont été présentées ont déjà été publiées dans le volume 49 (1994) ou le seront prochainement dans le volume 50 (1995).

Nous tenons à remercier toutes les personnes qui ont bien voulu participer à la réalisation de ce numéro spécial et contribuer ainsi à promouvoir le développement d'une filière où se trouvent impliquées de nombreuses zones rurales des tropiques.

BERNARD AUBERT
Responsable du Programme agrumes et arboriculture fruitière

I. Economy

The European Mango Market: a Promising Tropical Fruit. — D. Loeillet — 332-334

[mangoes, markets, European communities, tropical fruits, exports, imports]
[mangue, communautés européennes, fruit tropical, exportation, importation]
[mango, mercados, comunidades europeas, frutas tropicales, exportaciones, importaciones]

Tropical Fruit Trees in the Non-French Caribbean. Crops, Exports, Trends. — G. Barbeau — 335-339

[*Blighia sapida, Citrus, Anacardium occidentale, Artocarpus altilis, Persea americana, Averrhoa carambola, Malpighia glabra, Annona muricata, Psidium guajava, Mangifera indica, Spondias dulcis, Manilkara zapota, Calocarpum sapota* ...]
[... fruit trees, diversification, production, trade, Caribbean]
[... arbre fruitier, diversification, production, commerce, Caraïbes]
[... árboles frutales, diversificación, producción, comercio, Caribe]

New Challenges for the Mandarin/Mandarin-Hybrid Industry in the Mediterranean Basin. — B. Aubert — 340-343

[Citrus fruits, fruit growing, mandarins, development strategy, Southeast Asia, Mediterranean countries]
[Agrume, culture fruitière, mandarine, stratégie de développement, Asie du Sud-Est, pays méditerranéens]
[Frutas cítricas, fruticultura, mandarina, estrategia del desarrollo, Asia sudoriental, países mediterráneos]

Refrigerated Fruit Juices. New Outlets for World Fruit Crops. — D. Loeillet — 344-347

[Fruit juices, soft drinks, markets, trade, pasteurizing, quality, packaging, storage]
[Jus de fruit, boisson non alcoolisée, marché, commerce, pasteurisation, qualité, conditionnement, stockage]
[Jugo de frutas, gaseosas, mercados, comercio, pasteurización, calidad, empaquetado, almacenamiento]

The European Mango Market: a Promising Tropical Fruit

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France

Fruits, vol. 49, n°5-6
p. 332-334 (English)
p. 434-435 (French)

The market appeal and consumption of mango, the 5th-ranking fruit produced in the world, are sharply increasing in developed countries, especially in Europe. There are many producing countries, but imports are higher from the Americas than from Africa.

Mango is one of the most important fruits marketed in the world, its appeal and consumption are booming in developed countries, especially in Europe. Improving the relation between supply and demand, with respect to consumption periods and varieties, should enhance market development and, in turn, improve taste quality of export mangos.

Asia, the main production region

Mangos, the 5th-ranking fruit crop worldwide, are produced extensively in about 70 countries. According to the latest FAO figures, the yearly growth rate for mango production is slightly less than 2%.

Most mangos are grown in developing countries, with India as the undisputed leader (10 Mt — 60% of the world output); then far behind come Mexico (854 000 t), Pakistan (780 000 t) and Thailand (614 000 t).

Asia predominates in the geographical distribution of mango production, with 80% of the world output, followed by the Americas and Africa at much lower rates of 13% and 7% respectively.

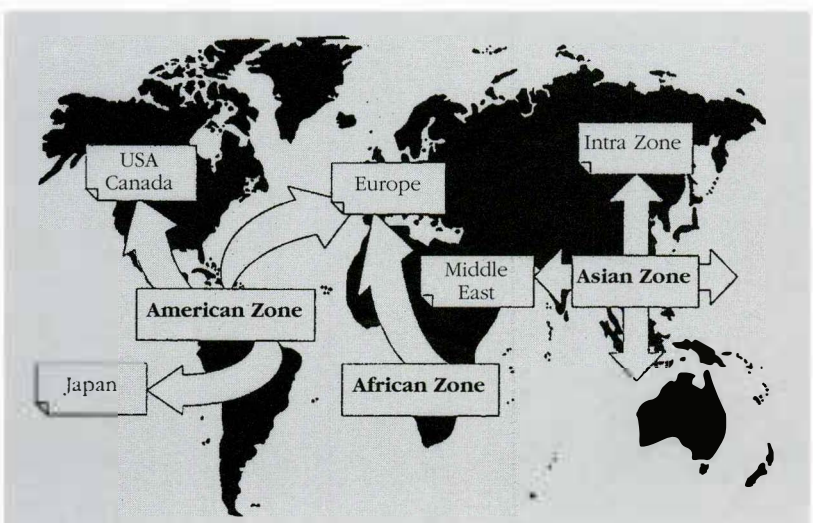

Figure 1
Main trade flow directions for mangos
Source: ODM CIRAD-FLHOR.

Central and South America, two important export regions

The global trade volume for these regions is estimated at more than 250 000 t.

Mexico, with nearly 100 000 t, is the world leader for mango exports. The US market, its major outlet, absorbs 90% of these exports.

Internationally, as shown in Figure 1, three trade flow directions have developed over the years:
– South and Central American countries supply the North American market, Europe and Japan;
– Asia preferentially exports to countries within its own region and to the Middle East;
– Africa markets most of its fruit on the European market.

the United States and Europe, the main importers

USA, with over 76 000 t of imports, is by far the top world import market (Appendix 1). Despite a slight slump in 1992, there has been a 30% average yearly mango import growth rate in USA since 1988.

Although the respective import rates for Canada and Japan (Appendix 1) are only, at best, a quarter that of the EU, these two markets have been increasing steadily over the past few years.

The EU, 2nd-ranking world importer of mangos, imported 46 000 t in 1992. The development of the EU import market since 1975 is illustrated in Figure 2.

Three countries consume more than 75% of the mangos imported in Europe: UK, Germany and France (Fig. 3).

The UK is by far the top European consumer, because of the oriental ethnic communities settled there and its privileged relationships with countries such as Pakistan and India. The UK is also one of the main driving forces behind the mango market.

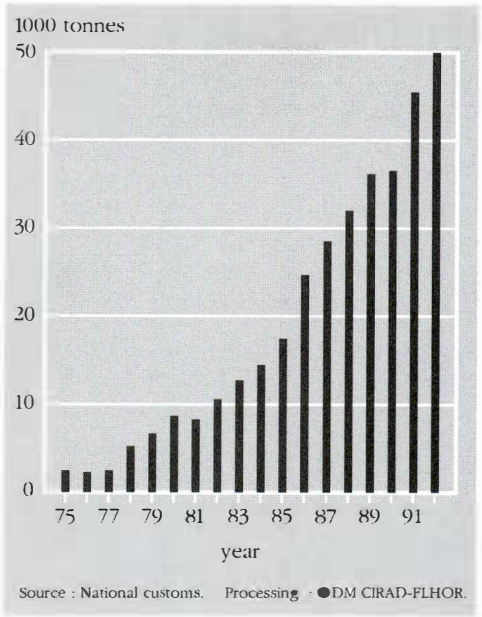

Figure 2
The EU mango import market since 1975.

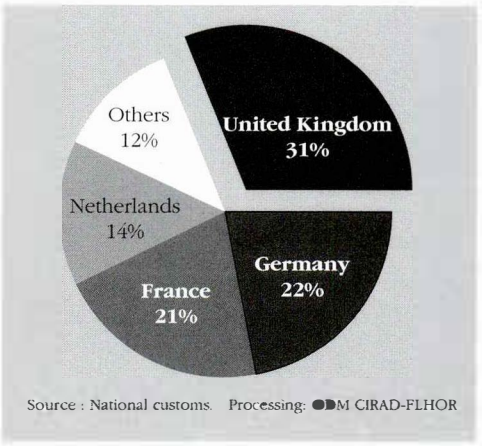

Figure 3
Main European mango importers in 1992.

mango producing countries and their market ranking

The EU, second for market volume after USA, is the most diversified market.

Most of the 90 classified mango producing countries (63 in 1992) supply less than 100 t of fruit for the European market. Brazil, Puerto Rico and South Africa are the only high volume exporters on this market.

Of the 26 main mango sources that supply the market (98% of yearly imports), 14 are from the Americas or the Caribbean, 8 are African and 4 Asian.

Market shares for mangos sourcing from ACP (Africa/Caribbean/Pacific) countries, bound to the EU by preferential trade agreements (Lomé IV), dropped by 11 points between 1985 and 1992 (Fig. 4). There was a short-lived reflation in 1991 for ACP countries, followed by a further decline in 1992 even though the mango market was developing rapidly.

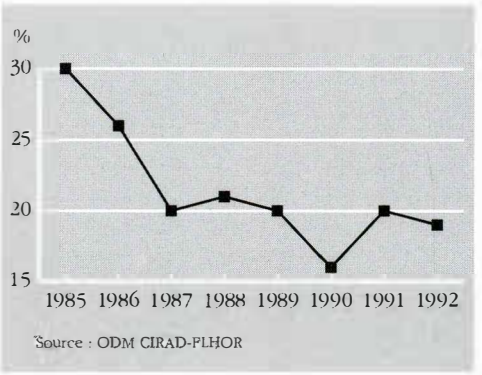

Figure 4
ACP market shares in the EU since 1985.

There are six essential reasons why ACP countries have chronic problems in marketing their mangos on the EU market (generally their only solvent market):

– high competition between ACP countries at the time (spring) when European consumption is oriented towards seasonal local fruit;

– difficulties in controlling sea transport;

– landlocked situation of some countries;

– predominance of one variety (cv Amélie) which is not yet fully appreciated by consumers because of its green coulour;

– high competition with Caribbean, Central American and South American mango producers;

– great difficulty in breaking into British and German markets; the French market represents almost half of all ACP outlets.

supervised development

The world mango market has been developing steadily over the past 10 years. The EU market is the most diversified, with respect to countries of origin and varieties offered to the consumer. New markets such as Spain and Italy still have a high consumption potential. Some Asian and American producing countries are now highly competitive with ACP producing countries, as African mango exports decline.

African producers will have to adopt three development strategies in order stall further market decline: establish quality-based policies (transport, packaging), extend their supply of mangos to the European market over a longer period, and intensify their promotional campaign for mango products.

Appendix 1
Source : National customs.
** first four months*

A) USA mango imports between 1988 and 1993 (tonnes)

Year	Total	Mexico	Growth rate
1988	34 646	27 269	+ 34
1989	52 273	43 923	+ 16
1990	59 007	50 922	+ 56
1991	92 122	76 402	– 17
1992	76 165	68 254	
1993 *	20 245	17 243	

B) Canadian mango imports since 1991

Tonnes	1991	1992
Total	**13 796**	**12 782**
Mexico	8 418	8 048
USA	2 333	2 555
Brazil	425	368
Venezuela	510	327
Costa Rica	8	238
Peru	231	231
Philippines	156	187
Dominican Republic	60	112
Taiwan	117	95
Thailand	67	86

C) Japanese mango imports between 1989 and 1992

Tonnes	1989	1990	1991	1992
Total	**6 013**	**5 445**	**6 925**	**8 005**
Philippines	4 664	4 212	5 768	7 177
Mexico	1 206	1 158	1 036	734
China	32	26	35	38
Thailand	78	23	20	18
Taiwan	21	6	50	14

Tropical Fruit Trees in the Non-French Caribbean. Crops, Exports, Trends

G. Barbeau
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Fruits, vol. 49, n°5-6
p. 335-339 (English)
p. 436-439 (French)

Some of the many fruit trees cultivated in the non-French Caribbean show a promising market potential.

The non-French Caribbean comprises many different countries marked by a wide range of histories, sizes, peoples and languages. The agricultural export crops that have long prevailed are increasingly affected by serious international competition. These countries are thus attempting to set up agricultural diversification programmes with tropical fruit production as a key component. This study examines development projects for ligneous fruit trees, marketing outlets for fresh and processed products and medium-term production prospects.

ackee
(Blighia sapida)

This fruit of African origin is widely grown in Jamaica, where it is served with salt fish. Almost every garden has an ackee tree. This apparently very hardy species bears red fruit, which open when ripened and expose shiny black seeds. The fruit must be eaten at a very specific time, otherwise it could be toxic. Ackee fruit is canned by several manufacturers, mainly for the local market, but small quantities are exported to other Caribbean countries.

citrus fruits
(Citrus sp.)

The citrus fruit industry has flourished for much of the 20th century in several Caribbean countries, particularly Jamaica, Trinidad and Dominica. Limes, especially West Indian lime, were initially cultivated by essential oil exporting industries, but began declining before World War II because of pest and disease problems After the war, some countries (e.g. Belize, Dominica and Trinidad) switched to cropping oranges and grapefruit, but elsewhere the industry is still steadily declining.

At the outset of the 1970s, Cuba launched a major citrus planting programme; it continues to be the focus of major attention, and 148 000 ha is presently cropped with citrus fruits in the country.

Production also started decreasing in Trinidad during the 1970s because of the oil boom, but it resumed in the mid-1980s. A private firm recently planted 1 300 ha with citrus fruits and planned to plant a further 200 ha in 1994.

Other Caribbean countries such as Belize, Jamaica and the Dominican Republic recently tried to develop their citrus industry. A 1 200 ha planting program was just started in western Jamaica.

Cuba, the largest exporter of fresh citrus fruits in the Caribbean region, exported 400 to 500 000 t/annum before 1990, mainly to socialist countries, and is supposed to have exported 600 000 t in 1991.

Jamaica exports fresh fruit to the EU (8 300 t in 1990, 7 400 t in 1991), including the famous cultivars Ortanique and Ugli. The Dominican Republic and Dominica export small quantities to

Guadeloupe and Martinique. Belize, Jamaica and Trinidad have their own processing industries to serve domestic and export markets, but Trinidad still imports concentrates from Belize (more than $3 million US in 1991).

The Caribbean citrus-growing industry has begun expanding again. However, there is a serious threat of a tristeza outbreak, a disease that spreads rapidly in this region. Most crops are grafted on sour orange trees and could thus be destroyed. Several countries (Cuba, Jamaica, Dominican Republic and Trinidad) have taken control measures.

cashew

(Anacardium occidentale L.)

Cashew trees are found throughout the Caribbean, mainly in areas with a marked dry season. Cashew is not cultivated, apart from a few exceptional cases (60 ha in Trinidad). The fruit and false fruit are consumed locally. A cashew development project was set up with Brazilian assistance in southern Saint Lucia. Jamaica is interested in cropping this fruit to develop its southern inland savannas; Guyana could crop cashew in areas inhabited by native Indians. The region generally imports commercial cashews. Cashew cropping, which is possible in areas with low precipitation, could give rise to a small-scale rural agricultural industry, thus reducing imports and stalling rural outmigration.

breadfruit

(Artocarpus altilis Fosb.)

This species is as common as coconuts and mangos in the Caribbean region. There are many different ways of consuming the fruit of the seedless variety. Although there are no commercial plantations (with intercropping), some countries export their surplus production. Saint Lucia exports an average of 900 t/annum, and Dominica, Grenada and Trinidad only export a few dozen tonnes, mainly to ethnic markets in Great Britain and Canada. Research is under way at the West Indies University and the Caribbean Agricultural Research and Development Institute (CARDI) in Port of Spain to improve transportation conditions and fruit shelf-life; the results could help to increase exports.

With respect to *A. altbilis* var. *seminifera*, the seeded form, only the seeds are consumed, either grilled or boiled. A few tonnes are exported to the usual breadfruit markets.

avocado

(Persea americana L.)

The Dominican Republic is by far the top Caribbean avocado producer, with an estimated 4 000 ha cropped with this fruit, and the equivalent of 12 000 ha in scattered trees, producing a total of 130 000 t/annum of avocados (FAO). This country recently started exporting to USA and EU, mainly cvs Semil 34, Choquette and Hall. The fact that these cultivars produce large-sized fruit does not seem to be problematic.

Cuba is the only other Caribbean country cropping avocado. There is an estimated 1 800 ha of avocado plantations in Cuba, but so far the entire crop is absorbed by the domestic market.

Fifteen years ago, Dominica tried cultivating avocados for export, but the results were disappointing. At present, there is an estimated 168 ha cropped with avocado.

Other countries intercrop avocados for domestic consumption. Grenada and Saint Vincent export substantial, but now decreasing, quantities to Trinidad.

carambola

(Averrhoa carambola L.)

This fruit is still quite unknown outside Guyana and Surinam, which have large numbers of scattered trees and a few homogeneous orchards. There are 120 ha of orchards and the equivalent of 2 450 ha of scattered trees in Guyana, and about 10 ha of orchards and an undetermined number of scattered trees in

Surinam. Most of the crop is lost because of the long transportation distances, despite the efforts of some small firms to develop this potentially profitable crop. A small percentage of processed carambola is exported to the Caribbean region.

A carambola fly [*Bactrocera* sp. (e.g. *Dacus dorsalis*)] has recently showed up in Surinam from Southeast Asia, and now threatens Guyana where a survey system has been set up to monitor the situation. In Surinam, an FAO coordinated program aims at eradicating this insect.

West Indian cherry
(Malpighia glabra L.)

The West Indian cherry tree, or Barbados cherry tree, looks like a bushy shrub. Red, slightly-ribbed, cherry-sized fruit are produced over a large part of the year, as long as there is sufficient rainfall. The fruit is rich in vitamin C and highly appreciated on certain markets, particularly in Japan. A few years ago, when labour costs got too high in Barbados, the Japanese tried unsuccessfully to find other partners in the Caribbean region, but finally turned to Vietnam.

In the Caribbean, the other countries producing this cherry are Puerto Rico, Guyana and Surinam. The planted surface area is still limited but rapidly increasing. Trees derived from plantlets obtained by vegetative propagation are productive in the first year and give satisfactory yields. Juice is made on the spot with the highly perishable fruit, it is sold on the domestic market. Surinam has started exporting small quantities to Barbados, which no longer produces enough to meet its own consumption needs. According to experts from the International Trade Center (ITC, UNCTAD/GATT Geneva), the West Indian cherry has a very promising international market potential.

soursop
(Annona muricata L.)

Soursop is cultivated on a small scale in market-oriented orchards only in Guyana and Surinam, where it is grown to be processed for domestic markets. Firms intend to expand production of this crop and export the fruit pulp.

The only countries exporting soursop are the Grenada islands and Saint Vincent, and the entire crop grows on scattered trees. These two islands have a noteworthy advantage, they have not been affected by fruit flies, Annonaceae weevils or other fruit pests. Trinidad is the main customer (around 600 t/year), for the fresh fruit market and making pulp, which is exported in small quantities to Great Britain and Holland.

A closely-related species, the custard apple *(A. squamosa* L.), is also grown in Grenada and Saint Vincent and exported to Trinidad, for the fresh fruit market only. Prospects for the expansion of this fruit are not very promising since it is highly perishable.

guava
(Psidium guajava L.)

Guava is found in all Caribbean countries. Cuba probably has the largest surface area cropped with guava, but the entire crop of this highly-esteemed fruit is absorbed by the domestic market.

In the other Caribbean countries, the produce is mainly derived from small orchards and scattered trees, and the fruit is often infested with many types of fruit flies (*Anastrepha* sp.). Cuba seems to be the only potentially serious candidate for developing guava as an export crop — they have bred extremely productive dwarf varieties.

mango
(Mangifera indica L.)

In English-speaking Caribbean countries, cv Julie is the main mango variety. A few other varieties such as cvs Graham, Bombay, Ceylon and Peach are also marketed.

Most of the mango trees are scattered in fields, not planted in orchards. Despite this, there are so many mangos produced that several countries export them — it

is the most plentiful fruit crop along with breadfruit. Saint Lucia exports 400-600 t/annum, Dominica around 100 t/annum, Grenada and Trinidad a few dozen tonnes.

Jamaica has been using Florida varieties since the mid-1980s, and has thus been able to regularly increase exports to the EU (more than 1 200 t in 1991); the Dominican Republic is following this trend. These two countries continue to plant mangos on large surface areas. Most Caribbean countries have to target the European market because of the phytosanitary restrictions applied to exports towards USA, as set out in the North American Free Trade Agreement (NAFTA).

ambarella

(Spondias cytherea Sonner)

Within a 3-year period, Grenada increased ambarella exports from a few tonnes (1989) to about 500 t (1991) and thus emerged as an exporter of this fruit on the international market. The produce is essentially aimed at New York markets, and London and Amsterdam markets to a lesser extent. The conventional Trinidad market also accounts for about 200 t. 90% of the fruit is exported green, to be canned and processed in traditional Caribbean preparations. The produce comes from scattered, intercropped trees. The Grenada Ministry of Agriculture is taking an active interest in this product and, following the setbacks experienced in 1992 due to problems of competition between exporters, is trying to improve quality and reduce grading differences. The neighbouring island of Saint Vincent also traditionally exports ambarellas to Trinidad and, following Grenada's example, is now targeting the international market.

The fruit of a closely-related species, myrobalan (*S. mombin* L.), called "mopé" in Surinam, is processed by small firms and widely consumed as delicious fresh juice in this country and Guyana. The species is not cultivated, it grows in natural forest stands.

sapodilla

(Manilkara sapota Van Royen)

sapodilla plum

(Calocarpum sapota Merr.)

Sapodilla is found everywhere but is not cultivated commercially. Trinidad imports a few dozen tonnes from Grenada and Saint Vincent. Everywhere else this delicious fruit is seriously infested by fruit flies and does not seem to have any promising prospects for future development.

Conversely, sapodilla plum is plentiful in Cuba and the Dominican Republic, where it is in high demand on the domestic market. However, substantial breeding research still has to be done on the many local types before this fruit is ready for export.

conclusion

Concerning perennial fruit trees, citrus, mango and avocado trees predominate in terms of planted surface area (Table 1), and they are the most commonly exported species.

Production and export of fresh citrus fruit and processed products should continue increasing in Cuba, Belize, Jamaica, Dominican Republic and Trinidad. However, a potential outbreak of tristeza is a major threat to this activity.

Two countries are expanding their mango production, Jamaica and Dominican Republic, with the European market as their main target.

Avocado cropping is only important in the Dominican Republic.

Otherwise, the good export performance of breadfruit and the progressive elimination of technical constraints are noteworthy.

There is considerable development potential for three fruits, so far considered as being minor products, i.e. soursop, West Indian cherry and ambarella. Research on the first two has been undertaken by private companies in Guyana and Surinam. Ambarella is currently very popular in Grenada and St Vincent.

Table 1
Areas cropped with perennial tropical fruit trees in the non-French speaking Caribbean (ha).

	Antigua	Barbados	Belize	Cuba	Dominica	Grenada	Guyana	Jamaica	Dominican Rep.	St Kitts	St Lucia	St Vincent	Surinam	Trinidad Tobago
Ackee														
B								***						
Citrus														
A	8	12	23600	144000	2020		1620	8100	7000			32	2425	6000
B		*				60	*	*	15000	10	680	*	*	*
Cashew														
A	2									1				60s
B				*			*	*	*		*			*
Breadfruit														
A		1												
B		29				*		*			820			*
Avocado														
A	2	3		1800	168		57		4000			7	18	2
B		*		*		*	*	*	12000	2	162	15		*
Carambola														
A							120						*	5
B							2450						***	
Cherry														
A		32					36						53	
B		38												
Soursop														
A							*					*	22	
B						*					*			
Guava														
A	2	22		2000			113			1				20
B		26						*					11	*
Mango														
A	12	47	585	18000	124	10		526	300			18		25
B	*	133		*	*	60	*	*	30000	20	545	22	250	*
Ambarella														
B		21				20					*	*		
Rambutan														
A														3
B							*						*	
Sapotaceae														
B				***					***					*

A: orchards
B: scattered trees

* casual trees
*** more common

sources

COLEACP Database - Yearly Reports.

FAO. Production and Trade Yearbooks.

Proceedings of the Caribbean workshop on traditional and potential fruit tree crop development. IICA - Ministry of Agriculture of Grenada. Grenada, November 9-14, 1980. Published by IICA San José, Costa Rica, 1981.

Proceedings of the Interamerican Society for Tropical Horticulture, Vol 33, 1989. International Carambola Workshop, Guyana, September 4-6, 1989.

Proceedings of the First Regional Workshop on Tropical Fruit Crops, Dominica, IICA, CARDI, UWI, February 1991.

Proceedings of the Second Regional Workshop on Tropical Fruit Crops, Antigua, IICA, CARDI, UWI, December 1991.

Proceedings of the Regional Workshop on Fruit Diversification, Guadeloupe, IICA/CIRAD, April 26-28, 1993. Port of Spain, Trinidad and Tobago, IICA/CIRAD, 139 p.

New Challenges for the Mandarin/Mandarin-Hybrid Industry in the Mediterranean Basin

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Fruits, vol. 49, n°5-6
p. 340-343 (English)
p. 440-442 (French)

Citrus output in the Mediterranean Basin (17 Mt) is much lower than in North and South America (30 Mt), although consumer markets in these regions are of similar size. It is predicted that by the year 2020 the population of the southern rim of the Basin will have expanded by 78%, with a probable marked increase in the domestic market demand for citrus fruits in these countries. European consumers are increasingly attracted by new seedless easy-peeling citrus fruits. The Mediterranean citrus industry will thus have to be substantially restructured to address the new challenges.

specific trends in Mediterranean and European citrus markets compared to those in North and South American markets

World citrus production has increased considerably over the past 20 years. Total output is currently some 75 Mt, with oranges ranking first, followed by mandarins, lemons and grapefruits (Table 1).

Historically, the initial citrus-producing areas were Asia and the Mediterranean Basin, where various types were first domesticated. Citrus growing has long been a traditional occupation in the Mediterranean area; Pliny the Elder, for instance, described citron cropping at the beginning of the present era. It is thus an important centre of secondary genetic diversification, and several different local types are known to originate exclusively from this region, e.g. blood oranges, willow-leaf mandarin (*Citrus deliciosa*), clementines, etc.

This diversity could be explained by the local horticulturists' practice of selecting natural mutations. Mediterranean consumers thus gradually came to appreciate fresh citrus fruit as a delicacy, and then as a common and easy-to-eat product.

Nowadays, the wider Mediterranean area includes 20 countries with overall citrus output of 17 Mt in 1992/1993 (Table 2), with:
– 58% marketed as fresh fruits on domestic markets in the producing countries (400 M consumers); citrus is the main type of fruit consumed in these countries;
– 29% exported as fresh fruit to markets in Northern Europe (west and east); these non-producing countries represent a market of 330 M consumers (excluding Russia);
– 13% only is destined for juice processing.

Comparatively, 30 Mt of citrus fruits are produced in North and South America,

Table 1
World citrus production for 1992/93 (thousand tonnes, FAO statistics).

Oranges	55 122	73.0%
Mandarins & hybrids	8 257	11.0%
Lemons and limes	6 624	8.8%
Grapefruits	4 981	6.6%
Total	74 984	

mainly oranges, to a lesser extent grapefruits and lemons, and very few mandarins. Of this output:
– 6% is exported as fresh fruit,
– 12% is absorbed by domestic fresh fruit markets,
– 81% is used for juice processing.

This breakdown highlights that New World consumers are as a whole more oriented towards juices than fresh fruits, whereas the trend is reversed for Mediterranean consumers. There are 302 M consumers in the North American market, i.e. USA and Canada, whereas there are 460 M consumers in the Latin American market, spread throughout 35 countries.

With an output of only 17 Mt, the Mediterranean area obviously cannot meet the demand of its 730 M consumers (Mediterranean countries, Europe, excluding Russia). Comparatively, the 30 Mt citrus output in the Americas (almost twice that of the Mediterranean) provides a better supply for their 762 M consumers.

Mediterranean citrus producers have clearly focused most of their efforts on the fresh fruit market, especially oranges and lemons and recently on mandarins and other seedless easy-peelers that are very attractive to European consumers. Mediterranean imports of 1.2 Mt of frozen concentrated orange juice (FCOJ) and 0.15 Mt of grapefruits and lemons from North and South America (chiefly from Brazil and Florida) compensate for the low output of the Mediterranean juice industry. 15 Mt of fresh fruits are required to produce this quantity of frozen concentrated juice.

Mediterranean citrus production over the last 20 years

Mediterranean citrus production for exports and processing is summarized in Tables 3 and 4.

General trends over the past 20 years are presented, comparing the Mediterranean situation with that of other citrus producing areas in the world.

Table 2
Citrus output and population of the Mediterranean area for 1992/93 (FAO statistics).

Country	Citrus (thousand t)	Population (M)
Northern Mediterraean rim	**9 536**	**199**
Albania	14	3
Spain	4 704	38
France	30	58
Greece	1 202	10
Italy	3 440	57
Portugal	138	10
ex Yougoslavia	8	23
Southern Mediterranean rim	**7 795**	**208.8**
Algeria	295	26
Cyprus	345	0.7
Egypt	1 820	60
Gaza	165	0.8
Israel	1 460	5
Jordan	111	4
Lebanon	450	3
Libya	104	5
Malta		0.3
Morocco	1 084	26
Syria	206	13
Tunisia	273	8
Turkey	1 482	57
Total	**17 331**	**407**

• The Mediterranean area now supplies 62% of world fresh citrus fruit exports (oranges, lemons, mandarins, etc.), as compared to 73% 20 years ago. Cuba and China are newcomers to the club of non-Mediterranean citrus exporters, i.e. South Africa, Argentina, Australia and Uruguay.

• Between 1973 and 1993, Mediterranean Basin orange production for fresh fruit exports decreased by 12%, while that of mandarins and easy-peeler hybrids increased by 112%.

• World exports of fresh grapefruits increased by 226% during the same period; USA, Cuba, Argentina and South Africa are the top producers in this area. Surprisingly, grapefruit exports from the Mediterranean Basin decreased by 22%, despite the tristeza-free status of most countries in this area.

• Conversely, the Mediterranean Basin has consolidated its leading world position with respect to exports of mandarins and hybrids (95.6% of world exports).

Table 3
World exports of fresh citrus fruits (*) (thousand t).

1992/1993 output	All citrus fruits	Oranges	Mandarins & hybrids	Lemons & limes	Grapefruits
Northern hemisphere	**6 344**	**3 332**	**1 448**	**765**	**799**
USA	1 106	495	20	132	459
Mediterranean region	**4 960**	**2 666**	**1 424**	**630**	**240**
Cuba	233	130	-	3	100
China	45	41	4	-	-
Southern hemisphere	**952**	**683**	**32**	**121**	**116**
Argentina	190	73	-	71	46
Brazil	130	123	7	-	-
Uruguay	101	63	18	20	-
Australia	79	72	-	-	-
South Africa	452	352	-	30	70
World output	**7 296**	**4 015**	**1 480**	**886**	**915**
Comparison with world 1972/73 output	6 290	4 037	749	811	691
Mediterranean region	4 578	3 034	648	585	308

(*) these figures only take official fresh-fruit exporting countries into account.

Table 4
Total utilization of citrus for processing (*) (thousand t).

992/1993 output	All citrus fruits	Oranges	Mandarins & hybrids	Lemons & limes	Grapefruits
Northern hemisphere	**12 564**	**9 385**	**773**	**802**	**1 604**
USA	9 675	8 000	125	300	1 250
Mediterranean region	**2 346**	**1 385**	**338**	**362**	**261**
Cuba	370	-	310	-	60
China	173	-	-	140	33
Southern hemisphere	**13 014**	**12 354**	**26**	**456**	**178**
Argentina	750	220	20	417	93
Brazil	11 610	11 588	-	-	22
Uruguay	45	45	-	-	-
Australia	366	326	6	16	18
South Africa	243	175	-	23	45
World output	**25 578**	**21 739**	**799**	**1 258**	**1 782**
Comparison with world 1972/73 output	14 093	10 602	1 000	789	1 694
Mediterranean region	1 543	1 077	68	229	168

(*) these figures only take official fresh-fruit exporting countries into account.

Out of an overall production of 2.3 Mt of these citrus fruits in 1992/93:
– 1.5 Mt was exported as fresh fruit to European markets,
– 0.34 Mt was processed for juices and segments, an area that was formerly dominated by Asian countries, especially Japan and China. In 1992/93, 44% of mandarins and hybrids destined for processing was produced in the Mediterranean area, as compared to 6.8% in 1972.

Mediterranean and European consumers are generally very attracted to fresh fruit aromas and flavours. This is a critical factor for defining future strategies:
– for the fresh fruit market, the marketing season should be extended by the introduction of late varieties that ripen in April and May;
– mandarins and hybrids contain limonin precursors — this flavonoid can produce a bitter taste in heat-stabilized juices; new technological advances are paving the way to novel potential uses of mandarin and hybrid juices, with new aromas and more colour;
– new dual-purpose varieties (fresh fruit/juices) could soon be available with the development of new hybrids.

Mediterranean constraints and new challenges

Citrus production in the Mediterranean Basin largely relies on traditional cropping techniques. On the southern rim, this activity is still often developed in old orchards, although production systems are now being modernized in Israel, Morocco and Turkey. In contrast, modernization is quite advanced in the five main citrus producing countries of the European Union (Portugal, Spain, France, Italy and Greece).

Nevertheless, 60% of Mediterranean citrus orchards are owned by smallholders, with an average orchard size of 0.5-2 ha; only 10% are citrus estates exceeding 10 ha.

Urbanization and water resource deficits are seriously limiting citrus production through the loss of suitable orchard land. More than 60% of citrus trees in the Mediterranean Basin are grafted on salt-tolerant Sour Orange, which unfortunately is being threatened by the spread of tristeza in the region.

Citrus production in the Mediterranean Basin will have to increase by 5.3 Mt in the coming 10-15 years to meet the expected demand from domestic markets and export markets in eastern Europe. An additional 65 M citrus trees will thus be needed overall. Moreover, about 30 M trees should be replaced with certified disease-free, tristeza-tolerant rootstock.

In all, 100 M trees will have to be provided by certified nurseries. In addition to the new salt- and tristeza-tolerant rootstocks that are needed, new cultivars will have to be developed to supply export markets with high quality fruits.

conclusion

Biotechnological advances should help in meeting these challenges, especially through efficient breeding and extension of elite citrus material.

Programmes to breed new cultivars for rootstocks and scions will be introduced progressively and involve techniques that are more specifically targeted than standard breeding procedures.

New interesting traits such as tolerance to salinity and different viruses, insect resistance and better fruit quality could soon be obtained with higher efficiency.

Quality will also be improved by the development of seedless fruits (triploid) with high juice content, very sweet deeply-coloured pulp and possibly lower limonin content. This new generation of cultivars will provide a basis for restructuring the Mediterranean citrus industry, to address the challenges that will arise with the coming of the third millenium. ●

Refrigerated Fruit Juices. New Outlets for World Fruit Crops

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p. 344-347 (English)
p. 443-444 (French)

The fresh fruit juice sector, as part of the soft drink market, is booming: Europe is still far behind the USA. There are many labels but actually only two main types of juice products: freshly squeezed juices and flash-pasteurized juices.

the soft drink market

The European soft drink market is second worldwide behind the United States. The Japanese, despite their leading position in the world economy, are still modest soft drink consumers, with the average consumption per inhabitant only half that of Europeans.

Of all beverages, the soft drink line has shown the sharpest increase in sales. This market has experienced 5% yearly growth in the United States and Europe over the past 10 years. In contrast, tea and coffee consumption is decreasing in the United States and that of beer is leveling off in Europe (Fig. 1).

Western Europe consumes close to 7 Ml of fruit juices (2/3) and nectars (1/3) (Fig. 2). Imports account for 90% of these products consumed in Europe.

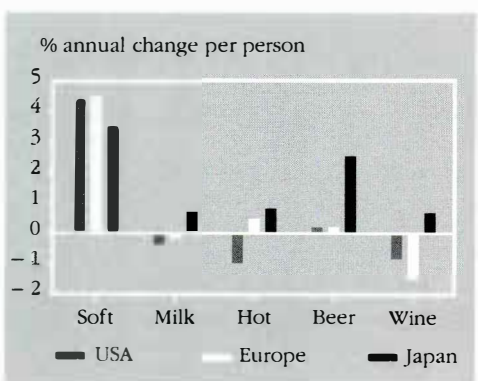

Figure 1
Worldwide drink consumption patterns. 1979-1989.

Germany is the European leader for all types of juices, with consumption exceeding 37 l/inhabitant/year (including former East Germany). Conversely, in Portugal juice consumption is barely 3 l/inhabitant/year. The European average is about 18 l (Fig. 3).

In France, where fruit juice consumption is low (9 l/inhabitant/year), the turnover in this line still exceeds 5 billion francs and the yearly growth rates (over 25% in volume) are promising.

The European fruit juice and nectar market has virtually exploded since the mid-1970s. Sales increased by more than 60% (in value) from 1987 to 1990.

refrigerated fruit juices are booming

In France, with annual sales growth of 125% between 1991 and 1992 and 80% between 1992 and 1993, the refrigerated fruit juice sector is expanding rapidly (Fig. 4).

This small segment of the market, which has been developing in France since 1985, was reactivated through the introduction of flash-pasteurized juices in 1990. Despite the good results over the last few years, this market only accounts for 3-6% of fruit juice and nectar sales

(depending on the data source). The French market is still quite limited as compared to the British and US markets where fruit juice consumption peak at 20% and 50%, respectively, with yearly growth rates varying from 10% to 25%.

a wide variety of labels

A public awareness campaign would be needed to explain the broad range of fruit juice prices with which consumers are faced (4 to 18 F/l). The "refrigerated" and "fresh fruit juice" labels that are widely used on packages and special offers concern two entirely different types of fruit juices: fresh or freshly squeezed juices and flash-pasteurized juices (Fig. 5).

Freshly squeezed juices have a maximum 10-day best-before date (BBD) and has to be stored at 0-4°C. They are produced by squeezing the fruit near the sites of consumption, without adding any preservatives, water or sugar. They are real fresh fruit juices, which some manufacturers even prefer to call "raw" juices.

Flash-pasteurized juices are often made from fruit squeezed at the production site, followed by a heat treatment (called flash-pasteurization), of a few seconds at 70°C, before refrigeration. The BBD can be extended to 24 days with this light heat treatment. Some brands offer juices of this type prepared from frozen and even concentrated juices, which means that any fruit variety from any source can be used, thus reducing production costs.

The full taste quality of the product is preserved in freshly squeezed juices, whereas it is noticeably diminished by the heat treatment in flash-pasteurized juices.

Only freshly squeezed juices can be considered as real ready-prepared fresh fruit products. These juices retain the organoleptic features of the fruit, which are close to those of fruit juices that are squeezed just before consumption.

Further down the fruit juice taste quality scale come pasteurized juices, and then juices prepared from frozen concentrates.

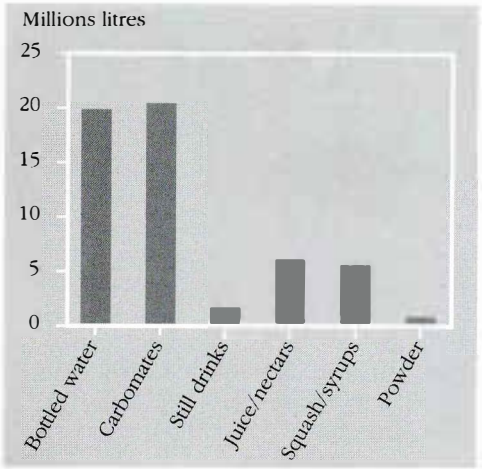

Figure 2
The European soft drink market in 1989.

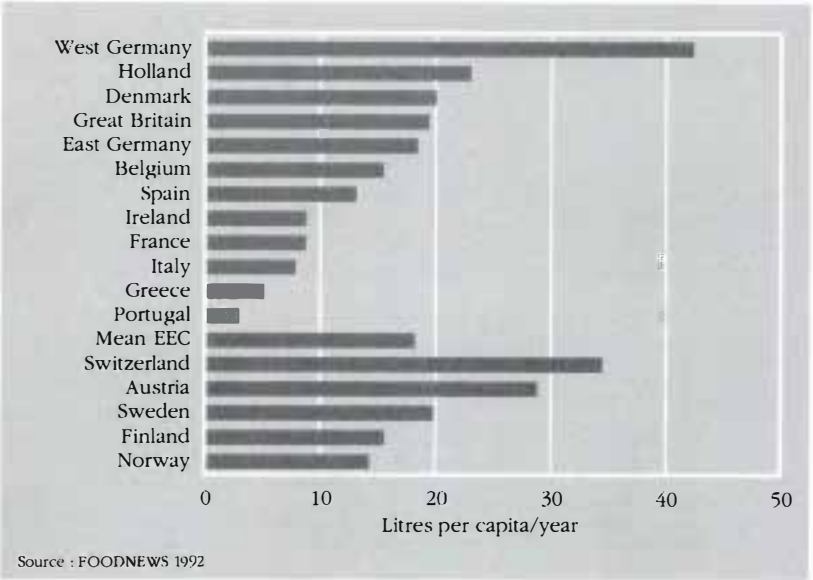

Figure 3
European fruit juice and nectar consumption in 1991.

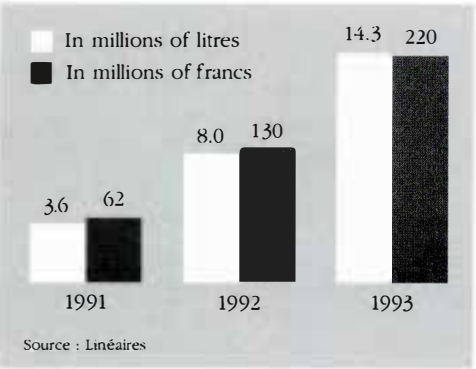

Figure 4
Variations in refrigerated fruit juice sales in large and small French supermarkets from 1991 to 1993.

packaging

Expansion of the fresh fruit juice market is dependent on the development of packagings that guarantee total product protection. Packaging specialists regularly offer different package closing systems and new materials. There are endless innovations, e.g. a complex external packaging system for double cap protection, a perfectly watertight retractable straw, the novel use of glass bottles for flash-pasteurized juices, and a wide range of container sizes.

health and natural products

All surveys confirm that the consumer craze for these new juice types is closely linked with the notions of dietary quality and natural products.

The French Direction Générale de la Concurrence, de la Consommation et de la Répression des Fraudes (DGCCRF) has been surveying the market since 1992 to detect occasional frauds. Hence, in November 1992, the magazine *Que choisir?* published the results of a test of 40 different orange juices, 10 of them were found to have suspiciously high sugar contents.

important constraints

Fruit producers and manufacturers who are obliged to provide their clientele with fresh fruit juices of consistent taste quality year-round are faced with major constraints. It means working throughout the year with a limited number of fruit varieties, and the need for consistency makes supply management extremely difficult.

Some manufacturers overcome this constraint by freezing freshly squeezed juice so that it can be stored for months. Others are conducting joint investigations with producers to develop techniques for lengthening the crop period or maintaining the fresh fruit under cold storage conditions.

In Australia, Valencia orange producers go as far as delaying the crop period by 4 months. However, this extension affects the next crop yields, which can be 30% lower than normal. Obviously production

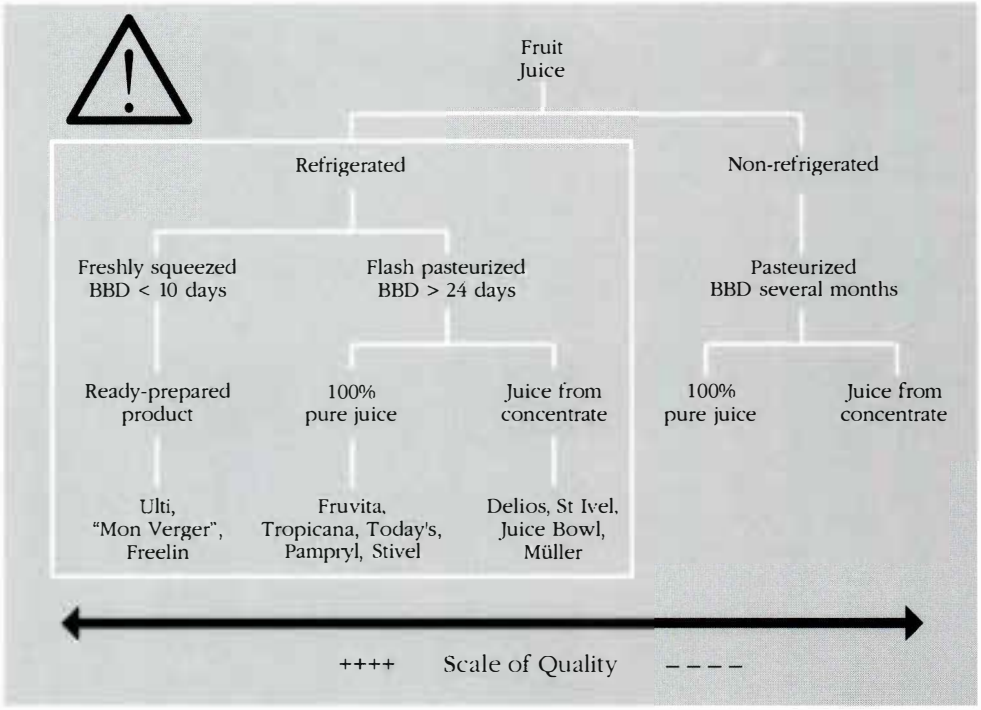

Figure 5
Flowchart for various types of fruit juice.
BBD: best-before date.

costs are markedly affected by such production decreases.

Cold storage of fruit with a suitable fungicide can lengthen a fruit's storage life from 6 to 12 weeks postharvest.

Production costs for refrigerated fruit juices are much higher than that for long-life juices, i.e. from 50% to 100% higher, depending on whether the juice is flash-pasteurized or freshly squeezed.

prime opportunities

Manufacturers were forecasting a 20-40% sales increase for fruit juices in France for 1994. These growth rates are quite high, even though they are 4- to 5-times lower than the rates obtained since 1991. Some distributors predict a leveling-off period which will enable product consolidation.

The wide variety of fruit juice labels, such as "fresh", "freshly squeezed", "pure juice", "multivitamin" and "light pasteurized", has led to marked differences in selling prices and in the locations where these products can be found in stores (ready-prepared fruit and vegetables, dairy products or drinks departments).

Producers with high production costs or low tonnage output can no longer be competitive on the same markets as large international fruit juice producers. They must resolutely turn towards this very quality-oriented fruit juice market.

The outlets handle the refrigerated fruit juice market and the frozen fruit juice market developed by some Israeli and French manufacturers.

Orange and grapefruit juices account for more than 80% of the market, followed by fruit cocktail, grape and apple juices (Fig. 6). Some manufacturers have placed all of their hopes on refrigerated pineapple juice, which has not yet been available.

Innovative producers and food manufacturers still have many options available, which should allow them to overcome the handicaps that restrain this promising sector.

Figure 6
Refrigerated fruit juice. Breakdown of the French market on a flavour basis.

FRuiTROP

Publication de l'Observatoire des marchés du CIRAD-FLHOR

EDITORIAL

J. GANRY

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LA QUALITE : UN ENJEU ECONOMIQUE, UNE PROBLEMATIQUE SCIENTIFIQUE

Tout comme la productivité agricole pour les dernières décennies, la qualité des produits agro-alimentaires constituera un enjeu majeur des années à venir. La saturation des marchés agricoles, couplée à l'évolution des modes de vie et des exigences des consommateurs, donnent une nouvelle dimension à la problématique de la qualité. Mais qu'entend-on exactement par qualité, alors que derrière ce terme se cache une grande diversité de significations ? La qualité est définie comme étant l'aptitude d'un bien ou d'un service à satisfaire les besoins exprimés ou potentiels des utilisateurs. Il s'agit d'une évolution récente qui tend plus à considérer la fonction, le client et l'organisation que le produit seul. L'enjeu est important car on peut estimer que l'économie et la politique agricoles sont entrées maintenant dans une véritable dynamique de qualité, et qu'il s'agit là d'une nouvelle voie de croissance et de réponse à la crise des débouchés et des revenus agricoles. Pour les productions fruitières et horticoles des régions tropicales et méditerranéennes, cette évolution récente prend une dimension toute particulière, en raison des produits eux-mêmes, souvent évocateurs de nouveauté et d'exotisme, et de la nature des marchés considérés, qu'ils soient limités aux consommations locales ou destinés à l'exportation. Les mots d'ordre sont : différenciation, normalisation, certification. Il s'agit maintenant de s'intéresser à la « construction sociale de la qualité » qui doit être « négociée » avec tous les acteurs de la filière. C'est dans un tel état d'esprit que chercheurs et partenaires socio-professionnels ont abordé cette problématique de la qualité, à l'occasion des journées de septembre au CIRAD-FLHOR à Montpellier, pour proposer des voies de recherche permettant de répondre aux enjeux de demain.•

Le chiffre du mois **20** *milliards de lires : dépenses des familles italiennes en 1994 pour l'achat de fruits et légumes*

Version française Septembre 1995 - 17 - page 1

Over the years, CIRAD-FLHOR has steadily increased its information gathering potential through the "Market Observatory". In March 1994, *FruiTrop*, a monthly information trade bulletin on tropical fruits and fresh and processed citrus has been launched so that more people can benefit from our analyses.
FruiTrop provides the various operators in the sector with regular, reliable information on trade movements, European prices, regulations and, in addition, an overview of news on tropical fruits around the world.
Each monthly issue includes a close-up on a particular fruit or country and a technical sheet in each month's issue.
Two editions of *FruiTrop* are published, one in English and one in French. There are 11 issues per year.

Le CIRAD-FLHOR, au travers de son « Observatoire des Marchés », a su acquérir et augmenter au fil des ans un potentiel informationnel en matière d'économie. Pour qu'un plus large public en soit bénéficiaire, un bulletin mensuel d'information sur les flux commerciaux des fruits tropicaux et des agrumes frais et transformés, *FruiTrop*, a été lancé.
Le premier numéro a paru en mars 1994.
FruiTrop propose aux différents interlocuteurs de la filière une information fiable et régulière au niveau des échanges, des prix en Europe, de la réglementation, avec, en outre, un tour d'horizon à l'échelon mondial de l'actualité en matière de fruits tropicaux. Chaque mois, un dossier complet présente un fruit ou un pays particulier. Une fiche technique vient s'ajouter aux autres données du bulletin.
FruiTrop est édité sous la forme de deux fascicules, dont l'un est rédigé en français et l'autre en anglais.
Annuellement, paraissent 11 numéros.

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II. Cropping techniques

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[*Vitis vinifera*, raisin de table, vigne, zone tropicale, variété, floraison, rendement cycle de développement, économie agricole, coût de production, Guadeloupe]
[*Vitis vinifera*, uvas de mesa, vid, zona tropical, variedades, floración, rendimiento, ciclo vital, economía agrícola, costos de producción, Guadalupe]

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Table Grape Growing in Tropical Areas

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Fruits, vol. 49, n°5-6
p. 350-352 (English)
p. 446-447 (French)

Promising results have been obtained in preliminary table grape cropping experiments in Guadeloupe. Variety trials highlighted the interesting qualities of cv Muscat d'Alexandrie.

introduction

Table grapes are being grown to an increasing extent in tropical regions worldwide (Thailand, Brazil, Venezuela, Colombia, etc.). In the West Indies, this crop could be interesting for diversification and reducing grape imports (about 400 t in 1992).

A table grape research programme was set up in July 1990 at the CIRAD-FLHOR research station in Vieux-Habitants, Guadeloupe. A 1-year vine tying operation was first undertaken, followed by an efficient crop protection programme that began in 1993. The preliminary results are very encouraging.

material and methods

Two 0.3 ha experimental vineyard plots were planted in July 1990 on the same site with two different irrigation systems:
– trickle system: 2 tricklers, 4 l/h/plant,
– sprinkler system: 1 sprinkler, 35 l/h /plant.

Two plant training systems were tested at the same planting rate of 1600 plants / ha (2.5 m between plants within the row and between rows):
– espalier training: vines tied vertically (bilateral cordon),
– arbour training: vines tied to arbours (2 m high).

Seven different table grape varieties were studied on various rootstocks and cuttings:
– Cardinal (on R110, S04, 3309c),
– Dattier de Beyrouth (on S04, cuttings),
– Muscat d'Alexandrie (on R110, S04, cuttings),
– Italia (on R110, S04, cuttings),
– Ruby Seedless (on S04, cuttings),
– Centennial (cuttings),
– Thompson Seedless (on S04, cuttings).

results

Experimental plots were divided into three parts to determine the best production periods: the first was pruned in December and June; the second in February and August; and the third in April and October. This test was conducted from December 1991 to August 1992. The bud burst rate after pruning, flowering rate and grape weights and quantities were determined.

Because of pest damage to the crops, trials focusing on pruning dates were based on flowering rates rather than grape yields.

bud burst rates

To determine optimal pruning lengths, spurs (branches with two buds) were considered separately from long branches (4-6 buds). For practical reasons, measurements were only done on espalier-trained vines.

Higher bud burst was obtained on spurs than on long branches, as noted in Table 1.

This indicates that it would be generally best to prune branches to the two-bud length in order to obtain optimal bud burst. Moreover, the best bud burst seemed to occur after a drought period in February-March.

flowering rates

As shown in Table 2, the highest flowering rate was obtained following February pruning. The same rates were obtained on spurs and long branches. Cultivars Muscat d'Alexandrie, Cardinal and Ruby Seedless bore the most flowers. Floriferousness seemed to be best favoured on the R110 rootstock.

In Guadeloupe, the best flowering could thus be obtained with cv Muscat d'Alexandrie, pruned to the two-bud length in February and August. Under these conditions, the vines are leafless during the cyclone season and fruitless during the rainy season.

yields

Despite the fact that a large proportion of the April and June grape crops were destroyed by a pyralid moth, almost 6000 kg/ha of cv Muscat d'Alexandrie grapes were harvested. These initial results are very promising (Table 3).

Table 1
Bud burst rates for seven grape varieties grown on espalier at Vieux-Habitants, Guadeloupe (n° burst buds/total n° buds).

	December pruning		February pruning		April pruning		Mean/cv		
	Spur	Long branch	Spur	Long branch	Spur	Long branch	Spur	Long branch	Mean
Ruby/cutting	64	39	87	89	92	85	81	71	76
Cardinal/3309	63	42	81	62	93	77	60	60	60
Centennial/cutting	38	49	85	71	89	71	71	64	67
Thompson/SO4	86	32	92	78	93	84	90	65	77
Italia/110	71	55	67	71	100	73	79	66	72
Italia/SO4	65		88	83	88	67	80	75	77
Dattier/cutting	80	56	87	76	96	72	88	68	78
Dattier/SO4	67		93	67	84	50	81	58	69
Muscat d'Alexandrie/110	58	20	79	67	92	82	76	56	66
Muscat d'Alexandrie/SO4	66	35	81	61	90	25	79	40	59
Mean	**66**	**41**	**84**	**72**	**92**	**69**			
Monthly rate		**63%**		**78%**		**80%**			

Table 2
Flowering rates for seven grape varieties grown on espalier at Vieux-Habitants, Guadeloupe (n° burst buds/total n° buds).

	December pruning		February pruning		April pruning		Mean/cv		
	Spur	Long branch	Spur	Long branch	Spur	Long branch	Spur	Long branch	Mean
Ruby/cutting	27	16	32	27	10	11	23	18	20
Cardinal/3309	18	25	45	25	30	33	31	28	30
Centennial/cutting	12	0	4	8	4	8	6	5	5
Thompson/SO4	6	0	19	18	6	11	10	3	6
Italia/110	10	0	13	0	17	13	13	4	8
Italia/SO4	6		14	0	0	0	7	0	3
Dattier/cutting	11	6	15	22	3	5	10	11	10
Dattier/SO4	10		4	0	6	0	7	0	3
Muscat d'Alexandrie/110	17	0	46	45	43	30	35	25	30
Muscat d'Alexandrie/SO4	14	50	44	55	45	25	39	43	41
Mean	**14**	**12**	**24**	**20**	**16**	**14**			
Monthly rate		**13%**		**22%**		**15%**			

Table 3
Grape yields in June 1992 for espalier-trained vines at Vieux-Habitants, Guadeloupe.

	N° grape bunches/plant	Mean bunch weight (g)	Yield (kg/ha)
Ruby/cutting	8	219	3 540
Cardinal/3309	-	-	-
Centennial/cutting	-	-	-
Thompson/SO4	1	222	710
Italia/110	2	200	666
Italia SO4	2	187	533
Dattier/cutting	4	244	1 567
Dattier/SO4	3	219	1 243
Muscat d'Alexandrie/110	13	266	5 762
Muscat d'Alexandrie/SO4	9	247	3 857
Mean	**5**	**225**	**2 235**

length of the production cycle

The mean interval between pruning and harvest was 140 days. The earliest cultivar was Muscat d'Alexandrie (125 days), and the latest were Italia and Dattier de Beyrouth (150 days).

economic data

table grape imports in Guadeloupe

Grape imports increased by more than 100 t in 1991, reaching a total of 400 t in 1992. This could be explained by a marked rise in grape imports from Chili and Spain, whereas imports from metropolitan France dropped drastically (– 100 t in 1991).

These imports were very high in the September-December and March-April periods. Wholesale grape prices in Guadeloupe were very high in July (35 F/kg in 1991) and levelled off at 10-15 F/kg throughout the rest of the year.

production costs

Annual vineyard installation and maintenance costs were calculated after a year of grape production at Vieux-Habitants (Guadeloupe):
– installation: 187 000 F/ha for espalier training and 237 000 F/ha for arbour training,
– maintenance: 82 000 F/ha/year for espalier and 128 000 F/ha/year for arbour.

Grape prices are generally below 12 F/kg in Guadeloupe (minimum import price). Considering the technical constraints that necessitate production in June and December, note that:
– in June, grape consumption is quite low (20 t in 1991), whereas prices are high (20-25 F/kg in 1991);
– in December, grape consumption is high (100 t in 1991), whereas prices are the lowest (12 F/kg).

In Guadeloupe, the grape production breakeven point (10 F/kg) is reached when a minimum of 7600 kg/ha/year are produced on espalier-trained vines. Arbour production data are still insufficient to reach a final conclusion.

conclusion

An efficient crop protection programme was set up in 1993 and the interesting qualities of cv Muscat d'Alexandrie were highlighted.

There are still substantial technical choices to be made, especially to determine the best rootstocks, vine training and pruning techniques under local conditions.

Although tropical grape production is labour intensive and requires high initial investments, it could be cost effective in Guadeloupe. Thirty ha of vineyards could produce enough grapes to meet the domestic market demand. ●

On-Site Topworking of Guava Trees

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p. 353-354 (English)
p. 448-449 (French)

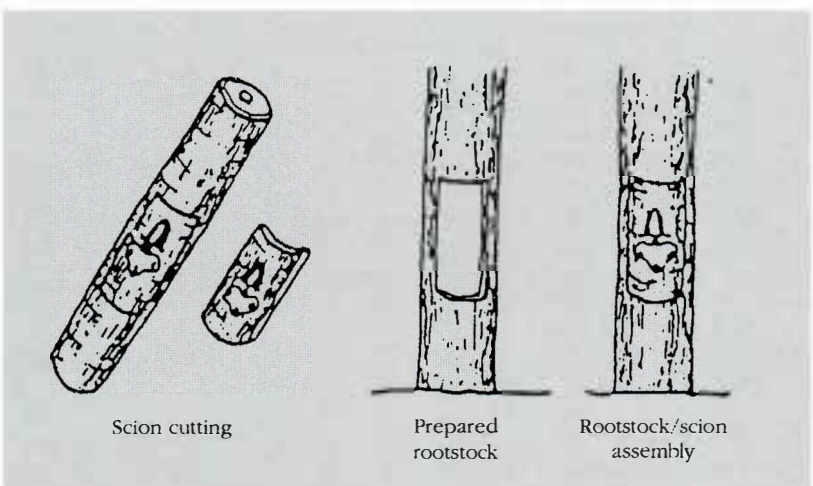
A technique to double-graft guava trees (cv Beaumont) could provide an alternative to standard uprooting/replanting practices.

introduction

The development of small- and medium-sized fruit processing units and the booming tourist industry have promoted an increase in the demand for local fruit in Guadeloupe. Local guavas are in high demand since imported guava pulp is often expensive and of unsatisfactory quality.

The guava cultivar Beaumont is of interest for its high yields and quality, particularly with respect to its processing performance (colour, flavour, sweetness and acidity). Varietal conversion of a guava orchard with this cultivar was thus investigated. Local and poor-performing improved varieties could be replaced by an on-site topworking technique, as an alternative to conventional uprooting/replanting.

Figure 1
Patch budding.



material and methods

topworking technique

Topworking is carried out as follows:

1. The trees to be grafted are cut back to the main branches, and the remaining trunk and main branch bases are daubed with thick whitewash to hinder sun scorching.

2. Four to six vigorous ratoons are selected; they should be spatially well distributed to give a well-balanced architecture to the tree. Frail, poorly located and excess branches are pruned.

3. Cultivar Beaumont is grafted onto the stocktree by patch budding when the ratoons are 10-15 mm diameter and beginning to lignify (Fig. 1). The buds are protected with grafting plastic.

4. Fifteen to twenty days after grafting, ties are removed from the bud union on grafted branches and they are partially pruned to 10-15 cm above the graft. Bud sprouting occurs very soon after this operation (< 1 week).

5. Branches are pruned to about 2 cm above the scions after they have reached a length of 15-20 cm, and the pruning wounds are sealed with grafting wax.

6. Buds are removed from the rootstock on a regular basis, generally 2-3 times.

experiments

The double-grafting experiments were carried out at the Vieux-Habitants research station, Guadeloupe, in an irrigated 0.3 ha guava orchard cropped with various cultivars that have poorer yield performance than cv Beaumont. The trees to be grafted (3.5 years old) were cut back on 27 October 1988, and grafted on 14-15 February 1989. They were planted in stands of 357 trees/ha (7 m x 4 m).

An equivalent-sized control plot (0.3 ha) was planted with cv Beaumont cuttings in 1989.

results and discussion

An assessment carried out in late March 1989 revealed a success rate of more than 95% in the double-grafted orchard. In December 1989, the first blossoms were noted, with subsequent yields of 11.6 t/ha in 1990, 32.6 t/ha in 1991, and 32.5 t/ha in 1992. However, 50% of the guavas could not be harvested because of a fungal disease (*Phoma* sp.).

The yield results on the control plot were 9.1 t/ha in 1990, 24.8 t/ha in 1991 and 59.5 t/ha in 1992.

These results indicated that topworked guava trees began producing slightly sooner than ungrafted trees.

Finally, a cost-effectiveness analysis study showed that the cost of labour involved in the topworking procedure (i.e. pruning, disposing of wood left after pruning, whitewashing trunks, grafting, bud removal, partial and final pruning of grafted branches) was equal to that required for conversion (uprooting, purchasing new plants, replanting) of a similar-sized plot, i.e. about 11 000 FF/ha.

conclusion

The present study highlighted the benefits of using the topworking technique to rehabilitate a guava orchard as compared to an uprooting/replanting procedure, i.e. the onset of production is earlier for the same technical costs. The 1992 harvest was poor because of a fungal disease and the yield figures will therefore have to be confirmed.

With this topworking technique, an efficient experienced grafter is required to obtain a high grafting success rate in a single operation.

Another interesting advantage of this technique is that it avoids potential rot development due to inefficient uprooting; this is a common problem after uprooting and land clearing operations.

Floral Induction Study in Mango in Guadeloupe

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p. 450-452 (French)

Mango trees were treated with several flower-inducing substances by leaf spraying and undertree irrigation applications. The initial results highlight the promising mango cropping potential in the Lesser Antilles.

introduction

Two mango cultivars (Haden and Eldon) from Florida (USA) were introduced in Guadeloupe in the early 1980s with the aim of developing the export mango industry. However, some flowering problems were noted when these trees were grown under prevailing conditions in Guadeloupe. Flowering was found to be poor and highly irregular (December to April flowering period) in lowland areas. These cultivars also show quite marked biennial bearing.

Irrespective of the varietal factor, this situation could be explained by several climatic conditions:
– irregular and often insufficient dry period,
– high humidity,
– high mean temperatures year-round.

The fumigation technique has long been used in India and the Philippines for flower induction. By this technique, trees are fumigated for several days until the appearance of inflorescences; the operation is repeated 2 months later if no flower bud burst occurs within 15 days. The results, however, are often poor and the operation is expensive and labour intensive.

Chemical treatments were successfully tested at the beginning of the 1970s. In the Philippines, for instance, potassium nitrate spraying treatments were carried out from 1970 to 1978, and yields were thus increased threefold (Anonymous, 1978).

Several other countries, particularly Mexico, have obtained positive results by adapting these techniques to their local conditions (Nuñez-Elisea, 1986 a & b; Nuñez-Elisea & Caldeira, 1987).

In the present study, two different flower induction treatments were conducted with these substances in a CIRAD-FLHOR research orchard at Vieux-Habitants (Guadeloupe).

material and methods

comparison of two flower-inducing substances on cv Eldon mango

Two flower-inducing substances, Flowerset (Bayer) and Miracle Blum Powder (Philippine Orchard Corp.), were tested in January 1991 on cv Eldon mangos grafted on 10 year old non-improved local mango trees.

Flowerset (240 g potassium nitrate/l) was applied by leaf spraying at 15 cc/l (36 g/l postassium nitrate).

The chemical composition of Miracle Blum Powder is not given, but analyses indicated a total nitrogen content of 25%, 14.5% as ammonium and 10% as nitrate. Part corresponds to ammonium nitrate, and the rest (about 1/3 of the ammonia

form) to other salts (phosphates, sulphates, chlorines, etc.). It was applied at 15 g/l.

These substances are often used instead of raw potassium nitrate in the Philippines since, for military security reasons, it is sometimes difficult to obtain authorization to use the latter compound (ANONYMOUS, 1978).

For each treatment, seven trees were treated by leaf spraying (about 14 l solution/tree). For practical reasons, only the lower 2/3 of the foliage was treated.

comparison of three flower-inducing substances on cv Haden mango

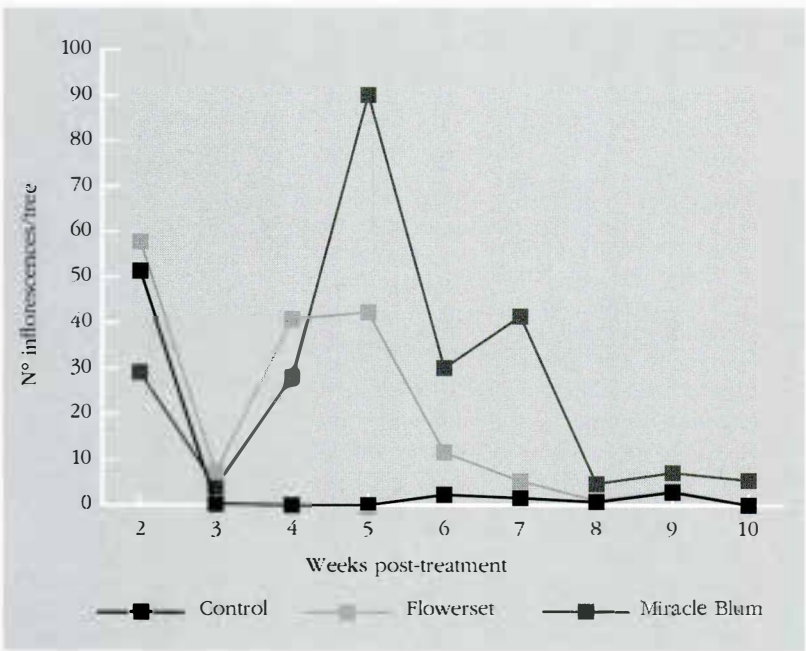
Since the preliminary flower induction tests with cv Eldon were successful, a second experiment was carried out in March 1991. However, only nitrate treatments were undertaken because data for the Miracle Blum Powder trial was not yet available.

Young 3 year old cv Haden mangos grafted on local non-improved mango trees were treated in this second experiment. Terminal buds on all trees tested were at the swelled or dormant stage. Paclobutrazol, a growth regulator commonly applied to increase yields in mango and other fruit trees, was used as a control compound for the potassium nitrate treatments (VUILLAUME, 1987; VUILLAUME & NYEMBI, 1991; VOON *et al.*, 1989).

Four different treatments were carried out with three flower-inducing substances:
– Flowerset (240 g/l potassium nitrate): 15 cc/l by leaf spraying (10 l/tree),
– potassium nitrate: 10 and 40 g/l by leaf spraying (10 l/tree),
– paclobutrazol: 60 cc Cultar (ICI) in 20 l water by undertree irrigation followed by sprinkling.

This test was carried out along a uniform line, at two trees/plot, two replications and adjacent controls.

Figure 1
Flower induction treatment on cv Eldon mango: mean inflorescence number/tree.



results

comparison of two flower-inducing substances on cv Eldon mango

Figure 1 shows the positive effects of two flower induction treatments as compared to the control: after the natural flowering stage (T + 15 d) in controls and treated trees, flowering began on the treated trees (peak at T + 35 d); the best results were obtained with Miracle Blum Powder.

The flower-inducing substances markedly increased yields, as measured by the harvested fruit quantities and weights (Figures 2 & 3).

However, there were no differences between the three treatments when separate fruit weights were analysed (control 480 g; Flowerset 530 g; Miracle Blum Powder 490 g).

comparison of three flower-inducing substances on cv Haden mango

The three potassium nitrate treatments had a positive effect on flower induction (bud burst at T + 15 d and full flowering at T + 35 d), and on fruiting (Table 1).

The Cultar treatment had almost no effect on flowering. The dwarfing effect of the compound was confirmed, i.e. shortening of the last internodes and a weeping branch habit.

discussion

effects of nitrates

In both experiments, potassium nitrate was found to induce flowering when applied by leaf spraying at a specific physiological stage: swelled and dormant terminal buds and brittle dark-green leaves, corresponding to a branch age of 6-7 months.

Ammonium nitrate was also found to induce flowering in the Miracle Blum Powder treatment. However, the exact role of this compound would be difficult to determine because of the complex chemical composition of this product.

The present results generally confirmed the hypothesis of NUÑEZ-ELISEA (1986) that nitrate ions have a prime role in the chemical flower induction process in mango.

potassium nitrate treatment dose

The results indicated an ideal potassium nitrate treatment dose of 10 g/l, applied in March, to obtain flower induction in cv Haden under the prevailing climatic conditions of Guadeloupe.

In the Colima region of Mexico, a dose of 40 g/l has been recommended for cvs Haden and Manila with treatments beginning in the first 2 weeks of November. In the Philippines, a dose of 10 g/l is effective for cvs Pico and Carabao with treatments in February or October.

The treatment dose can therefore be adjusted according to varieties, and the application date should be set in terms of the physiological stage of the branches.

application dates

Treatments in mid-January on cv Eldon and mid-March on cv Haden led to an increase in natural seasonal flowering and induction of late season flowering.

These techniques should now be assessed in terms of reproductivity and the effects of treatments relative to the physiological stages of branches and climatic conditions.

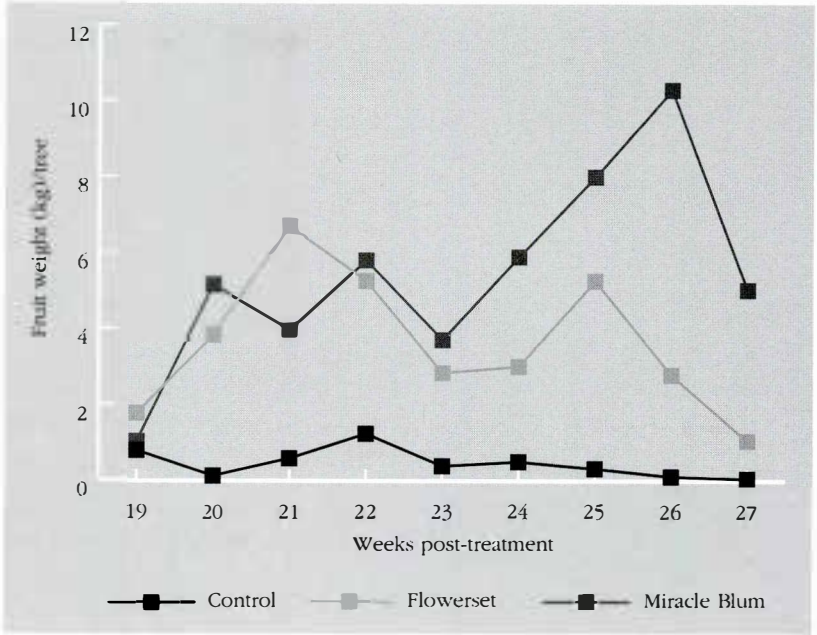


Figure 2
Flower induction treatment on cv Eldon mango: mean fruit weight/tree.

effect of paclobutrazol

The very poor results obtained with the paclobutrazol treatment could be explained by several factors:
– the young age of the plants treated (3 years),
– the low paclobutrazol sensitivity of the varieties tested,
– the low late-season flower-inducing efficiency of paclobutrazol.

Figure 3
Flower induction treatment on cv Eldon mango: mean fruit number/tree.

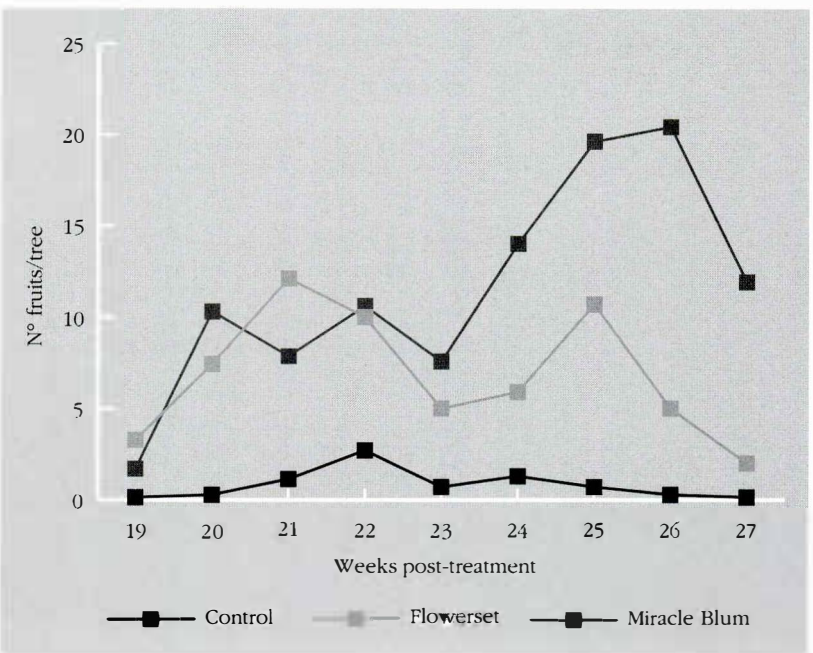


Table 1
Results of the flower induction treatment with cv Haden.

	Flowers/ tree	N° fruits/ tree	Fruit weight/ tree (kg)	Size
Control	1.76	0.94	0.37	0.39
KNO_3 10 g/l	59.25	25	7.16	0.29
KNO_3 40 g/l	32.75	14	4.3	0.31
Cultar	0	0	0	0
Flowerset	77	32	10.76	0.34

In these conditions, it would be interesting to compare the growth-reducing effects of paclobutrazol with the flower-inducing effects of nitrates (VOON *et al.*, 1989).

conclusion

These initial positive results could lead to more harmonious and reliable development of mango cropping in Guadeloupe and throughout the lesser Antilles.

Although further experiments should be carried out to improve cropping techniques, under the treatment conditions investigated in this study, it seems possible to obtain:
– more uniform flowering,
– a reduction in biennial bearing,
– late season flower induction.

However, in the light of the present know-how, these techniques will probably not enable year-round mango production under the highly irregular tropical climatic conditions in Guadeloupe.

references

ANONYMOUS, 1978.
The Philippines Recommends for Mango, 70 p. Los Baños, Laguna, Philippines, Philippine Council for Agriculture and Ressources Research, p. 11-13.

NUÑEZ-ELISEA R., 1986a.
Producción temprano de mango 'Haden' y 'Manila' con aspersiones de nitrato de potasio. Campo Agricola Experimental Tecomán, Mexico, SAEH-INIFAP-CIAPAC, 8 p.

NUÑEZ-ELISEA R., 1986b.
Potencial del nitrato de amonis (NH_4 NO_3) para inducir la floración del mango. *In*: Congresso nacional de la ciencia del suelo, 19. Resúmen. Sociedad Mexicana del suelo, p. 29.

NUÑEZ-ELISEA R., CALDEIRA M.L., 1987.
Adelanto de la floración y cosecha en mango 'Haden' con aspersiones de nitrato de amonio. *In*: IX Congresso brasileiro de fruticultura. Sociedade brazileira de fruticultura, p. 561-566.

VUILLAUME C., 1987.
Paclobutrazol - PP 333. Un nouveau régulateur de croissance et des résultats prometteurs en cultures fruitières tropicales. Montpellier, France, RA 1987, IRFA/CIRAD, 4 p. (document n° 100).

VUILLAUME C., NYEMBI Z., 1991.
Vers une maîtrise de la floraison du manguier au Cameroun. Utilisation d'un régulateur de croissance : le paclobutrazol. *Fruits* 46 (2) : 187-198.

VOON C.H., PITARPAIVAN C., TAN S.J., 1989.
Mango cropping manipulation with Cultar. *In:* 3rd International Mango Symposium. *Acta Horticulturae* 291, p. 219-228.

Hand Pollination in Sugar Apple

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A simple hand pollination technique is recommended to enhance sugar apple productivity, a fruit that is highly appreciated in Guadeloupe.

introduction

Natural pollination rates are low in many *Annona* species, thus explaining their poor productivity.

Annona flowers are highly protogynous (i.e. the stigma are receptive before stamen maturity), which limits self-pollination. The morphology of the flowers (colour, shape) also reduces entomophilous and anemophilous cross-pollination.

Many cherimoya and/or atemoya producing regions (Australia, California, Chili, Spain, etc.) have overcome this problem through hand pollination practices.

These techniques were modified for sugar apple (*Annona squamosa*), a species that is closely related to cherimoya and atemoya but better adapted to dry tropical climates as found in the West Indies.

material and methods

Annona squamosa trees from two different origins were used in this study:
– a 4 year old tree of Florida origin (cv Thai Lup grown from seed);
– eight 2.5 year old trees of New Caledonian origin (from local improved seed).

The method was simple: pollen was collected from flowers at the male stage (fully separated petals). It was then dusted onto the stigma of other flowers in the female stage (barely half-open petals) with a small fine-bristle brush. Trees were monitored for fruit setting 10-15 days postpollination.

This operation was repeated four times at 15 day intervals in order to treat as many flowers as possible.

Flowers on cv Thai Lup were only pollinated with pollen from the same variety of flowers (intravarietal pollination).

With the New Caledonian cultivar, intravarietal (with its own pollen) and intervarietal (with cv Thai Lup pollen) pollinations were carried out.

results and discussion

fruit setting rate

The low fruit setting rates noted in *A. squamosa* controls were in line with reported rates for *A. cherimoya* and *A. attemoya*, which have fruit setting rates of about 1% under natural pollination conditions.

Table 1
Results of hand pollination in *Annona squamosa*.

Treatment	N° flowers	N° set fruits	% fruit budded	Mean wt/ fruit(g)	gain vs control
cv Thaï Lup					
Control	40	0	0	143 (*)	
Intra poll.	38	38	100	230	+ 62%
Inter poll.	-	-	-	-	
cv New-Caledonia					
Control	111	4	3.6	230 (**)	
Intra poll.	33	30	90.9	269	+ 17%
Inter poll.	54	50	92.6	313	+ 36%

* mean for 83 fruits harvested outside of the test period (natural pollination).
** mean for 39 fruits harvested from controls and outside of the test period.

A fruit setting rate of more than 90% was obtained in all cases with hand pollination, thus confirming the efficiency and benefits of artificial pollination (Table 1).

mean fruit weight

Very marked fruit weight gains (17-62%) were obtained in all cases with hand pollination. These gains were great since the mean fruit weights under natural conditions were very low.

Mean weights of fruit produced on the New Caledonian variety after intervarietal pollinations were higher than those produced after intravarietal pollinations (gains of 36% and 17%, respectively).

This weight gain was associated with improved well-formed fruit (well rounded, no flattening), which could be explained by the fact that hand pollination improves pollen coverage on the stigma.

conclusion and prospects

Sweet apple trees are only grown on a single-tree basis in some creole gardens in Guadeloupe. This fruit is therefore quite rare despite its popularity in Guadeloupe.

Nevertheless, sweet apple is very well adapted to the pedoclimatic conditions of Côte Sous le Vent (Basse-Terre) and Grande Terre. The hand pollination technique boosts production and could thus help promote sweet apple development in Guadeloupe.

This technique, based on a mean flowering/harvest interval of 110 days, would also be interesting for grouping and programming harvests.

The present preliminary results could be confirmed by:
– conducting the same study during the whole flowering period, with a larger sample if possible;
– checking the advantages of intervarietal pollination;
– adapting the technique for other *Annona* species such as *A. reticulata* (bullock's heart), and especially *A. muricata* (soursop); the initial results for this species were quite inconclusive.

further reading

AHMED M.S., 1939.
Pollination and selection in *Annona squamosa* and *A. cherimola*. Bul. Min. Agr. Egypt Tech. Sci. Serv. Hort. Sect, 157, 1.

GEORGE A.P., NISSEN R.J., CAMPBELL J.A., 1992.
Pollination and selection in *Annona* species (cherimoya, atemoya and sugar apple). *In*: International symposium on tropical fruit: frontiers in tropical fruit research, Pattaya City, Thailand, 20-24 mai 1991. Wageningen, Netherlands, ISHS, p. 178-185.

SAAVEDRA E., 1977.
Influence of pollen grain stage at the time of hand pollination as a factor on fruit set of cherimoyer. *HortScience*, 12, 117.

SCHROEDER C.A., 1943.
Hand pollination studies on the cherimoya. Proceedings of the American Society for Horticultural Science, 43, 39.

THAKUR D.R., SINGH R.N., 1965.
Studies on pollen morphology, pollination and fruit set in some *Annonas*. *Indian Journal of Horticulture*, 22, 10.

III. Genetics

Genetic Resources

Characterization and Performance of 51 *Citrus* Varieties in New Caledonia.

F. Mademba-Sy *et al.*

[citrus fruits, variety trials, environments, trees, quality, production, New Caledonia] 362-370
[agrume, essai de variétés, environnement, arbre, qualité, production, Nouvelle-Calédonie]
[frutas cítricas, ensayos de variedades, medio ambiente, árboles, calidad, producción, Nueva Caledonia]

Genetic Resources of Mangos in Côte d'Ivoire.

T. Goguey

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[*Mangifera*, matériel génétique, collection, hybridation, amélioration des plantes, Côte-d'Ivoire]
[*Mangifera*, germoplasma, colecciones, hibridación, fitomejoramiento, Côte d'Ivoire]

Management of Litchi Genetic Resources in Réunion.

F. Normand *et al.*

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[*litchi*, germoplasma, colecciones, procedencia, criterios de selección, calidad, fecha de recolección, Reunión]

Inventory of Tropical Fruit Trees in Central America and the West Indies.

G. Barbeau

[*Anacardiaceae, Annonaceae, Guttiferaceae, Lauraceae, Lecythidaceae, Malpighiaceae, Moraceae, Myrtaceae, Oxalidaceae, Rhamnaceae, Rubiaceae, Rutaceae, Sapindaceae, Sapotaceae* ...] 383-389
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[... arboles frutales, América central, Caribe]

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[*Citrus*, taxonomía, evolución, biodiversidad, genomas, número de cromosomas]

Optimized Management of Citrus Embryogenic Calli for Breeding Programmes.

P. Ollitrault *et al.*

[*Citrus*, callus, freezing, embryonic development, somatic embryos, plant breeding] 394-397
[*Citrus*, cal, congélation, développement embryonnaire, embryon somatique, amélioration des plantes]
[*Citrus*, callo, congelación, desarrollo embrionario, embrión somático, fitomejoramiento]

Facultative Apomixis, Spontaneous Polyploidization and Inbreeding in *Citrus volkameriana* Seedlings.

P. Ollitrault *et al.*

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[*Citrus*, apomixis, poliembrionía, portainjertos, isoenzimas, número de cromosomas]

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[*Citrus*, *Fortunella*, fusion de protoplastes, cal, hybride somatique, isoenzyme, fragmentation de l'ADN].
[*Citrus*, *Fortunella*, fusión del protoplasto, callo, híbrido somático, isoenzimas, fragmentación de la ADN]

Genetic Mapping of an Intergeneric *Citrus* Hybrid Using Molecular Markers.

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[*Citrus*, génome, isoenzyme, enzyme de restriction, carte génétique, ségrégation, amélioration des plantes]
[*Citrus*, genomas, isoenzimas, enzima de restricción, mapas genéticos, segregación, fitomejoramiento]

Characterization and Performance of 51 Citrus Varieties in New Caledonia

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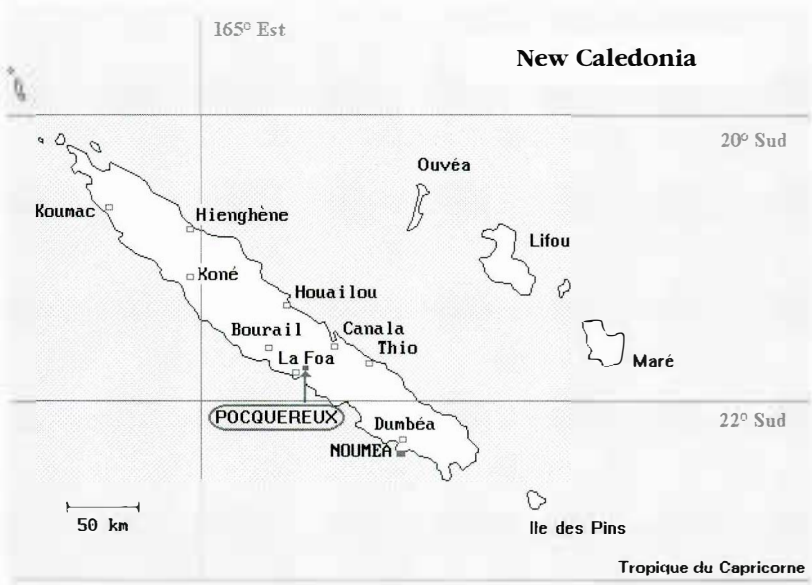
Fruits, vol. 49, n°5
p. 362-370 (English)
p. 456-460 (French)

Although citrus fruits are not yet widely grown in New Caledonia, interesting results were obtained in analyses of recently-introduced grapefruit, orange and mandarin varieties.

introduction

Intensive *Citrus* cropping is a recent phenomenon in New Caledonia (Guillaumin, 1952), and the first *Citrus* development programme in this country only began in the early 1980s (Praloran, 1971). Varietal breeding plots were set up at the CIRAD fruit research station at Pocquereux, New Caledonia, to obtain data on the performance of citrus in this region, that is:
– in 1986, with 60 cultivars
– in 1991, with 160 cultivars.

Interesting preliminary results were obtained for several cultivars in an initial trial that had been planted in 1986.



description of the environment

geographical location

New Caledonia is 18 000 km from metropolitan France. This archipelago is located north of the Tropic of Capricorn, from 19° to 23° latitude S and 158° to 172° longitude E (Map). The overall surface area is 19 100 km^2, about twice the size of Corsica and 18-fold that of Martinique. There is one main northwesterly/southeasterly oriented island (Grand Terre: 16 900 km^2) and several smaller flanking islands (îles des Pins, îles Loyauté and îles Bélep: 2 200 km^2) (Orstom, 1989).

Grand Terre (about 400 km long, 50 km wide) has a central mountain range that peaks at 1 628 m, with deep perpendicular valleys on the east and west coasts. These valleys are at low elevations (< 200 m), and longer on the west coast than on the east coast. The flanking coral islands are volcanic.

climate

The archipelago has a tropical-to-Mediterranean type of climate; part of the year the territory is influenced by the intertropical convergence zone (ITCZ), and the other part by temperate depressions from the South Pole:
– mid-December to mid-April is the main hot rainy season that peaks in February-March, tropical depressions and cyclones occur at this season;
– mid-April to mid-May is a minor dry season when the rainfall and temperature

decrease with the northward movement of the ITCZ;
– mid-May to mid-September is the cool season, which can be rainy due to the arrival of cold fronts from the South Pole, causing temperate depressions;
– mid-September to mid-December is the main dry season, when temperatures rise and the ITCZ begins moving southwards.

temperatures

Temperature is a determining factor for citrus performance; it affects internal fruit quality and colour.

Temperatures recorded at the meteorological station in La Foa (New Caledonia) are presented in Figure 1. For a 34 year period, the mean annual temperature was 22.5°C (mean maximum 28.5°C, mean minimum 16.4°C). Note that these are not typical temperatures, i.e. the minimums are quite low despite the average to low elevation and latitude and the insularity effect.

As shown in Figure 2, the temperatures were midway between those found in Martinique (tropical climate) and Corsica (Mediterranean climate).

hygrometry, evapotranspiration and precipitation

The mean hygrometry ranged from 48% to 96%. The potential evapotranspiration was 1463 mm, with a June low of 65 mm and a December high of 177 mm.

The mean annual rainfall was 1 155 mm, but there was a broad range of levels (610 mm in 1967, 2 292 mm in 1973).

Precipitation was poorly distributed throughout the year (mean 84 days), which means that crops have to be irrigated.

soil

The citrus cultivars studied were planted on recent alluvial river terraces. The soils were heavy sandy clay loam (85% clay/loam). These recent alluvial soils have a substantial organic matter content (2.9%), with high magnesium content and only trace levels of potassium and calcium, and no sodium. The soil pH is 5.5 (Godefroy, 1990).

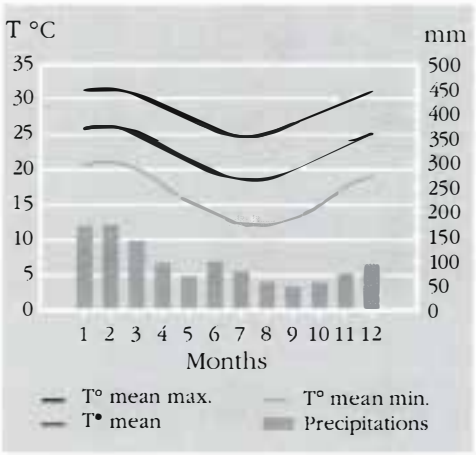


Figure 1
Climatic data for La Foa. Elev. 18m, Lat. 21°40'S, Long. 169°494E.

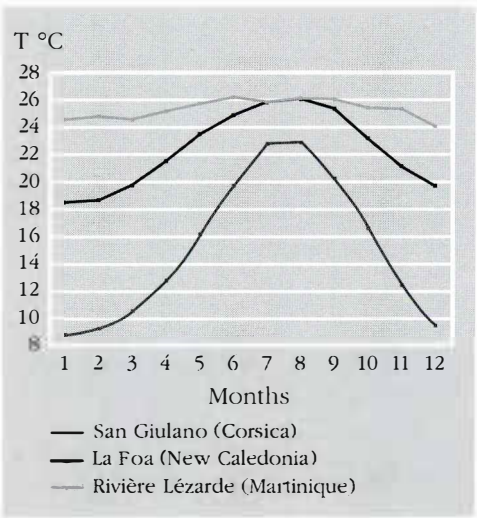


Figure 2
Comparison fo mean temperatures for La Foa, Martinique and Corsica.

These soils are not *a priori* ideal for citrus cropping because the orchards are flooded during the first quarter of the year as a result of tropical depressions. However, they are generally close to water sources (rivers) and more fertile than other soils in New Caledonia. Specific development projects (banking, hilling) also enable the trees to withstand temporary exundation.

material and methods

cropping techniques

The experimental plot, located on the Pocquereux River floodplain and thus subject to periodic flooding, was initially a dry forest of cajeput (*Melaleuca quinquenervia*) and candlenut (*Aleurites*

moluccana). It was cleared with a bulldozer and then the soil was heavily fertilized (2 t/ha acetylene manufacturing residues[1]). NPK fertilizer (0-32-16; 2 t/ha) was applied as a basal dressing.

The trees were planted in turf (3 m long x 3 m wide x 60 cm high) in September 1986. In 1992, a system of open trenches was set up for quick floodwater drainage, since such events do not last more than 12 h. With this system, the orchard was able to withstand six 2 m high floods that occurred since the trees were planted, without significant damage (no mortality). The conditions on this varietal breeding plot are typical of those found in most citrus orchards of New Caledonia.

The trees were planted at 7 m x 7 m spacing. Each variety was represented by blocks of 4 trees. Aciduous varieties (lime, lemon, grapefruit) were grafted on *Citrus volkameriana*, and sweet varieties (orange, mandarin) on Carrizo and Troyer citrange.

irrigation

Trees were irrigated with two microjets (36 l/h) set at 180° and on opposite sides of the tree to avoid wetting the trunk. The irrigation period lasted 5-9 months, depending on rainfall levels, with a PE of 0.75.

fertilization

The orchard was fertilized three times yearly, as follows:

50% 1 month before flowering (July),
25% 2 months after flowering (September),
25% 4 months after flowering (November).

The annual fertilizer input for 7-year-old trees was 1500 g urea and 2500 g NPK (13-13-21).

plant material

health status

About 60 citrus varieties were grown on the test plot; the results for 49 of these are presented here. All plant material was certified and originated from the INRA-CIRAD agricultural research station (SRA) in Corsica. The trees were periodically indexed for tristeza virus. No trees were positive even though tristeza has been detected elsewhere in the archipelago in Navel oranges from Australia that were introduced in the early 1960s. All diseased trees were destroyed and an eradication campaign carried out. *Toxoptera citricidus* Kirkaldy, the main tristeza vector, is not present in New Caledonia.

varietal performance

Varieties were evaluated according to IBPGR-FAO criteria and standards, the details are given in Appendices. The main traits of interest for growers are:
– fruit shape (ED/PD ratio = equatorial diameter/polar diameter),
– peel thickness (epicarp and mesocarp),
– number of seeds,
– juice content (%),
– acidity (A),
– soluble dry extract (SDE),
– fruit weight
– yield,
– flowering-harvest period.

sampling

The quantitative and qualitative measurements for each citrus variety were based on 10-fruit samples harvested in 1990, 1991 and 1992.

results

grapefruits

Six varieties of grapefruit (*Citrus paradisis* Macf.) were compared: Marsh SRA 120, Shambar SRA 22, Redblush SRA 56, Star Ruby SRA 199, Ruby SRA 286 and Thompson SRA 121 (Photo 1).

canopy

Grapefruit trees in New Caledonia have a smaller canopy volume than trees grown under real tropical climate conditions (only 42 m^3 for 7-year-old trees, 4.1 m high x 4.6 m diameter canopy). All six varieties had a rounded habit.

ripening period

The grapefruit varieties were late, with a 9 month period from flowering (September) to maturity (June). The fruit

(1) Type of whitewash containing 13% CaO, obtained following water erosion of calcium carbide. *Citrus* growers can obtain this product free-of-charge from the acetylene manufacturer.

can stay on the trees for 4 months without any change in internal fruit quality.

fruit quality

The fruit was round (ED/PD = 1/1), with a thick skin (9 mm) and few seeds (n = 5). The soluble dry extract levels were low with little variation (SDE = 7.5). The varieties differed in terms of acidity and juice content. Shambar and Ruby were the least juicy (45% and 48%, respectively) and the most aciduous (A = 1.1 g and 1.07 g citric acid, respectively) of all the grapefruit varieties. Star Ruby was the most juicy (57%) and least aciduous (A = 1.03 g) variety.

Grapefruits grown in the New Caledonian climate had very little fruit colour. The temperatures were too low during ripening to produce the pigments responsible for colouring in grapefruit (lycopene and beta-carotene). Hence, cvs Redblush, Shambar and Thompson produced fruit with lower colouring than fruit grown in tropical conditions. Star Ruby was the only variety that produced suitably coloured fruits under the conditions investigated in the present study.

production

There was little variation in grapefruit weights (mean 510 g). The largest fruits were produced by cvs Ruby and Redblush. Mean fruit yields/tree for all varieties were 105 kg at 5 years, 130 kg at 6 years, 167 kg at 7 years and 249 kg at 8 year, for a mean cumulated yield/tree over 4 years of 652 kg.

Cumulated yields/tree for each variety over 4 years (trees aged 5 years in 1991, 6 years in 1992, 7 years in 1993 and 8 years in 1994) are presented in Table 1.

The most productive cultivars were Shambar and Marsh, with 750 kg and 727 kg cumulated 4-year yields, respectively. These yields were almost threefold higher than noted for cv Marsh under dry tropical climate conditions (MADEMBA-SY, 1989).

These cultivars performed particularly well in New Caledonia, apart from the poor fruit colouring observed in some varieties (Shambar, Redblush, Thompson).

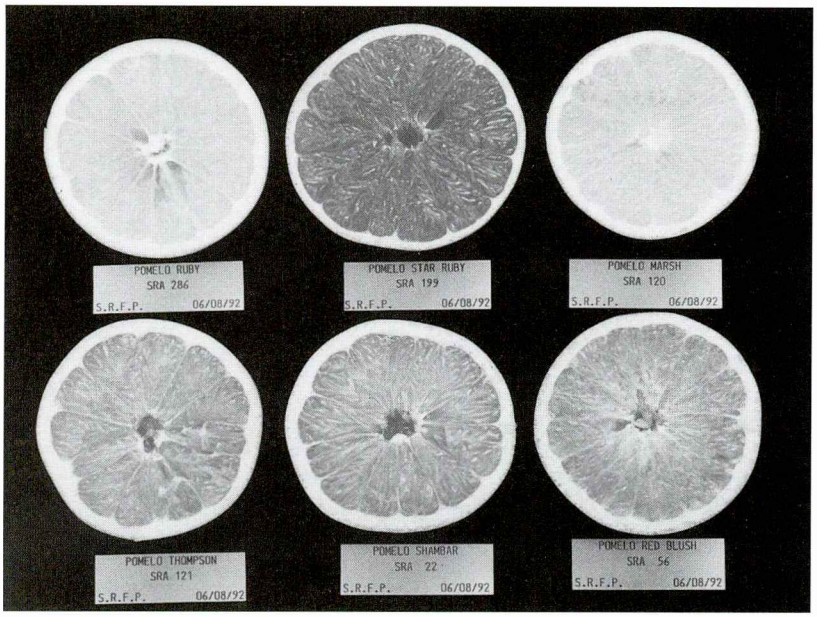


Photo 1
The six varieties of grapefruit studied in New Caledonia.

Table 1
Cumulated yields/tree for grapefruit varieties over 4 years.

Variety	4-year cumulated yield (kg/tree)
Shambar SRA 22	727
Marsh SRA 120	750
Thompson SRA 121	691
Ruby SRA 286	678
Star Ruby 199	567
Redblush SRA 56	488

oranges

Fourteen varieties of oranges (*Citrus sinensis* [L.] Osb.), blond, blood and Navel, were tested (Table 2).

canopy

The canopy volume (23 m^3, 3.2 m high x 3.7 m diameter) of orange trees in New Caledonia is half that of trees grown

Table 2
Orange varieties studied in New Caledonia.

Blond oranges	Blood oranges	Navel oranges
Cadenera SRA 232	Double Fine SRA 259	Atwood SRA 157
Hamlin SRA 97	Sanguinelli SRA 243	Gilette SRA55
Maltaise SRA 237		Navelate SRA 307
Pineapple SRA 142		Navelina SRA 306
Shamouti SRA 299		Newhall Navel SRA 182
Valencia Late SRA 105		Washington SRA 141

under wet tropical climate conditions (MADEMBA-SY & COTTIN, 1988). The trees of all 14 varieties had a rounded habit.

ripening period

The orange trees flowered in September. The ripening period was longer than that of grapefruits. Hence, cv Newhall had the shortest flowering-maturity period (5 months) and cv Valencia had the longest (10 months), with a mean of 6.5 months for all varieties.

The ripening periods for each variety studied are given in Table 3.

Table 3
Ripening periods for the 14 orange varieties studied.

Very early February	**Early March**	**Full season April**	**Very late July**
Newhall	Atwood	Cadenera	Valencia Late
	Gilette	Double Fine	
	Hamlin	Maltaise	
	Navellate	Pineapple	
	Washington	Sanguinelli	

fruit quality

Fruit quality could not be assessed in two varieties (Shamouti and Navelina) since they had not yet flowered. The results were thus based on a sample of 12 varieties.

Navels were more oval shaped (ED/PD = 0.91) than the other orange varieties. They were found to be thin skinned (4.5 mm). There were generally few seeds in all varieties (n = 3), and the Navel varieties were seedless, except for cv Navelate.

The varieties differed in terms of the juice content and soluble dry extract levels. Navel varieties had low juice (46%) soluble dry extract (SDE = 8) and acidity (A = 1 g) levels. There was very little difference between blond and blood oranges. They were found to be juicier (53%), sweeter (SDE = 8.35) and slightly more aciduous (A = 1.05 g) than the Navel cultivars, thus providing them with more character. Overall, cv Hamlin was the juiciest (63%), sweetest (SDE = 8.9) and least aciduous (A = 0.96 g) of all the orange varieties studied.

Skin adhesiveness was high to average in the three types of oranges. Generally, the Navel varieties were easier to peel than the other varieties, except for cv Hamlin.

The oranges generally had a yellow internal and external orange fruit colour. Very early and early varieties (February-March) had a less intense and even nonexistent external fruit colour; full season varieties were definitely yellow, and end of the season, late and very late varieties had a marked yellow external fruit colour. The appearance of anthocyanin pigments could be explained by the low temperatures (less than 10-15°C) that occurred during the ripening period.

production

The mean orange weight was 280 g, ranging from 445 g for cv Gilette to 170 g for cv Sanguinelli. Navel varieties had a very high mean fruit weight (376 g) relative to that of the blond and blood varieties (213 g).

Mean yields/tree for all varieties were 44 kg at 5 years, 79 kg at 6 years, 96 kg at 7 years and 105 kg at 8 years, for a mean cumulated yield/tree over 4 years of 324 kg.

Cumulated yields/tree for each variety over 3 years (trees aged 6 years in 1992, 7 years in 1993 and 8 years in 1994) are given in Table 4.

Table 4
Cumulated yields/tree for orange varieties over 3 years.

Variety	**3-year cumulated yield (kg/tree)**
Sanguinelli SRA 243	384
Pineapple SRA 142	368
Hamlin SRA 97	309
Atwood SRA 157	307
Washington SRA 141	300
Newhall SRA 182	289
Cadenera SRA 232	285
Valencia Late SRA 105	244
Navelate SRA 307	231
Gilette SRA 55	220
Double Fine SRA 259	194
Maltaise SRA 237	180

Although cvs Sanguinelli and Pineapple were the most productive, they had the lowest fruit weights. Navel varieties, however, produced high yields without any negative effect of fruit weight. Yields of cv Valencia Late in New Caledonia were higher than obtained under dry tropical climate conditions (175 kg).

mandarins and hybrids

Thirty-one mandarin varieties were compared (Table 5).

canopy

Mandarin trees had a canopy volume of 27 m^3. The growth habit of the mandarin trees differed markedly: upright for cvs Ponkan and Swatow, hanging for Satsuma varieties and rounded for clementines.

ripening period

All mandarins flowered in September. The flowering-maturity period ranged from 5 to 9 months (mean 6.5 months) in the varieties studied. The classification for all varieties is given in Table 6.

fruit quality

The fruits were flat-shaped (ED/PD > 1), except for cvs Carvalhal and Minneola which were neck-shaped. The skins were fine (3.5 mm) to medium thick, and thickest for cv King of Siam (7 mm). The mean number of seeds/fruit was increased by the presence of pollinating varieties (Commune, Dancy). The Satsuma varieties had very few seeds (n = 3), or were seedless. Varieties with less than 10 seeds/fruit were: Fortune, Fremont, Minneola, Orlando and Ortanique. Under these experimental conditions, clementines clearly had the most seeds (mean 28/fruit).

Mandarin varieties mainly differed in terms of juice content, acidity and soluble dry extract levels. Mandarins (various, large-fruit and Mediterranean varieties) had low juice content (37%) and high acidity (A = 1.12 g) and soluble dry extract (SDE = 8.6) levels. The clementine and Satsuma varieties were the juiciest of all the mandarins studied (42%). However, they were also the least sweet (SDE = 7.66, as compared to 8.18) and aciduous (A = 1 g, as compared to

Table 5
Mandarin varieties studied in New Caledonia.

Clementines (*Citrus clementina* Hort ex Tan)	SRA 63 SRA 64 SRA 85 SRA 92
Satsumas (*Citrus unshiu* Marc.)	Kowano SRA 167 Saigon SRA 225 Saint Jean SRA 108 Wase SRA 230
Mediterranean mandarins (*Citrus deliciosa* Ten.)	Commune SRA 118
Large-fruit mandarins (*Citrus nobilis* Lour.)	King of Siam SRA 273 SRA 166
Various mandarins (*Citrus reticulata* Blanco.)	Beauty SRA 261 Carvalhal SRA 111 Dancy SRA 114 Ponkan SRA 234 Sanguine SRA 264 Swatow SRA 175
Hybrids	(M. King x M. Commune) Kinnow SRA 26 Wilking SRA 112 (M. King x Satsuma) Kara SRA 165 (M. Dancy x Duncan grapefruit) Orlando SRA 21 Minneola SRA 156 (Mandarin x orange) Murcott SRA 181 Ortanique SRA 110 (Clementine x M. Dancy) Fortune SRA 31 (Clementine x M. Ponkan) Fremont SRA 147 (Clementine x T. Orlando) Fairchild SRA 30 Lee SRA 49 Nova SRA 158 Osceola SRA 48 (Clementine x T. Minneola) Page SRA 159

Table 6
Ripening periods for the different mandarin varieties studied.

Very early February	**Early March**	**Full season April**	**Late season May**	**Very late June**
Carvalhal	Satsuma Saigon	Clementine 63	Dancy	Fortune
Commune	Satsuma Wase	Beauty	King of Siam	Minneola
Satsuma Kowano	Clementine 64	Fairchild	Kinnow	
Satsuma St Jean	Clementine 85	Kara		
	Clementine 92	Murcott		
	Fremont	Orlando		
	Lee	Ortanique		
	Nova	Ponkan		
	Osceola	Sanguine		
	Page	Wilking		
	Swatow			

1.07 g), which explains their lack of character. The mandarin hybrids were much juicier (49%), with as much as 59% juice content for cv Orlando and 61% for cvs Fortune and Lee.

Low to high peel adhesiveness was noted, i.e. it was low in clementine and Satsuma varieties and various large-fruit and Mediterranean mandarin varieties, and average to high in all hybrids.

All mandarin varieties studied had remarkable internal and external fruit colouring, much more intense than in oranges. Varieties that reached maturity in February (very early) or March (early) had little or no colouring; they only turned yellow after degreening. From April on, colouring appeared in seasonal varieties, with intensely coloured fruits obtained from June to August. There were a few noteworthy exceptions: cv King of Siam and its hybrids Wilking and Kinnow were almost colourless, although they reached maturity during the cold period. In contrast to cv Fremont, cvs Beauty and Page had a magnificent reddish-orange colouring.

production

The mean fruit weight for the varieties studied was 177 g. Mandarin varieties had the lightest fruits (146 g), except for cv King (350 g), followed by clementine (150 g) and Satsuma (158 g) varieties. The hybrids (Photo 2) were generally the heaviest (181 g), with high values obtained for cvs Orlando (203 g), Kara (246 g), Ortanique (288 g) and Minneola (297 g).

Mean yields/tree were 46 kg at 5 years, 75 kg at 6 years, 93 kg at 7 years and 123 kg at 8 years, for a mean cumulated yield/tree over 4 years of 337 kg. Cumulated yields/tree for each variety over 3 years (trees aged 6 years in 1992, 7 years in 1993 and 8 years in 1994) are given in Table 7.

The least productive varieties (cumulated yields of < 220 kg for 1992-93-94 harvests) were Swatow, Lee, King of Siam, Malvasio, Murcott, Fremont and Ponkan. The most productive varieties (cumulated yields of > 350 kg for 1992-93-94 harvests) were Minneola, Orlando, Sanguine, Dancy, Satsuma Wase, Beauty, Fairchild and Kinnow. Overall, this productive variety group produced 2- to 4-fold more than levels obtained for crops grown in dry tropical zones.

conclusion

The varietal improvement studies carried out at the Pocquereux research station in New Caledonia highlighted factors that affect performance in about 50 citrus varieties. Oranges and mandarins produced high yields of top quality fruit (internal and external) under the climatic conditions of the present study.

These preliminary results will be useful for guiding New Caledonian citrus growers in choosing varieties that are best adapted to the pedoclimatic conditions of this archipelago.

Table 7
Cumulated yields/tree for mandarin varieties over 3 years.

Variety	3-year cumulated yield (kg/tree)
Minneola SRA 156	517
Orlando SRA 21	477
Sanguine SRA 264	444
Dancy SRA 114	394
Satsuma Wase SRA 230	389
Beauty SRA 261	389
Fairchild SRA 30	388
Kinnow SRA 26	373
Nova SRA 158	337
Ortanique SRA 110	325
Commune SRA 118	313
Satsuma Kowano SRA 167	311
Clémentine SRA 64	306
Clementine SRA 63	303
Clementine SRA 85	302
Clementine SRA 92	298
Satsuma Saigon SRA 225	294
Page SRA 159	281
Fortune SRA 31	281
Kara SRA 165	280
Satsuma St Jean SRA 108	253
Carvalhal SRA 111	246
Osceola SRA 48	238
Wilking SRA 112	235
Swatow SRA 175	218
Lee SRA 49	201
King of Siam SRA 166	186
Murcott SRA 181	186
Malvasio SRA 163	171
Fremont SRA 147	170
Ponkan SRA 234	164
King of Siam SRA 273	145

Photo 2
Mandarin Page SRA 159.

references

GODEFROY J., 1990.
Etude agropédologique de la station fruitière de Pocquereux (Nouvelle-Calédonie). Montpellier, France, IRFA-CIRAD, 132 p. (internal document).

GUILLAUMIN A., 1952.
Les arbres fruitiers en Nouvelle-Calédonie. Fruits 7 (4) : 147-148.

MADEMBA-SY F., 1989.
Comportement de six variétés d'agrumes dans la zone des Niayes au Sénégal. Fruits 44 (4) : 205-213.

MADEMBA-SY F., COTTIN R., 1988.
Comportement de trois variétés d'agrumes sur plusieurs porte-greffe en climat tropical humide. Montpellier, France, Annual meeting of IRFA, document n°17.

ORSTOM, 1989.
Atlas de Nouvelle-Calédonie. Nouvelle-Calédonie : Hachette Calédonie, édition du Cagou, 91 p.

PRALORAN J.C., 1971.
La production fruitière en Nouvelle-Calédonie. Paris, France, Mission report, 80 p.

appendices

Appendix 1
Traits measured on the citrus varieties studied.

Flowering date: corresponding to the Citrus phenological E stage (open flower).

Maturity date: determined according to the dry extract/acid ratio, which was set at 7.5 for oranges and mandarins and 7 for grapefruit.

Flowering-maturity period: from the E stage (open flower) to maturity as determined by the dry extract/acid ratio.

Fruit weight: mean (g).

Yield/tree: mean yield from four trees.

Polar diameter (PD): diameter measured from the base of the peduncle to the apex (mm).

Equatorial diameter (ED): fruit diameter (mm).

Peel thickness: measured from the epicarp to the mesocarp (mm).

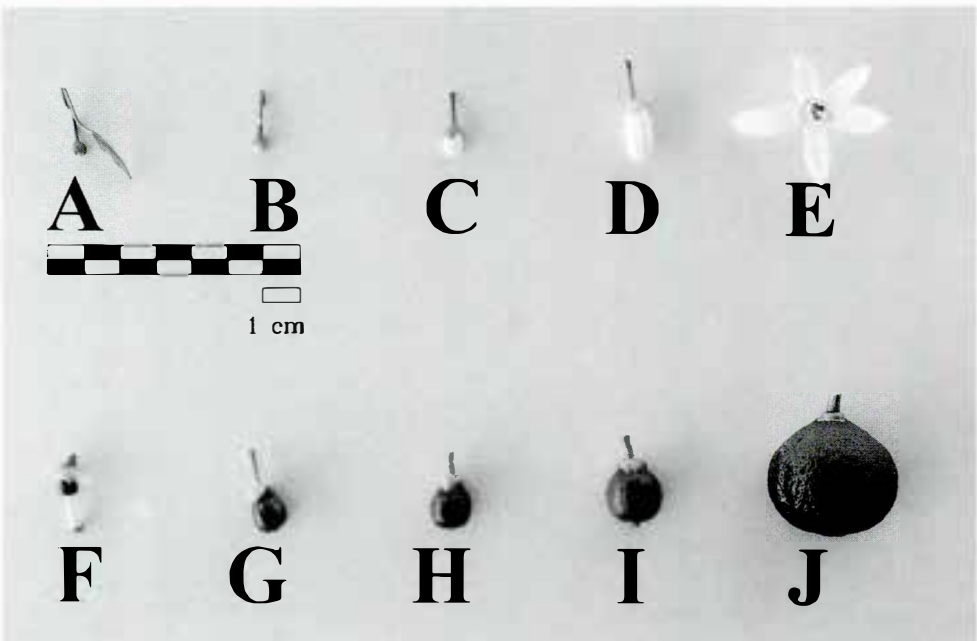
Juice content (SDE): percentage juice relative to the fruit weight.

Soluble sugars: dry extract measured by refractometry (°Brix).

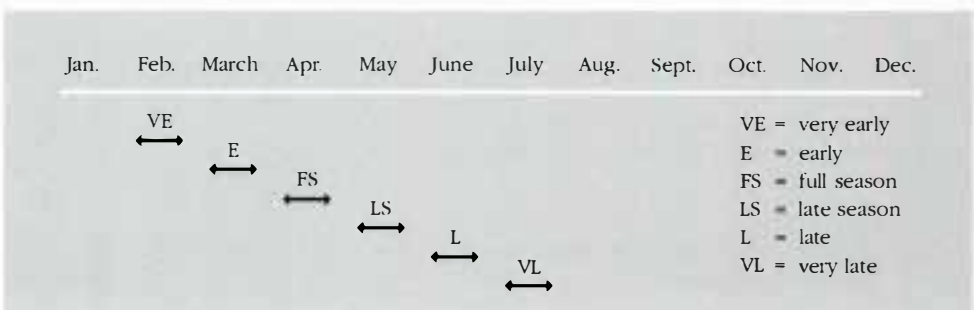
Acidity (A): citric acid content (g) after neutralization with a sodium base (NaOH N/10).

Appendix 2
Citrus phenological stage.

A Green bud
B White bud
C Round bud
D Long bud
E Open flower
F Petal fall
G Style fall
H Fruit-set
I Walnut-size
J Fruit swelling



Appendix 3
Citrus ripening periods in New Caledonia.



Genetic Resources of Mangos in Côte d'Ivoire

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A germplasm repository of the main mango varieties exported worldwide has been set up in northern Côte d'Ivoire. The genetic variability in this collection could be tapped for varietal breeding purposes once all accessions are characterized and their cropping potentials assessed.

Fruits, vol. 49, n°5-6
p. 371-375 (English)
p. 461-463 (French)

the Lataha germplasm repository

varietal inventory

Interesting Florida mango varieties (Kent, Keitt, Palmer, Smith, Zill, Ruby and Valencia) were introduced at the Lataha repository immediately after the station was founded in the Korhogo region of northern Côte d'Ivoire in 1981. This is still acknowledged as being a valid germplasm pool. An experimental orchard was set up in 1982 to test their performance and that of cv Amélie (also known as cv Gouverneur and cv Mangue Greffée), which is common throughout western Africa. At the same time, several other varieties were introduced, including cvs Irwin, Springfield, Miami Late, Tommy Atkins, Broocks, Early-Gold, Haden, Améliorée du Cameroun, Eldon and Beverly.

A project to expand the initial collection with other widely-marketed varieties was undertaken in 1989. There are thus now 137 *Mangifera indica*, *M. laurina* and *M. pelipisan* varieties in the repository; this plant material is listed in Table 1. The collection is still far from being exhaustive since there are 1 100 known *M. indica* varieties and 61 *Mangifera* sp. worldwide; nevertheless it does include all of the 30 or so most common export varieties.

Ultimately, a germplasm repository should contain a wide variety of genetic material that can be used in varietal improvement programmes. It also should be regularly updated and evaluated.

accession origins

The 137 mango varieties in the Lataha repository were collected in nine different countries: Cameroon, Canary Islands, Côte d'Ivoire, Egypt, Guadeloupe, Guinea, Indonesia, Mali and Martinique. These accessions actually originate from Florida, the West Indies, North and South America, Africa and especially Asia.

The poor representation of accessions of Asian origin could be explained by the prevalence of some bacterial diseases (*Xanthomonas campestris*) and the unattractive colour of mangos from this region. However, the genetic variability offered by these varieties, which differ phenotypically from the Florida varieties, could be of considerable interest for varietal breeding programmes. Some Asian varieties produce high yields which are consumed domestically in India (9-10 Mt); few of these are represented in the Lataha repository.

Table 1
List of mango varieties in the Lataha repository in northern Côte d'Ivoire.

Variety	Collection location	Variety	Collection location
Adams	Canaries via Cameroon	Ifac 1	Cameroon
Aéromanis	Mali	Irwin	Côte d'Ivoire (Azaguie)
Ah Pingh	Canaries	Jacqueline	Mali
Alphonse	Mali	Je 4	Guinea
Alphonse de Goa	Mali	Jose	Cameroon
Alphonse Hawai	Cameroon	Julie Lataha	Côte d'Ivoire
Alphonse Pahéri	Mali	Keitt	Côte d'Ivoire
Amééri	Guinea	Kensington	Mali
Amélie	Côte d'Ivoire	Kensington	Cameroon
Amélie Guinea	Mali	Kent	Côte d'Ivoire
Améliorée du Cameroon	Côte d'Ivoire	Linzolo	Mali
Anderson	Canaries	Linzolo	Mali
Auguste	Cameroon	Lippens	Guinea
Bédami Rouge	Mali	Lippens	Côte d'Ivoire
Bédami Vert	Mali	Longo Diego	Mali
Beverly	Côte d'Ivoire	Mabroka	Cameroon
Big Yellow	Canaries	Mabrouck	Côte d'Ivoire
Black	Guinea	Maison Rouge	Reunion
Bombay	Mali	Malembe	Mali
Bombay Green	Canaries	Man	Guadeloupe
Boy Toy 15	Canaries via Cameroon	Mangotine	Mali
Broocks	Côte d'Ivoire	Mangot Vert	Mali
Camayenne	Cameroon	Martin	Guinea
Cambodiana	Cameroon	Maya	Mali
Carrie	Cameroon	Mechouang	Guinea
Cécile	Mali	Miami Late	Côte d'Ivoire
Christian	Mali	*M. laurina*	Indonesia
Coq's Hall	Mali	*M. pelipisan*	Guadeloupe
Crazou	Mali	Mulgo Round	Guinea
Cuisse	Mali	Nimrod	Mali
Dabsha Drahnet	Mali	Noura	Mali
Davis Haden	Mali	Odette	Mali
Diego	Mali	Osteen	Canaries via Cameroon
Divine	Côte d'Ivoire	Paheri	Guinea
Dixon	Mali	Palmer	Côte d'Ivoire
Djibelor	Senegal via Cameroon	Paris	Mali
Djibelor Casamance	Mauritania via Cameroon	Passy Hative	Mauritania via Cameroon
D'or	Mali	Peche	Côte d'Ivoire
Early Gold	Côte d'Ivoire	Peter Passand	Mali
Edward	Guinea	Petit Greew	Guinea
Egypte a	Egypt	Philipino	Canaries
Egypte b	Egypt	Pico	Mali
Egypte c	Egypt	Pirie	Canaries
Egypte d	Egypt	Pomme	Cameroon
Egypte e	Egypt	Pope	Canaries
Egypte f	Egypt	Rachel	Mali
Eldon (1)	Côte d'Ivoire	Romania	Mali
Eldon (2)	Côte d'Ivoire	Ruby	Côte d'Ivoire (Azaguie)
Eldon Ferke	Côte d'Ivoire	Saber	saber
Eugenie	Mali	Sabot	Mali
Fascell	Mali	Sabre	Côte d'Ivoire
Ferke	Côte d'Ivoire	Sabre	Côte d'Ivoire
Florigon	Canaries via Cameroon	Sacabi	Mali
Fraisinette	Côte d'Ivoire	Sans Pareil	Mali
Francis	Mali	Sensation	Côte d'Ivoire
Gabriel	Guinea	Smith	Côte d'Ivoire
Galerie	Côte d'Ivoire	Soudan 2	Cameroon
Gedong	Mali	Springfield	Côte d'Ivoire
Glazier	Mali	Sybil	Mali
Glazier	Cameroon	Taymour	Canaries
Glenn	Canaries	Tolbert	Canaries via Cameroon
Golek	Mali	Tommy Atkins	Mali
Gomera a	Canaries via Cameroon	Tommy Atkins	Cameroon
Gomera 2	Canaries via Cameroon	Tommy Atkins	Côte d'Ivoire
Gomera 3	Canaries via Cameroon	Valencia	Côte d'Ivoire
Gordon	Guinea	Valencia Pride	Canaries
Grosse Rouge	Mauritania via Cameroon	Van dyke	Canaries via Cameroon
Haden	Côte d'Ivoire	Whitney	Cameroon
Haden x Carabao	Mali	Wooten	Guinea
Heart	Mali	Xoi-Cat-Mytho	Mali
Hindibi Sinara	Mali	Zill	Côte d'Ivoire
Hybrides	Côte d'Ivoire	9 c	Mali

varietal characterization

standard varietal description sheets

Mango varieties in the Lataha repository are assessed according to descriptors published by the International Board for Plant Genetic Resources (IBPGR, now IPGRI). The problem is that the Indian team that drew up this report (Anonymous, 1989) determined the descriptors only on the basis of varieties grown in India. Moreover, they did not take into account some traits (e.g. colouring and fruit size) that are unstable in certain environments.

Despite these minor theoretical problems, use of the IBPGR varietal description sheets should become standard practice in order to homogenize the characterization of mango varieties worldwide. The basic description could be supplemented with other details in the light of new research findings. A chapter on the floral biology of the tree, based on studies of the mango collection at Lataha, has therefore been added (Table 2); data on panicles and flowers can thus be recorded.

The mango varieties Amélie, Zill, Kent, Keitt, Valencia, Palmer, Early Gold and Broocks have been described since 1990 using the standard data sheets; cvs Haden, Smith, Ruby, Miami Late and Beverly are now being described.

Systematic use of these varietal description sheets could highlight traits to be modified in breeding programmes.

use of the data

Descriptions of different commonly grown mango varieties should facilitate characterization, between-variety comparisons, genetic distance evaluations, and possibly parentage determinations. In turn, genetic analyses could be conducted on the basis of calculations of correlations between variables, heritability, genetic variability and environmental factors (Perrier, pers. comm.).

The observations are therefore both:
– qualitative, with a theoretical tree representative of the variety taken as the basic unit;
– and quantitative, with data pertaining to one or more trees at a given site.

Table 2
Characters involved in the floral biology of mango trees and which provide information on panicles and flowers. This supplements the criteria considered in the IPGRI character description sheet.

Number of flowers	
Flower colour	(qualitative)
Distribution of flowers on the inflorescence	apex (%), base (%)
Sex ratio per inflorescence part	apex (%), base (%)
Pollen life	(short or average or long)
Pollen germination	(short or average or long)
Stamen-pistil length ratio	
Ovary condition	(description)

varietal improvement

breeding objectives

Breeding objectives are set according to consumers' and producers' needs, which are not always identical. This means that many different criteria have to be taken into account, especially those having an impact on quality.

Fruit quality, a critical parameter for consumers, is obtained by controlling various constraints: grade, organoleptic qualities and appearance of the mango fruit, and also crop protection, shipping and storage qualities. The essential criteria for producers are earliness of producing, yield, harvest regularity and length of this period.

Work involved in breeding programmes based on such criteria requires considerable labour, space and especially time. A mango tree is only considered to be fully mature after 8-10 years growth; the tree has to be another 3-5 years older before these production criteria can be evaluated. Multilocation performance studies should also be carried out in different regions to determine the often considerable influence of the environment (climate, soil, diseases, parasites, etc.) on the phenotypic expression of certain mango characters.

The results of a preliminary quantitative/qualitative study of this type with some mango varieties are given in Table 3.

varietal breeding

controlled hybridization

Only two countries have a structured varietal breeding programme, i.e. India (Sharma, 1987) and South Africa (TOMER *et al.*, 1988).

At the Lataha station (in northern Côte d'Ivoire), a controlled hybridization programme began in 1989 using parents that were selected for specific characters of agronomic interest. Five fruits have been obtained (two ripened) since 1991 using a hybridization technique adapted to local conditions (GOGUEY, 1991). The two pits, from fruits obtained by gamete fusion with cv Amélie (female parent) and cv Early Gold, were successfully sown. Scions were cut from the resulting plantlets after 1-month growth; five trees have now been grown from each of these hybrids at the Lataha station. These trees have not yet flowered or fruited; the long juvenile phase in mango tree development is a hurdle that will have to be overcome by suitable techniques (single-axis growth management, arcure training, etc.).

Hybridization of mango is an especially long process requiring a great deal of precision because of the size of the flowers (4-6 mm), self-fertilization (which automatically emasculates hermaphrodite flowers) and low fertilization rates in this fruit tree. In addition, the resulting hybrids have to be monitored for long periods to assess their agronomic qualities.

open pollination

The so-called random hybridization technique is much easier to set up. It involves sowing a number of pits obtained from fruit of monoembryonic varieties. The sexually-obtained embryo should give rise to a tree producing fruit that differs markedly from that produced by the mother-tree. Many Florida varieties have been obtained in this way, and most of the mangos marketed worldwide are of this origin. Varieties Tommy Atkins, Smith, Springield, Valencia, Zill, Eldon, Osteen and Glenn, for instance, are derived from cv Haden seed; cv Broocks is derived from cv Sandersha, cv Irwin from cv Lippens, cvs Keitt and Haden from cv Mulgoba, and cv Kent from cv Broocks.

About a hundred pits from six monoembryonic varieties (cvs Kent, Valencia, Broocks, Zill, Amélie and Early Gold) have been sown at the Lataha station in Côte d'Ivoire. Following two years of production, the traits of a few trees have been found to clearly differ from those of their mother-trees. The phenotypes of fruit from these variant trees (grade, colour, shape) were assessed visually. Further in-depth studies should be carried out in the coming years to assess the agronomic potentials of these new varieties. If they are found to have interesting quality and yield features, these new genotypes could be vegetatively propagated from adult mother-trees.

conclusion

The Lataha mango germplasm repository in northern Côte d'Ivoire is of interest for evaluating the performances of a wide range of mango varieties in the Sudano-Sahelian climatic environment of western Africa; it is also a useful pool for varietal breeding. The repository will therefore be a natural asset for promoting development of the mango sector in the coming years. ●

references

ANONYMOUS, 1989.
Descriptors for mango. Rome, Italy, IBPGR, 22 p.

GOGUEY T., 1991.
Collections établies en Afrique de l'Ouest et sur le réseau IRFA. Korhogo, Côte-d'Ivoire, Annual meeting of IRFA n°66, 21 p.

SHARMA D.K., 1987.
Mango breeding. *In*: Acta Horticulturae, number 196 : 61-67.

TOMER E., SNYMAN J.C., MULLINS P.D.F., 1988.
Mango selection at the CSFRI and recommendations for a breeding programme. Nelspruit, South Africa, CSFRI, 4 p.

Table 3
Internal and external features of a few mango varieties.

		Fruit							Pulp						Pit				
Variety	**Harvest**	**Long. (cm)**	**Width (cm)**	**Thick. (cm)**	**Weight (g)**	**Shape**	**Colour**	**Appear (*)**	**Taste (*)**	**Fibres (*)**	**F. long. (*)**	**Pulp (%)**	**Pulp waste**	**Peel thick. (mm)**	**Long. (cm)**	**Weight (g)**	**Fibres (*)**	**F. long. (*)**	**Storage life (d)**
Beverly	Season	11.1	8.9	8.8	487	Round	"Red"	7	6	4	7	70.0	2.30	0.48	8.5	51	5	9.0	30
Miami Late	Late	12.2	10.1	9.3	625	Round	"Mixed"	5	4	2	5	60.3	1.52	0.44	9.5	49	5	2.6	30
Ruby	1/2 early	9.3	6.1	5.6	189	Long	"Red"	7	7	3	5	72.4	2.63	0.52	7.7	22	7	7.7	20
Broocks	Late	11.3	7.7	7.2	315	Oblong	"Green-yellow"	2	3	7	5	55.5	1.25	0.52	9.3	53	6	7.5	35
Keitt	Late	12.5	9.7	7.8	465	Round	"Mixed"	6	7	6	6	66.0	1.94	0.72	10.7	39	6	8.4	35
Valencia	Season	13.9	67.8	6.9	415	T. oblong	"Mixed"	6	7	7	7	67.5	2.10	0.53	11.7	43	6	7.5	25
Zill	Early	9.1	7.3	6.6	345	Round	"Red"	7	8	7	7	62.9	1.70	0.71	6.5	30	5	3.9	20
Kent	Early	12.2	10.6	9.6	470	Round	"Red"	8	8	1	4	72.5	2.64	0.47	9.9	48	4	4.6	30
Palmer	Season	14.8	8.5	7.8	483	Oblong	"Purple"	6	6	8	8	45.6	0.84	0.50	12.6	86	5	4.2	30
Early Gold	1/2 early	12.8	8.1	7.1	365	Oblong	"Red"	8	7	4	7	63.1	1.71	0.30	9.0	41	5	4.3	25
Amélie	Early	10.4	8.4	7.2	371	Round	"Orange"	5	8	3	3	75.2	3.03	0.66	7.3	17	4	2.3	30

(*) Data correspond to a variety rank (scale from 1 to 20).

Management of Litchi Genetic Resources in Réunion

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p. 464-468 (French)

A litchi germplasm repository was set up in Réunion to diversify litchi crops and provide a basis for breeding programmes. Fruit and floral descriptors were determined to characterize litchi varieties.

introduction

Litchis (*Litchi chinensis* Sonn.) were first brought to Réunion (Indian Ocean, 21°20' latitude S, 55°25' longitude E) by Pierre Poivre in 1779. They were cropped on the island throughout the 19th century; there are now more than 1 000 ha of litchi orchards, making it the most widely grown fruit crop in Réunion.

These orchards are mainly cropped with cvs Kwaï-Mi and Taï-So, which produce excellent-flavoured litchis that are suitable for both domestic and export markets. There are also some so-called "cv Litchi Toupie" trees that produce a spinning-top shaped fruit with an aborted pit.

The shortness of the production period could be explained by the lack of diversity in litchis of Réunion, mainly due to the conventional use of the air marcotting technique for propagating this fruit. Litchis are harvested from late November to mid-January because the climate differs on the windward and leeward sides of the island. In addition, there are several drawbacks concerning cv Kwaï-Mi, i.e. the fruit does not stand up well to cyclonic winds, it shows marked biennial bearing and high vigour.

CIRAD-FLHOR has set up a litchi germplasm repository at different locations in Réunion with the aim of broadening the varietal base and minimizing drawbacks that arise as a result of monocropping cv Kwaï-Mi. The following features are being sought:

– lengthening the production period,
– improving resistance to cyclonic winds,
– reducing biennial bearing,
– increasing fruit quality and storage potential.

This repository provides a litchi pool that is utilized for varietal breeding programmes whose results have a direct impact in the field. Varietal descriptions are also under way with this plant material.

setting up the litchi repository

accession origins

The first mass introduction of litchi varieties took place in 1985 with 26 different varieties that had been imported from Australia, India and the Seychelles.

Other varieties were introduced after being collected in various countries, i.e. Bali, Hawaii, Mauritius, New Caledonia and Thailand.

These litchi varieties were generally introduced in the form of suckers and scions, and less commonly as seeds.

Eleven different varieties producing fruit that differ from that of cv Kwaï-Mi were obtained in surveys conducted in Réunion (Normand, 1990a).

Table 1 provides a list of the different varieties and their origins.

locations of litchi introductions

The first litchi introductions in Réunion took place in 1986 at Bassin-Plat on a 150 m elevation site in the southwestern part of the island. There were further introductions on this plot in 1989, with varieties of Hawaiian origin, and in 1990, with varieties collected in a local survey.

In 1990, the collection was partly duplicated at Bassin-Martin (Réunion), on a 300 m elevation site in the same part of the island.

In 1993, a few selected varieties were planted on a smallholder's farm, as part of a CIRAD research programme funded by ODEADOM to investigate litchi cropping under real field conditions. This site is at 300 m elevation in the southeastern part of the island (Sainte Rose).

A number of varieties planted in 1986 have been flowering and producing since 1988. Flowering was also noted in 1992 on trees planted in 1990.

Table 1
List and origins of litchi varieties in the CIRAD-FLHOR repository in Réunion.

Variety	Origin	Variety	Origin
Kwaï-Mi	Réunion	Borsworth	Australia
Gros fruit (2)	Réunion	Salathiel	Australia
Lisse (2)	Réunion	Thailand	Australia
Lisse coeur	Réunion	Wai Chee	Australia
Piquant (2)	Réunion	Brewster	Australia and Hawaii*
Tardif	Réunion	Groff	Australia and Hawaii*
Toupie (3)	Réunion	Haak Ip	Australia abd Hawaii*
Violet	Réunion		
Litchi X	Réunion	Takafuji	Hawaii
Litchi Y	Réunion	Kwaï Mi Hawaii	Hawaii
		Kawai	(Hawaii)?
A1	Seychelles		
B3	Seychelles	Emperor	Thailand
C4	Seychelles		
D1	Seychelles	Bali Planteur	Bali
D2	Seychelles		
E7	Seychelles	Mauritius	(Mauritius)?
G2	Seychelles	Kwaï Mi Maurice	(Mauritius)?
PDM	Seychelles		
		Litchi Nlle-Caléd.	New Caledonia
Calcutta	India		
Dehradum	India	Kwaï Mi Nialo	
Muzzafapur	India	Kwaï May Pink	
Saharampur	India	Soueytong	
Rose Scented	(India)?	Hueng Lai	
Seedless Late	(India)?		
Bengal	(India)?		

(n) Number of varieties
* Variety introduced as seed

varietal breeding

selection criteria

There are only one, two or three trees representing each variety in the repository, thus fruit quality and earliness of harvest were the main characters that could be selected. Some agronomic features could also be taken into consideration, e.g. earliness of production, tree vigour, graft compatibility on cv Kwaï-Mi, shortness of the fruiting period and productivity. However, the degree of reliability of the results could not be assessed because of the low number of trees/variety tested. Detailed and more statistically-valid analyses of these characters will thus be carried out in the future in experimental orchards cropped with improved varieties.

fruit quality

Fruit quality was defined by the following criteria:
– mean fruit weight,
– fruit size,
– fruit flavour,
– percentage of different fruit components (shell, aril, pit),
– adhesiveness of the shell to the aril, and the aril to the pit,
– shell and aril colour,
– juice acidity and dry extract,
– aril moisture content.

Analyses were conducted with 11 varieties in 1989, including Kwaï-Mi (NORMAND, 1990b), and 17 varieties in 1991 (BERTIN, 1992).

harvest dates

Earliness of the harvest is an essential consideration for evaluating the spread of the production period. Litchi producers seek early varieties to be able to supply world markets before competing litchi-producing countries in the region, i.e. Madagascar and Mauritius. Late varieties are a drawback because they produce during the cyclone period, which can lead to considerable crop losses.

analysis of tested criteria

The percentages of aril and pit, the main factors studied in the two analyses, were similar in 1989 and 1991 (Table 2). These important qualitative parameters did not seem to vary between years at a given site.

Table 2
Aril and pit percentages for the different varieties in 1989 and 1991.

Variety	Percentage aril		Percentage pit	
	1989 (*)	1991 (**)	1989 (*)	1991 (**)
Kwaï-Mi	75.2	70.0	10.3	12.8
Kwaï May Pink	64.5	67.5	11.7	11.0
Thailand	62.4	56.5	10.1	25.5
Calcutta	62.7	62.4	15.6	15.6
Bengal	49.7	56.2	18.7	20.4
D2	57.5	60.4	14.1	14.6
Brewster	52.9	56.7	18.1	21.3

(*) Normand, 1990b (**) Bertin, 1992

The harvest dates for varieties that yielded in 1988 and 1989 (NORMAND, 1990b) and 1991 (BERTIN, 1992) in the Bassin-Plat collection indicated that:

- most of the varieties produced during the first half of December at Bassin-Plat, i.e. almost the same time as Kwaï-Mi, which meant a harvest-date gain of only about 10 days over Kwaï-Mi (Seychelles variety D2, cvs Dehradum, Mauritius and Kwaï May Pink);
- only a few varieties were found to be very early (cv E7 (Seychelles) - mid-November harvest; cv B3 (Seychelles) and cv Bali-Planteur - late November harvest) or very late producers (cv Calcutta - early January harvest).
- harvest dates varied substantially between years, but the spread of the harvest period was not modified for extreme varieties (i.e. very early or late), and only slightly modified for other varieties. This variable is therefore a valid selection criterion.

breeding interesting varieties

Multivariate analyses involving the main quality variables highlighted groups of varieties with similar characteristics (BERTIN, 1992), these were:

– cv Dehradum, cv PDM (Seychelles) and cv Haak Ip: very high quality varieties with high fruit weights, low pit and high aril percentages, and very flavourful fruit;
– cv B3 (Seychelles) and cv Bali-Planteur: with an early harvest date, average acidity and aril percentage;
– cvs Muzzafapur, Rose Scented and Thaïland: with low aril and high pit percentages, and low fruit weight.

All other varieties were shared between these groups.

The results revealed:

- varieties with interesting characters: Dehradum, Haak Ip, Kwaï-Mi, Kwaï May Pink, Soueytong, Mauritius, Bali-Planteur and three varieties from the Seychelles (B3, D2 and PDM). The local variety Kwaï-Mi was high in this classification. Two varieties were markedly better than the others, i.e. PDM (Seychelles) and Haak Ip, especially in terms of fruit flavour;
- varieties with characters of little interest for cropping in Réunion: Thaïland, Brewster, Saharampur, Calcutta, Muzzafapur, Rose Scented and Bengal. Note that several of these were of Indian origin.

The best varieties, i.e. Haak Ip, PDM (Seychelles), Dehradum and Kwaï May Pink, will be planted in experimental orchards for varietal comparisons with cv Kwaï-Mi. Production processes of new varieties in the collection will be monitored to add to the present results and determine a set of interesting varieties to improve litchi cropping in Réunion.

varietal characterization

historical background

Litchis are originally from southeastern China. The qualities of this fruit have been renowned for centuries in this country and the first descriptions were Chinese (LIANG, 1981). Chinese names for litchi varieties are very imaginative, but often ignored or changed when they are introduced outside of China: the Chinese name is sometimes translated, for instance cv Hei Ye, means "black leaf", which is its varietal designation in USA; sometimes the original phonetics are kept but the

spelling is changed, e.g. cv Haak Ip comes from the Chinese "Hei Ye", and cv Tai So is derived from "Da Zao"; sometimes the accession is named after the person who first introduced it, such as cvs Groff and Brewster.

Moreover, litchis were long ago introduced in India; this country is probably the second centre where the species diversified. Many litchi varieties have Indian names and it is often quite difficult to determine whether a variety is of Indian or Chinese origin.

There is indeed a great deal of confusion concerning litchi variety names and a detailed morphological description of each variety is necessary to supplement studies on the origins of the present variety names.

Characters that are most often used to identify litchi varieties pertain to fruit descriptions (BATTEN, 1984; ANONYMOUS, 1985; MENZEL and SIMPSON, 1986). They can be associated with vegetative characters to describe the most commonly marketed varieties. SINGH and SINGH (1954) introduced inflorescence-related characters in their descriptions of Indian litchis. However, current descriptions are incomplete and deal chiefly with production; they provide little information to clarify the taxonomy.

research under way in Réunion

CIRAD-FLHOR studies conducted in Réunion since 1989 have focused on fruit characters and, more originally, floral characters. There are several reasons for this choice:
– flowers are commonly used in determination keys,
– floral characters are often the most stable types in various environments (HILU, 1989),
– no detailed studies have been undertaken to date on litchi flowers,
– litchi varietal characterizations could be performed from the flowering stage, which is earlier than the harvest stage.

fruit descriptors

The litchi fruit descriptors defined by NORMAND (1990b) can be divided into two groups (Table 3):
– fruit quality descriptors which are a prime consideration for varietal breeding; these were described above;
– taxonomic descriptors; to unify the descriptions (shapes of fruit, segments and protuberances), these descriptors are generally in line with the conditions set out by MENZEL & SIMPSON (1986). However, some other characters have been added, including the shell suture line and the pit.

These data were recorded for litchis collected in a local survey (NORMAND, 1990a), and for varieties that began fruiting in 1988 (NORMAND, 1990b; BERTIN, 1992).

floral descriptors

NORMAND *et al.* (1990) defined 22 quantitative and qualitative floral descriptors, which are divided into three groups:
– general flower characters, irrespective of the flower type (male or female),

Table 3
List of fruit descriptors used to characterize litchi varieties.

Organ	Descriptor
Whole fruit	Shape of fruit, shoulders[1], apex[2] Dimensions: length, diameter 1[3], diameter 2[4] (mm) Mean fruit weight (g) Percentage of twinned fruit[5] Suture line on the fruit: marked, barely visible, undetectable Percentage of different components: shell, aril, pit
Shell	External colour at maturity Internal colour at maturity Thickness (mm) Protuberances: general shape[2], length and width at the base, height, number/cm^2
Aril and juice	Shell-aril adhesion: strong, average, weak Aril-pit adhesion: strong, average, weak Colour Soluble dry extract at maturity (E) in °Brix Acidity at maturity (A) in meq/100 ml E/A Flavour Moisture content (% fresh weight)
Pit	Pit description: shape, colour Dimensions: height, diameter 1[3], diameter 2[4] Percentage aborted pits

(1) swelling at the peduncle
(2) see MENZEL and SIMPSON (1986)
(3) diameter along the suture line axis
(4) diameter perpendicular to diameter 1
(5) fruit with both ovaries developed, thus forming a double-joined fruit

– characters and conditions specific to male flowers,
– characters and conditions specific to female flowers.

The flower sampling and monitoring techniques for measuring quantitative characters are described by NORMAND *et al.* (1990).

These data were recorded for 11 varieties in the Bassin-Plat collection in 1989 (NORMAND *et al.*, 1990) and for 36 varieties, including 23 from the Bassin-Plat collection and 13 from the young Bassin-Martin collection, in 1992 (COMMON, 1993).

data management

The quantity of fruit and flower data recorded is very important, and they should be computerized for efficient management. The LITAID software program was developed by the CIRAD-FLHOR biometry service (NORMAND *et al.*, 1990). It is a derivative of the MUSAID program that was designed to manage morphotaxonomic data and provide an identification aid for banana (PERRIER & TEZENAS DU MONTCEL, 1988).

LITAID has the same two main functions as MUSAID:
– fruit and flower data can be managed;
– it is an identification aid which enables the operator to match an unknown plant with an already identified and described variety, with a reasonable margin of error.

The operating principle is the same as that of MUSAID. The unique aspect is that each descriptor is provided with an error matrix, weighting it relative to its reliability. A descriptor with two distinct stable conditions will thus have a low error function; in contrast, when two or more conditions are difficult to distinguish or are not very stable, the error function will be higher.

Determining the error matrix for each descriptor is a critical step because it clearly specifies the degree of reliability and quality of identifications for unknown plants.

After the second set of observations in 1992, these error matrices were refined as a function of the descriptor reliability and stability results. It seems that quantified descriptors are generally only useful for comparisons of extreme values (COMMON, 1993).

LITAID has a no-answer function which enables identifications with only a few descriptors.

The program includes a module to calculate phenotypic distances; this is the mean distance between two individuals, for all descriptors, weighted by the associated error functions. This distance is not a real distance in mathematical terms, because at zero there is no probability in the matrix. The distance only indicates the extent of convergence or divergence of the studied character for two individuals within the reliability limits of these characters.

varietal choices

validity of some floral characters

The initial flower results highlighted some intervarietal diversity in the floral characters (Photo 1), which led to the development of a determination key for the 11 varieties studied (NORMAND *et al.*, 1990). The first two dichotomies of this key are based on two stable characters, stamen number and colour of the nectariferous disk, under clear-cut conditions; they are also independent of the flower type and easy to monitor.

Following the second set of observations (COMMON, 1993), the validity of the descriptors was assessed by studying flowers of certain varieties grown at the same site (Bassin-Plat) at 3-year intervals, and at two different sites (Bassin-Plat and Bassin-Martin) during the same year.

Comparisons of descriptions of the same variety for different years and different sites revealed the high stability of two characters, i.e. the colour of the nectariferous disk and the anther shape. Other characters were found to be relatively stable, i.e. anther length on male flowers, stamen number and calyx colour (COMMON, 1993).

The conditions associated with each variable were also defined in further detail on the basis of the latter results.

determining groups

Three groups were determined on the basis of the calculated phenotypic distances between 22 varieties from the Bassin-Plat collection (COMMON, 1993).

Two very close groups, which differ in terms of the colour of the nectariferous disk, are formed by Kwaï-Mi type varieties: one includes cvs Kwaï-Mi, Kwaï-Mi Maurice, Kwaï-Mi Nialo, Takafuji, B3 (Seychelles), and three locally-collected varieties (cvs Gros Fruits n°2, Litchi Tardif and Litchi Piquant); the other includes cvs Mauritius, PDM (Seychelles), Haak Ip and Dehradum.

The third group comprises three varieties of Indian origin, cvs Calcutta, Bengal and Rose Scented.

Although incomplete, since only the floral characters were taken into account, the present results are of interest for the study of genetic resource diversity in litchi. Moreover, varieties that were grouped on the basis of their highly convergent floral characters also had similar fruit characters. The fruit produced by varieties Kwaï-Mi Maurice, Kwaï-Mi Nialo, B3 (Seychelles), Gros Fruits n°2 and Litchi Tardif, classified in the first cv Kwaï-Mi related group, was similar to that produced by cv Kwaï-Mi and only differed in their sizes and mean fruit weights. The fruit of cv Takafuji has not yet been studied. The locally-collected cv Litchi Piquant was the only one of this group to differ markedly from cv Kwaï-Mi in terms of fruit and leaf characters.

Similarly, in the second group, cvs PDM (Seychelles), Haak Ip and Dehradum have already been grouped according to fruit-related criteria considered for varietal breeding purposes.

prospects

At various locations in Réunion, CIRAD-FLHOR has a large repository of litchi varieties of different origins. The first accessions have already been bred to produce four hybrids of the same quality as the local variety Kwai-Mi, but they can be harvested slightly earlier.

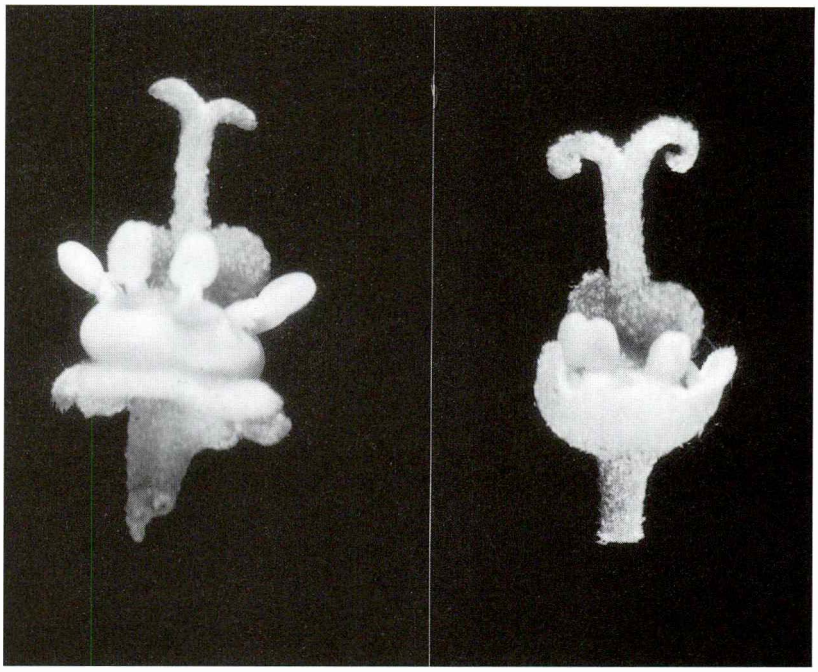

Photo 1.
Female flowers for cv Kwaï-Mi (left) and a variety from the Seychelles (right). Note the marked morphological differences in the shape of the calyx, protuberance of the nectariferous disk, length of the stamen filaments, length and shape of the stigma.

Varietal studies using fruit and floral descriptors are currently under way. This work is facilitated by the LITAID software program that was designed to manage morphotaxonomic data and to serve as an identification aid. It now handles flower and fruit data for several varieties. Groups can be determined on the basis of the stable reliable floral descriptors.

One of the main objectives now is to enhance the characterizations with new phenotypic, vegetative and inflorescence descriptors, and with biochemical markers.

The current system could be optimized and utilized by:
– reducing the number of descriptors used in flower studies,
– analysing the results already obtained on fruit and on fruit/flower combinations,
– comparing local results with those obtained elsewhere in the world,
– building up the reference data bases.

New litchi varieties should be rationally introduced in Réunion to enable continuous selection of well-adapted varieties and broaden the scope of varietal characterization research.

Description sheet LITAID CIRAD-FLHOR	section	: Litchi
	species or group	: *Litchi*
	s/species or s/group	: *chinensis*
	form or cultivar	: Kwai Mi ( )

COLLECTION: P92 number code 1 1 1 11

General Flower Characters

1	Date of onset of flowering	: Normal	(Ref.: Kwaï Mi)
2	Date of bud burst	: Normal	± 10 days
3	Calyx colour	: Green	
4	Hairiness	: Downy	
5	Sepal shape	: Pointed	
6	Sepal suture	: United	
7	Nectariferous disk colour	: Orange	
8	Anther shape	: Wide	0.7 < L/L
9	Number of stamens	: 6 or 7	
10	Peduncle length (mm)	: Average	0.30 < h ≤ 0.65

Male Flowers

11	Calyx size (mm)	male fl	: Average	3.0 < d ≤ 3.5
12	General shape	male fl	: No answer	
13	Boll shape	male fl	: Bell	
14	Boll constriction	male fl	: No	
15	Position of nect. disk	male fl	: Not enclosed	0 < h
16	Disk protuberance	male fl	: Protuberant	0.25 < h ≤ 1.00
17	Filament length (mm)	male fl	: Average	3 < L ≤ 4
18	Anther length	male fl	: Average	1.10 < L ≤ 1.25
19	Peduncle colour	male fl	: Pink	
20	Ovary length	male fl	: Long	0.4 < L
21	Ovary width	male fl	: Wide	0.9 < l
22	Stylus length (mm)	male fl	: Very long	1.20 < L
23	Stylus colour	male fl	: Greenish	

Female Flowers

24	Calyx size (mm)	fem fl	: Large	3.5 < L ≤ 4
25	General shape	fem fl	: Bowl	
26	Boll shape	fem fl	: Bell	
27	Boll constriction	few fl	: No	
28	Position of nect. disk	fem fl	: Not enclosed	0 < h
29	Disk protuberance	fem fl	: Barely protuberant	h ≤ 0.25
30	Filament length (mm)	fem fl	: Short	L ≤ 1.0
31	Anther length	fem fl	: Short	L ≤ 1.15
32	Peduncle colour	fem fl	: Greenish	
33	Ovary length	fem fl	: Short	L ≤ 0.7
34	Ovary width	fem fl	: Narrow	l ≤ 1.2
35	Stylus length (mm)	fem fl	: Short	L ≤ 1.8
36	Stylus colour	fem fl	: Greenish	
37	Stigma length (mm)	fem fl	: Average	1.2 < L ≤ 1.8
38	Stigma shape	fem fl	: Bent	
39	Stigma shape	fem fl	: Greenish	

Figure 1
Description sheet for cv Kwaï-Mi floral characters produced by the LITAID software program.

references

ANONYMOUS, 1985.
An Album of Guangdong Litchi Varieties in Full Colour. Guangdong, Chine, Guangdong Provincial Agricultural Commission, Guangdong Provincial Scientific and Technical Commission, 78 p.

BATTEN D., 1984.
Lychee varieties, Agfacts H 6.2.7. Dep. Agri. N.S.W. 15 p.

BERTIN L., 1992.
Le litchi à la Réunion : possibilités d'amélioration des exportations. Mémoire de fin d'études. ISTOM - CIRAD/FLHOR Réunion, 52 p. + annexes.

COMMON J.H., 1993.
Contribution à l'identification variétale chez le litchi (*Litchi chinensis* Sonn.). Analyse des caractères morphotaxonomiques floraux. Mémoire de fin d'études ISTOM CIRAD/FLHOR Réunion, 41 p. + annexes.

HILU K.W., 1989.
Taxonomy of cultivated plants. IBPGR Training Courses: Lecture Series 2, Scientific Management of Germplasm: Characterization, Evaluation and Enhancement. H.T. Stalker et C. Chapman, IBPGR, Rome, Italy, p. 33-40.

LIANG J., 1981.
Le litchi, origine, utilisation et développement de sa culture. Jour. d'Agric. Trad. et de Bota. Appl. XXVIII (3-4) : 259-269.

MENZEL C.M., SIMPSON D.R., 1986.
Lychee cultivars - Description and performance of major lychee cultivars in subtropical Queensland. Queensland Agricultural Journal : 125-136.

NORMAND F., 1990a.
Compte-rendu de la prospection locale de litchis 1988. LI-RE n° 38, IRFA-Réunion, 8 p., internal document, ARC 20-002.

NORMAND F., 1990b.
Deux ans d'observation de la collection de litchis Réunion BPL07. LI-RE n° 39, IRFA - Réunion, 22 p., internal document, ARC 20-001.

NORMAND F., BOUFFIN J., PERRIER X., HUAT J., 1990.
La reconnaissance variétale chez le litchi (*Litchi chinensis* Sonn.) à l'aide de caractères floraux, IRFA Réunion, 10 p., internal document, ARC 20-265.

PERRIER X., TEZENAS du MONTCEL H., 1988.
MUSAID: a computerized determination system. In : Proceedings of INIBAP workshop, Los Baños, Philippines, 5-7 September 1988. Ed. Jarret, 218 p.

SINGH L.B., SINGH U.P., 1954.
The litchi. Saharanpur, Inde, Lucknow, U.P., 87 p.

Inventory of Tropical Fruit Trees in Central America and the West Indies

G. Barbeau
Projet fruitier régional
MAE/IICA
Trinidad and Tobago

Fruits, vol. 49, n°5-6
p. 383-389 (English)
p. 469-474 (French)

There is a broad range of tropical fruit genetic resources in Central America and the non-French West Indies. Some relatively isolated species could be developed.

introduction

Many different tropical fruit species were brought to the non-French West Indies from India, Indonesia, Central and South America during the colonial period. Although some of these species have only a curiosity value, others are now of economic importance.

Central America was long the private ground of Spain and other foreign powers had but temporary and geographically limited effects in the region. Some fruits, such as citrus and mango, only recently infiltrated this area from the West Indies. The plethora of local fruit resources compensated for this unfortunate isolation.

Some Caribbean countries (Guyana, Surinam, Trinidad), because of their geographical positions, also have genetic resources native to the Amazon region. A number of locally-appreciated species have yet to be investigated in detail.

Knowledge of fruit genetic resources is essential for the development of agricultural diversification programs. Various factors such as deforestation and financial shortages are threatening the survival of some species. A germplasm inventory of fruit trees from Central America and the non-French West Indies is now available; this is an important step towards the conservation and utilization of this plant material.

Anacardiaceae

mango

Mangos were introduced in Brazil in the 17th century and then they slowly infiltrated the West Indies and Central America, where *Mangifera indica* is the only species present.

There are now very many cultivars in Central America, the Greater Antilles and especially the Dominican Republic that were obtained by seed propagation of monoembryonic varieties.

There is not so much diversity in the Lesser Antilles, despite the variety of types; cv Julie is dominant in many areas.

There is more diversity in the south. In the 17th and 18th centuries, English and Dutch colonialists introduced many Indian varieties (in Trinidad and Guyana) and Indonesian varieties (in Guyana and Surinam). Mango varieties adapted to a broad range of ecological conditions, from zones with a marked dry season in the southwestern coastal region of Trinidad to the wet tropical conditions of Surinam, can now be found. This resource potential would be interesting to tap, particularly to obtain varieties resistant to anthracnose and fruitflies. In Trinidad, this promising potential is highlighted by the fact that mangoes are rarely infested even though 16 different *Anastrepha* fruitfly species are present and ready to infest a variety fruit species.

A limited list of mango varieties found in Trinidad, Guyana and Surinam is given in Table 1.

cashew

Cashew (*Anacardium occidentale*) originates from tropical regions of the Americas. It is well adapted to Central American and West Indian areas with a marked dry season. They are cropped in

Table 1
Varieties of mango (*Mangifera indica*) found in Trinidad, Guyana and Surinam.

Trinidad	Guyana	Surinam
Alphonso	Bombay	Aromanis
Axe	Buxton spice	Buxton spice
Buxton spice	Colonial Bank	Cayenne
Calabash	Dor	Goleth
Ceylon	Graham	Julie
Cheese	Hard spice	Pandiet
Coden	Julie	Roodborstje
Doux douce	Number 11	Teté, etc.
Graham	Peter	
Julie	Primrose	
Long	Sand spice	
Peach	Vauraj, etc.	
Sandersha		
Starch		
Vert		
Zabricot, etc.		

commercial plantations in Salvador and Panama and in a small orchard in Trinidad. Improved varieties from Brazil were introduced in Nicaragua in the 1970s, and in Saint Lucia more recently. They are currently being bred, especially for anthracnose resistance, in Panama and Trinidad. In a germplasm repository in Salvador, there is a type that produces a black false fruit! The species is commonly found growing wild on plateaus and white sandy savannas of Guyana, and cashew nuts represent a considerable resource for local Indians.

Spondias species

The Spanish plum (*Spondias purpurea* L.) is very common on the Pacific coast of Central America and in regions of the Greater Antilles with a very marked dry season, its preferred environment. It is a wide-crowned upright tree.

About a dozen different types are known and have been propagated by smallholders. It is easily propagated from large branch cuttings at the end of the dry season, thus explaining why they are used for fence posts by farmers. Red plums are abundant during the dry season, but unfortunately this fruit is often infested with fruitfly larvae (*Anastrepha* spp.); these pests, however, are not present in Grenada or Saint Vincent.

A close species, the red mombin (*S. mombin* L. = *S. lutea*), is a tall slender tree that produces clusters of yellow fruit during the rainy season. In Central America, the fruit is cooked before consumption. It grows better in wet tropical areas and is found in natural forest stands in Trinidad, Guyana and French Guiana. In Surinam and Guyana, the fruit is harvested and used to produce fresh juices that are sold in restaurants and by street vendors.

The ambarella (*S. cytherea* Sonner), from Polynesia, is another species of this genus that should be mentioned. It is not very common in Central America, but is widespread in the Antilles, and some small countries such as Grenada and Saint Vincent now export ambarellas (mainly to Trinidad and Canada). Small volumes are also exported to UK and the Netherlands. A varietal breeding programme is under way in Grenada. There is an interesting and promising dwarf type from Southeast Asia that has been introduced in Trinidad.

Annonaceae

This family is well represented in Central America and the West Indies and many important species originate from these regions. Soursop (*Annona muricata* L.) and custard apple (*A. squamosa* L.) are common garden species. There are commercial soursop orchards in Costa Rica, Panama and Surinam. It is abundant in Grenada and Saint Vincent where it is grown in gardens or intercropped; Trinidad is the main export market. Varietal improvement of soursop is under way in a few countries, including Costa Rica.

Other less common Annonaceae species are garden crops or grow subspontaneously, including the Guatemalan annona or papauce (*A. divesifolia* Safford) and bullock's heart (*A. reticulata* Mill.). The former species produces large delicious pinkish-green fruit, which unfortunately tends to crack during ripening, making it susceptible to ant infestation. The latter species produces smooth yellowish-red fruit and is hardier and very drought resistant; it is sometimes used as rootstock for soursop.

Soncoya (*A. purpurea* Moc. and Sessé) is much less common. This self-sown species is found in natural forest stands of Central America and Trinidad. It has very large leaves and orange-fleshed fruit covered with pyramid-shaped protuberances. As *A. reticulata*, it has graft-compatibility with soursop and can therefore be used as rootstock for this species.

Note that pond apples (*A. glabra* L.) are often found in wet habitats and sometimes used as rootstock for corossol in poorly drained areas.

In addition, there are other yet uninvestigated species of this genus in Central America and the West Indies (*A. montana* Macfad., *A. scleroderma* Saff., *A. paludosa* Abul., etc.).

Another genus, *Rollinia*, is also present and grown for its fruit. Biriba (*R. deliciosa* Saff. = *R. pulchrinervia* DC.) is a garden crop in Trinidad, with several endemic species in Guyana and French Guiana, including *R. mucosa* Baill. and *R. pulchrinervia* A. DC..

Unfortunately, many annona fruit crops are plagued by weevils (*Cerconata anonella, Bephrata maculicollis*), whose larvae attack the seeds and cause fruit rot. This is not yet a problem in Grenada and Saint Vincent.

In response to a request by Andean countries, the International Plant Genetic Resources Institute (IPGRI), which is based in Palmira (Colombia), intends to begin a project on Annonaceae species.

Guttiferae

The mangosteen (*Garcinia mangostana* L.) is relatively unknown in Central America and the West Indies. To our knowledge, there has only been one mangosteen orchard (about 4 ha; 50 years old) in these regions; this was at Cukra Hill, on the Atlantic coast of Nicaragua, which might have been destroyed by cyclone Johan in 1988. This species is also present at Lancetilla (Honduras). We were quite surprized to come across several stands of old mangosteens in Trinidad; they are flourishing and seem to be quite productive. The Trinidad Ministry of Agriculture has set up nurseries to propagate this species.

Other *Garcinia* species have been found growing wild, and in botanical gardens and private collections, especially in Salvador, Nicaragua and Trinidad. They are difficult to identify.

Lauraceae

Avocado (*Persea americana* Mill.) originates from Central America and the West Indies. There is a wide range of types in these countries since each tree propagated from a pit is actually unique. The species has a high degree of plasticity considering the fact that there are three races, with many intermediary hybrids, adapted to various ecological conditions. It is quite possible to select economically-interesting new cultivars from wild forms; many countries are thus propagating their own improved varieties for domestic and sometimes export markets. A few examples are given in Table 2.

Avocado harvests could be extended throughout the year by promoting some of these locally-improved varieties, producers would thus be able to meet the domestic market demand.

In Central America, many so-called wild types have been grouped together under the umbrella of *Persea schiedeana* Ness.. Californian research scientists have conducted many studies on these populations, seeking forms that are resistant to collar rot (*Phytopthora* spp.).

Lecythidaceae

Brazil nuts (*Bertholletia excelsa* Hum. and Bon.) and other similar nuts (*Lecythis*

Table 2
Varieties of avocado (*Persea americana* Mill.) obtained in local breeding programmes.

Nicaragua	Guyana	Dominican Republic
Apante	Chanasue	Gripina 12
Campos azules	Hercules	Gripina 5
Chalet	Hosororo 5	Meléndez 2
Laura	Hosororo 6	Semil 31
Mangeño	Khan	Semil 34
Masatepe	Mahabir	
Moyeño	Matthew's Ridge	
Rosario	Pierre	
Silva		
Ticomo		

zabucajo Aubl., *Lecythis elliptica* H.B.K., etc.) from the Amazon region are not very common in Central America and the West Indies, and little is known about them. Nevertheless, several stands of *L. zabucajo* were introduced in Trinidad about 50 years ago and they are still in excellent shape. The nuts are consumed locally and sometimes sold in supermarkets. This species would be of interest for rehabilitating poorly drained lands in wet tropical areas.

Malpighiaceae

The Barbados cherry or West Indian cherry (*Malpighia glabra* L.) originates form the Antilles and is cropped in Barbados, Guyana and Surinam; it is also quite common in the rest of the West Indies.

This cherry is not as widespread in Central America. Improved varieties have been bred in Puerto Rico, the Dominican Republic and Surinam. Many other species have been described in the Antilles and Central America, i.e. *M. angustifolia* L., *M. aquifolia* L. and *M. coccifera* L. in the Lesser Antilles, *M. cnide* Spreng. in the Dominican Republic, *M. fucata* Ker Gawl. in Jamaica, *M. incana* in Honduras, etc. This highlights the considerable breeding potential of this fruit.

Moraceae

All fruit tree species in this family that are of interest in Central America and the West Indies originate from Southeast Asia and Polynesia.

Breadfruit is the first species of this family to be introduced in the West Indies; it was brought by Captain Bligh on the famous Bounty. Saint Vincent celebrated the 200th anniversary of this visit in November 1993.

seeded and seedless breadfruit

Breadfruit (*Artocarpus altilis* [Park.] Fosberg) is grown everywhere in the West Indies where it is consumed traditionally. It is also exported by Saint Lucia and Jamaica. Breadfruit is less common in Central America where it is only found in wet tropical regions. There are white- and yellow-fleshed varieties but, due to the fact that it is only propagated vegetatively, there is little variability concerning the other characters.

There have been several studies on this species, notably at UWI Trinidad, in Jamaica and Barbados. Because of its high market value, West Indian countries are interested in introducing other varieties obtained from their origin and diversity centres.

Seeded breadfruit (*Artocarpus altilis* var. *seminifera*) is not quite as interesting, only the grilled or boiled seeds are consumed.

jackfruit and chempedak

Jackfruit (*Artocarpus heterophyllus* Lam.), in contrast to breadfruit, has whole or only partially denticulate leaves. Single fruits can weigh as much as 20 kg, and they develop on the trunk and largest branches (similar to cacao). This species is only a curiosity in Central America, but is grown throughout the West Indies where the fruit is mainly consumed by Hindus (in Guyana and Trinidad).

Chempedak (*Artocarpus integer* [Thun.] Mer.) is smaller than the jackfruit tree. The fruit peel and pulp are yellow; the fruit has a banana-like smell and taste.

Myrtaceae

This large family can be found in the tropics and subtropics, adapted to almost all biotopes. Many cropped species originate from tropical regions of the Americas, and others are from Southeast Asia.

guava

Psidium guajava L. is a species with high plasticity, producing relatively large fruit of various shapes, with a yellow to red pulp. It is cropped in commercial orchards in some countries, to be processed on a small industrial scale. It was formerly the focus of a substantial improvement programme in Trinidad (cv Centeno Prolific), and more recently in Cuba, where it is very popular and crop-

ped in about 2 000 ha of orchards. Two high-yielding dwarf varieties are now available to producers. Guava is very susceptible to fruitflies, which limits its presence on fresh fruit markets.

Costa Rican guava

Psidium friedrichsthalianum is native to Central America. The fruit is more sour than that produced by *P. guajava*; it is greenish-brown with white aromatic pulp. This sour Costa Rican guava is mainly found in Central America where it is grown in gardens and processed into fresh juice. The shape and size of the fruit varies. It should be investigated in terms of its potential development, in the light of its very special flavour (quite different from *Psidium guajava*) and low susceptibility to fruitfly infestation.

malay apple

Syzygium malaccensis Merr. and Perry is limited to the Atlantic side of Central America where the moisture conditions are suitable for its development. This species, which originates from Malaysia, is much more common in the West Indies where it is grown in gardens, and sometimes serves as a windbreak for other crops (Trinidad). In Grenada, it is called the «French cashew» because of the similarity between its fruit and the false fruit of cashew trees. The fruit is mainly consumed fresh, but sometimes as juice. There is very little genetic variability. The seeds are polyembryonic and the mother-plant characters are reproduced in the progeny. Two types are propagated commercially from cuttings in Trinidad, the fruit of one is red and the other is streaked with white. The fruit is often infested by fruitflies.

jamelac

Jamelac (*Syzygium samarangense* Merr. and Perry) is found in botanical gardens and private collections as a curiosity; it is commonly grown in gardens in Surinam. Jamelac was probably brought from Southeast Asia by the Dutch, or by Javanese people that now live in Surinam. The fruit is white or pale-pink, with a Chinese-hat shape, and is used to make delicious candied fruit.

Java plum

The Java plum or Black jamoon (*Syzygium cumini* Skeels) is called jambolan in the French West Indies; it originates from Southeast Asia. It is common in the English West Indies where it serves as a windbreak for other crops. The dark-purple cherry-sized fruit, which grows in clusters, is used to make jam and wine. Some types produce more oblong-shaped fruit.

Oxalidaceae

carambola

Carambola (*Averrhoa carambola* L.) originates from Indonesia. The tree is average sized, very ramified, and produces yellowish-orange fruit with five clearly-marked sides. Its popularity is increasing on world markets.

Although this species was introduced in many regions, it is now only found in large numbers in some countries, i.e. coastal areas of Guyana (Pomeroon), Surinam, and southern Nicaragua (Rivas, Buenos Aires, Potosí). Carambola is propagated sexually and there is considerable variability in some characters, especially fruit size, shape and size of the sides, peel and pulp colour and the fruit oxalic acid content. The latter character differentiates sweet and sour varieties. The wide array of intermediate varieties are now considered for varietal improvement, and vegetative propagation techniques are being developed in Trinidad.

In Nicaragua, the fruit is mainly processed into juice. It is used to make a prune substitute in Guyana, and a date substitute in Surinam.

bilimbi or pickle

Bilimbi (*Averrhoa bilimbi* L.) is a small upright tree originating from Malaysia. The green acidic fruits resemble pickles and hang from the trunk or the main branches in tight clusters. It is found everywhere in the West Indies and Central America but its distribution is limited. The fruit is used in pickled form and for the preparation of Hindu dishes

(Trinidad, Guyana). Small plantations have recently appeared in Trinidad and the crops are mainly processed.

Rhamnaceae

jujube

Most jujube species originate from Asia (*Ziziphus jujuba* Mill., *Z. mauritania* Lam.) or Africa (*Z. lotus* Lam., *Z. spina-christi* Willd.). Only *Z. mauritania* is well acclimatized to the tropical conditions in the Americas, and especially the West Indies. It often grows as a shrub, sometimes a large tree, and is found in dry and moist zones. Small-fruit varieties are most common, but improved large-fruit varieties, propagated by budding, are also found. The fruit is consumed in fresh or processed form (sold in supermarkets in Trinidad). It could be developed for cropping in dry areas of the West Indies.

Rubiaceae

Genipa (*Genipa americana* L.) is found in natural forest stands in wet tropical regions of the Americas and the West Indies. It also grows in dry areas, but this is not very common. The rounded, greyish, hard-shelled fruit grows to various sizes and its quality also varies markedly. Large-fruit varieties with bulky sweet pulp have been bred in the Dominican Republic.

Rutaceae

Citrus fruits were first introduced in the West Indies at the end of the 15th century.

Citrus research has never been as important in Central America and the West Indies as it has been, and continues to be, in Florida and some other states in USA. Nevertheless, the West Indies have also been instrumental in promoting citrus fruit through the development of grapefruit in the the 18th century and cvs Ortanique and Ugli in Jamaica in the 20th century. The Imperial Agricultural College of Trinidad used to conduct investigations on citrus fruit. There is still some evidence of this research in gardens and cacao plantations: a sweet orange variety, Cocoa, is known for its adaptation to shady conditions; a lemon hybrid, a blend of West Indian lime (*C. aurantifolia* Swing.) and Tahiti lime (*C. latifolia* Tan.), was also bred for resistance to anthracnose, which was devastating lime crops. There are also several types of cv Cleopatra mandarins, which could replace cv Sour Orange as rootstock, since this latter variety has been affected by tristeza virus and can no longer be used.

Sapindaceae

rambutan

Rambutan (*Nephelium lappaceum* L.), originating from Southeast Asia, was introduced in many parts of Central America and the West Indies. It is present in some repositories, i.e. in Honduras and Costa Rica, but rarely cropped; nevertheless, there are a few small orchards in Costa Rica and Trinidad, and experiments are under way in Honduras. Fruit from some scattered trees are marketed in Guyana and Surinam. This species is mainly propagated from seed and shows very high diversity for characters such as yield, fruit size, colour and pulp adhesion to the seed, etc. A rambutan breeding programme is under way in a small orchard in Trinidad.

pulasan

Pulasan (*Nephelium mutabile* Blume), also originating from Southeast Asia, is even less common than rambutan. To our knowledge, only a few trees are grown on a property in Trinidad.

The latter two species seem to perform suitably in wet tropical areas of the Americas and could be cropped on a larger scale.

akee

Akee (*Blighia sapida* Koenig), native to Western Africa, has been introduced in many areas, but is still only a curiosity in the West Indies. In Jamaica, on the other hand, akees are very common garden trees and the fruit is used in local dishes.

honey-berry

Honey-berry (*Meliccoca bijuga* L.) is endemic to northern regions of South America. It is a large hardy tree grown in

gardens, hedges between properties, or intercropped. The fruit is green, grows in clusters and there is considerable variability in its shape, pulp sweetness and bulk, which can be explained by the fact that it is dioecious. The fruit is sold everywhere in markets and along roadsides. It is generally consumed fresh, but sometimes as a cool drink in Central America.

Sapotaceae

This family is very well represented in Central America and the West Indies. Some species are sold widely on domestic markets, but there is very little export trade. One exception concerns sapote pulp, which is processed at a plant in Guatemala and exported to USA. A few of the most important species are discussed below.

mammee sapote

Mammee sapote (*Calocarpum sapota* Merr. (= *C. mammosum* Pierre) is abundant throughout Central America, Cuba and the Dominican Republic. There are many different types with high variability for some characters, such as fruit size and shape, pulp colour and quality. There has been very little research focusing on this species, and it is almost always propagated from seed. Sapote crops are susceptible to fruitfly infestation.

sapodilla

Sapodilla (*Manilkara zapota* Van Royen = *Achras sapota* [Mill.] Fosb.) has the same characteristics as the mammee sapote. Its distribution also includes the Lesser Antilles and Trinidad, where some varieties have been identified (De Meillac, Abdool) and propagated by budding. It is susceptible to fruitfly infestation.

star apple

Star apples (*Chrysophyllum cainito* L.) are found throughout Central America and the West Indies. There are two main groups, one with purple fruit and pulp, the other with green fruit and white pulp. It is propagated from seed. Some types differ with respect to fruit size and shape. A large-fruit variety was bred in Cuba. It is also susceptible to fruitfly infestation.

canistel or egg-fruit

Canistel (*Pouteria campechiana* Baehni = *Lucuma nervosa* D.C. and *L. salicifolia* H.B.K.) has golden-coloured fruit with abundant sweet fruit whose texture resembles cooked egg yolk. There is marked variability in tree size, growth habit and fruit size. It has not been the focus of any breeding programmes. It is almost always propagated from seed.

balata

Balata (*Manilkara bidentata* Dub.) is a forest species in the Antilles. It is propagated in nurseries in Trinidad and planted in gardens. The milky-pulped fruit is consumed fresh and sold in markets and along roadsides.

other species found in Central America and the West Indies

There are some other noteworthy native Central American and West Indian species that are not propagated but their fruit is harvested:
– green sapote (*Calocarpum viride* Pitt.) in Central America,
– several *Chrysophyllum* species in the Antilles, Guyana and French Guiana,
– several *Lucuma* species in Cuba and Puerto Rico,
– several *Pouteria* species in Trinidad, Guyana and French Guiana, including the penny piece (*Pouteria multiflora*) in Trinidad, and *P. macrophylla* and *P. guianensis* in Surinam.

Sweetberry (*Synsepalum dulcificum* Daniell), which is found in botanical gardens and private collections, is also noteworthy. In the 1930s and 1940s, many studies were carried out in USA on this species with the aim of developing a sugar substitute.

In response to a request by Central American countries, the International Plant Genetic Resources Institute (IPGRI), which is based in Palmira (Colombia), intends to begin a project on Sapotaceae species of Central America. ●

Nuclear Genome Size Variations in *Citrus*

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Systematic analysis of genome sizes in Citrus *is important for programmes involving gene mapping and plant breeding via sexual crossing.*

introduction

Numerical taxonomic studies (Barrett and Rhodes, 1976) and molecular marker analyses (Green *et al.*, 1986; Ollitrault and Faure, 1992; Yamamoto *et al.*, 1993) have demonstrated that the wide variety of cultivated *Citrus* species can be clearly grouped around three basic taxa since *Citrus medica* (citrons), *Citrus reticulata* (mandarins) and *Citrus grandis* (pummelo) are generally considered to be the three ancestral species of currently cultivated *Citrus*. Despite the number of sympatric zones, this level of structuring suggests that many factors limit interspecific recombination. Some of these limitations are genomic, as shown by the structural heterozygosity (translocations, inversions, etc.) that has been noted in interspecific hybrids (Raghuvanshi, 1969; Gmitter *et al.*, 1992). In the present study, we looked for a quantitative component to account for the structural differentiation between nuclear genomes of various *Citrus* species.

material and methods

The relative nuclear genome sizes of four to five diploid cultivars of the eight main cultivated *Citrus* species were assessed (Table 1). For each cultivar, evaluations relative to the control triploid cultivar cv Tahiti lime were done in triplicate. Leaf samples from the test cultivar and control were minced finely in PBS buffer supplemented with dithiothreitol (1 mg/ml), Triton X100 (0.3%) and RNAase (10^{-3} U/ml). After filtration, 0.3 ml of the nuclear suspension was mixed with 0.3 ml extraction buffer supplemented with propidium iodide (200 mg/ml). Two thousand nuclei per sample were then analysed by Fascan flow cytometry connected to the Lysis 2 software programme. The size of the cv Tahiti lime nuclear genome was evaluated relative to chicken erythrocytes (2.33 pg/2C) so as to determine absolute sizes of genomes for each diploid cultivar considered. The data were analysed using hierarchical analysis of variance to determine possible size variations within each species and assess interspecific diversity.

results

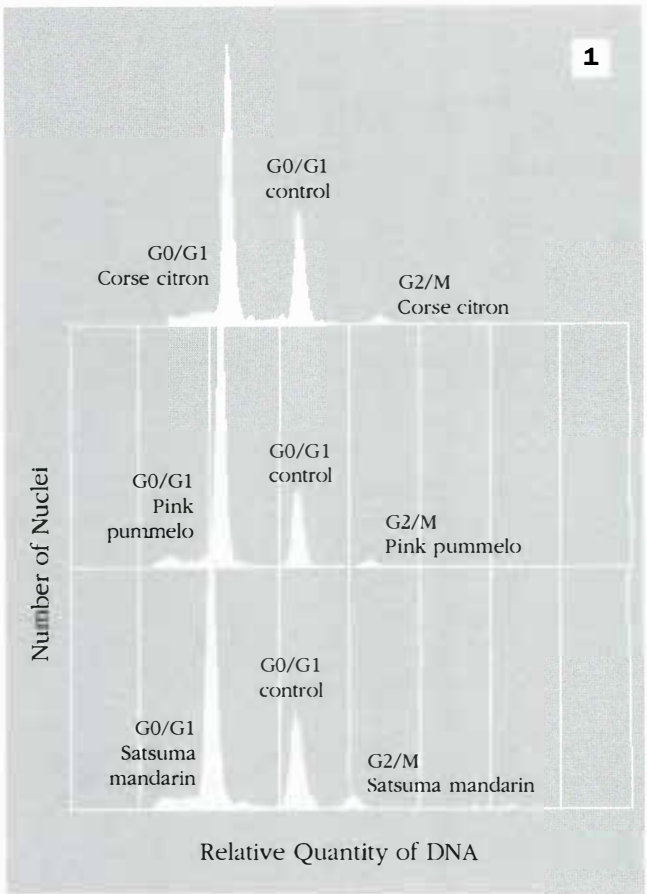
The absolute size of the cv Tahiti lime nuclear genome was estimated at 1.17 pg/2C for 2N=3X=27 chromosomes. The coefficients of variation (c.v.) concerning the G0-G1 peaks for the different diploid samples was around 2.5-3% for most of the cultivars (Fig. 1). However the c.v. of peaks were systematically higher for some varieties of sweet orange sweet (*C. sinensis*), lime (*C. aurantifolia*) and mandarin, which resulted in higher variance for the genome size estimates. In six cases, there were significant variations in genome sizes (not higher than 3%) between cultivars of the same species (Table 1).

There was also very marked interspecific variability, i.e. reaching 10% between mandarin and citron (Figs. 1 and 2), the smallest and largest *Citrus* genomes respectively. The other species were divided between two other intermediate-sized groups. One included sweet orange and sour orange (*C. aurantium*) and the other lemon (*C. lemon*), lime, pummelo and grapefruit (*C. paradisi*). This division into four separate groups, revealed by the

Table 1
Estimated relative and absolute sizes of nuclear genomes in *Citrus* cultivars (/cv Tahiti lime).

Mean values for each species are presented in bold.
H.G. = homogeneous groups determined by the Newman-Keuls test.
F and p = statistics associated with the Newman-Keuls test.

Cultivars	Relative size	Absolute size	H.G.	Intra specific variability
C. aurantium **(Sour orange)**	**0.643**	**0.752**		
Bigaradier Goutou	0.642	0.751	a	F = 2.39
Bigaradier Granito	0.644	0.753	a	p = 0.14
Bigaradier Maroc	0.641	0.756	a	N.S.
Bouquetier Nice	0.646	0.756	a	
C. medica **(Citron)**	**0.696**	**0.814**		
Corse	0.696	0.815	a	F = 10.71
Digité	0.697	0.816	a	p < 0.01
Etrog	0.702	0.821	a	**
Poncire commun	0.690	0.807	b	
C. limon **(Lemon)**	**0.665**	**0.778**		
Lisbonne	0.672	0.786	a	F = 11.93
Sweet	0.665	0.778	b	p < 0.01
Eureka	0.664	0.777	b	**
Meyer	0.660	0.772	b	
C. aurantifolia **(Lime)**	**0.659**	**0.771**		
Brazil Sweet	0.646	0.756	a	F = 9.08
Kirk	0.666	0.779	b	p < 0.01
Mexican	0.666	0.779	b	**
Rangpur	0.660	0.772	b	
C. sinensis **(Sweet Orange)**	**0.647**	**0.757**		
Parson Brown	0.646	0.756	a	F = 0.02
Shamouti	0.646	0.756	a	p = 0.99
Washington Navel	0.647	0.757	a	N.S.
Valencia late	0.647	0.757	a	
C. paradisi **(Grapefruit)**	**0.666**	**0.779**		
Star Ruby	0.660	0.772	a	F = 7.36
Cecily	0.665	0.778	b	p = 0.01
Marsh	0.669	0.783	b	*
Thomson	0.670	0.784	b	
C. grandis **(Pummelo)**	**0.669**	**0.783**		
Kao Pane	0.656	0.768	a	F = 25.01
Pink	0.666	0.779	b	p < 0.01
Seedless	0.673	0.787	bc	**
Inde	0.673	0.787	bc	
Sunshine	0.679	0.795	c	
C. reticulata **(Mandarin)**	**0.630**	**0.737**		
Satsuma Wase	0.623	0.729	a	F = 9.14
Willow-leaf	0.624	0.730	a	p < 0.01
Cleopatra	0.627	0.733	a	**
Ponkan	0.636	0.745	b	



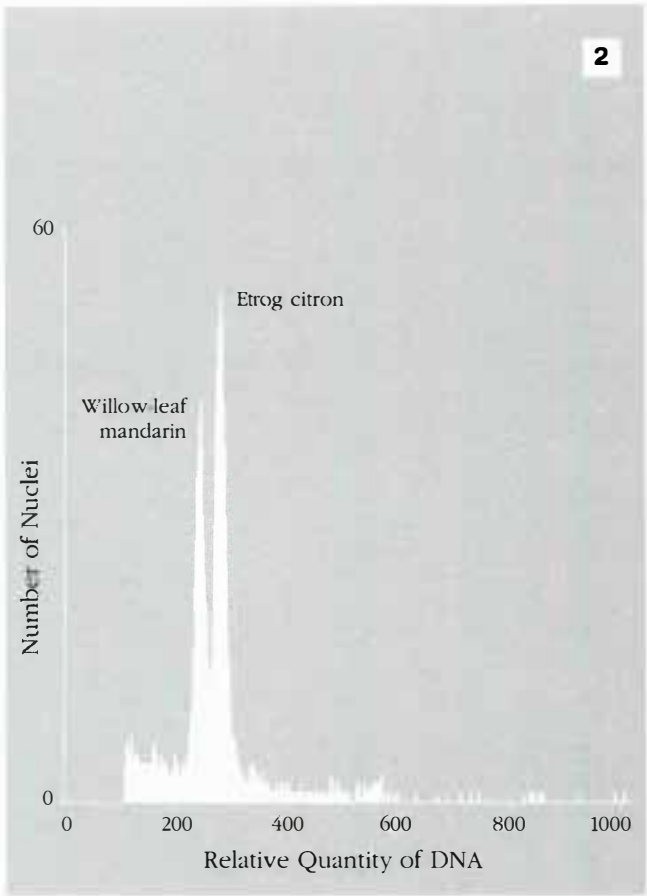


Figure 1
Estimated relative sizes of nuclear genomes in three diploid cultivars relative to cv Tahiti lime.

Figure 2
Genome size differentiation in cv willow-leaf mandarin and cv Etrog citron.

Newman-Keuls interspecific test results, was confirmed by the quadrimodal distributions of single observations (Fig. 3).

discussion

This is the first systematic genome-size study that has been carried out in *Citrus*. In *C. sinensis*, ARUMUGANATHAN and EARLE (1991) estimated a genome size of 0.76 pg/2C in comparision to chicken erythrocytes, but there are no other previous results for the other species covered here. Diploid cultivars seemed to have relatively small genomes (0.73-0.82 pg/2C). ARUMUGANATHAN and EARLE (1991) obtained similar results for many other fruit trees, e.g. apricot (0.61 pg/2C), peach (0.54 pg/2C), mango (0.91 pg/2C) and pear (1.03 pg/2C).

In *Citrus*, significant intraspecific diversity was noted, in species that have evolved solely by mutations (*C. lemon* and *C. paradisi*) and those that have diversified by sexual crosses and mutations (*C. grandis*, *C. aurantifolia*, *C. medica* and *C. reticulata*). Note that the pomelo variety Star Ruby, with a smaller nuclear genome than the other varieties of this species, was developed in a gamma irradiation programme (HENSZ, 1960).

Interspecific diversity was relatively high and the genome size variations noted are in line with phylogenic hypotheses. The extreme values obtained for *C. medica* and *C. reticulata* confirm their ancestral roles in cultivated *Citrus*; the estimated genome sizes for secondary species is in agreement with their assumed hybrid origins (OLLITRAULT and FAURE, 1992). The quantitative differentiation in the three basic taxa is evidence of advanced evolution towards real speciation. It undoubtedly helped maintain high linkage disequilibrium in *Citrus* and could explain some non-Mendelian segregations that have been observed in the progeny of interspecific hybrids (OLLITRAULT and FAURE, 1992). This differentiation and its impact should be taken into account in gene mapping studies and plant breeding programmes involving sexual crossing.

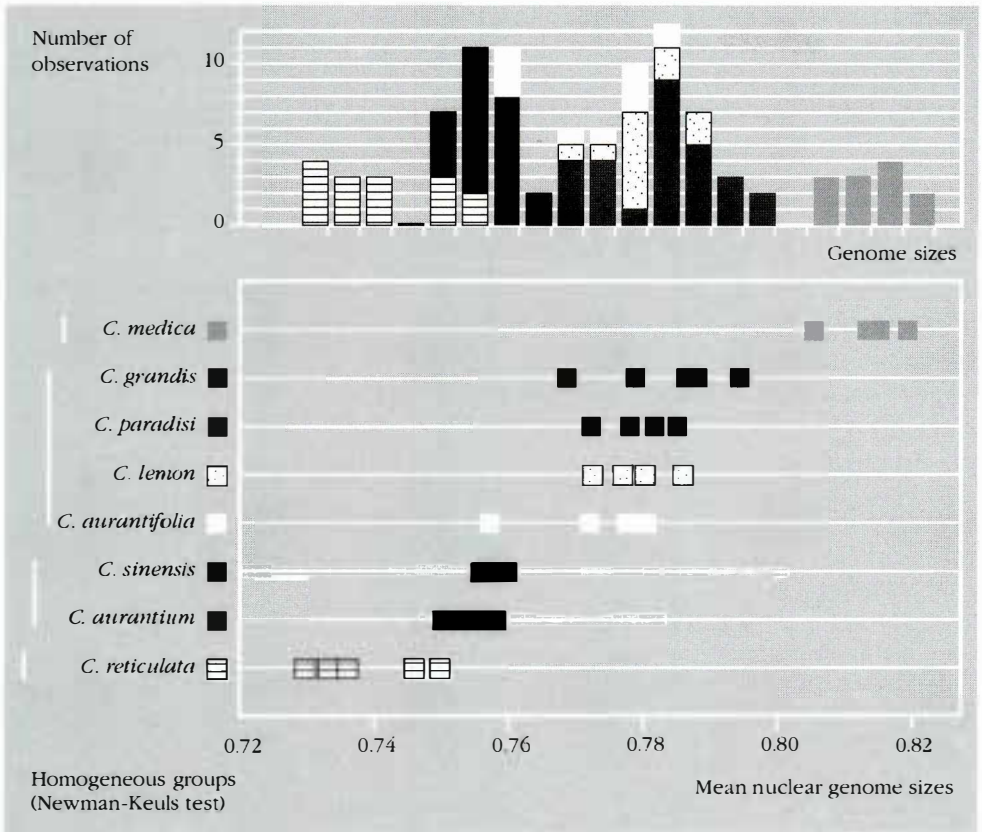


Figure 3
Variations in the size of nuclear genomes in the Citrus *genus (pg/2C).*

references

ARUMUGANATHAN K., EARLE E.D., 1991.
Nuclear DNA content of some important plant species. Plant Mol. Biol. Rep. 9 (3): 208-218.

BARRET H.C., RHODES A.M., 1976.
A numerical taxonomic study of affinity relationships in cultivated *Citrus* and its close relatives. Syst. Bot. 1: 105-136.

GREEN R.M., VARDI A., GALUN E., 1986.
The plastone of *Citrus*. Physical map, variation among *Citrus* cultivars and species, and comparaison with related genera. Theor. Appl. Genet. 72: 761-769.

GMITTER F.G., DENG X.X., HEARN C.J., 1992.
Cytogenetic mecanism underlying reduced fertility and seedlessness in *Citrus*. *In*: Proc. of VII Int. *Citrus* Cong., Int. Soc. of Citriculture. p. 113-116.

HENSZ R.A., 1960.
Effect of X-ray and thermal neutrons on citrus propagating material. J. Rio Grande Val. Hort. Soc. 14: 21-25.

OLLITRAULT P., FAURE X., 1992.
Système de reproduction et organisation de la diversité génétique dans le genre *Citrus*. Proceedings of the international conference "Complexe d'espèce, flux de gènes et ressources génétiques", Paris, France, 8-10 January 1992. Paris, France, Bureau des Ressources Génétiques ed., p. 133-151.

RAGHUVANSHI S.S., 1969.
Cytological evidence bearing on evolution in *Citrus*. *In*: Proc. 1st Citrus Symp., Chapman ed., Univ. of California, Riverside 1: 207-214.

YAMAMOTO M., KOBAYASHI S., NAKAMURA Y., YAMADA Y., 1993.
Phylogenic relationships of citrus revealed by RFLP analysis of mitochondrial and chloroplast DNA. Japan. J. Breed., 43: 355-365.

Optimized Management of *Citrus* Embryogenic Calli for Breeding Programmes

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Embryogenic calli were obtained for 15 Citrus *cultivars. Cryoconservation is now routinely used for long-term callus conservation. Isoenzyme and flow citometry techniques are applied for callus caracterization.*

introduction

Somatic embryogenesis is now widely used for protoplast fusion and gene transfer in *Citrus* breeding programmes. These latter techniques provide means to overcome some obstacles concerning genetic structures of cultivars and considerably expand the genetic base available to breeders. However, they require controlled management of embryogenic calli, the essential component of this system (Fig. 1). The main methodological advances jointly developed by CIRAD-FLHOR, INRA and ORSTOM are presented.

embryogenic callus induction

Friable embryogenic calli from polyembryonic varieties are conventionally induced by ovule culture. Depending on the genotype, the ovule can produce friable calli and embryos, compact chlorophyll calli, or just embryos. The results of isoenzyme studies (Ollitrault *et al.*, 1992b) and histological analyses (Cabasson, 1993) revealed that friable embryogenic calli are of nucellar somatic origin. Six months to 1 year after induction, such calli can be propagated on media without hormones. Callus strains have thus been obtained for 15 cultivars representing a wide-range of diversity within the *Citrus* genus. Embryogenic calli have also been formed around the hypocotyl in micropropagated somatic hybrids (Photo 1).

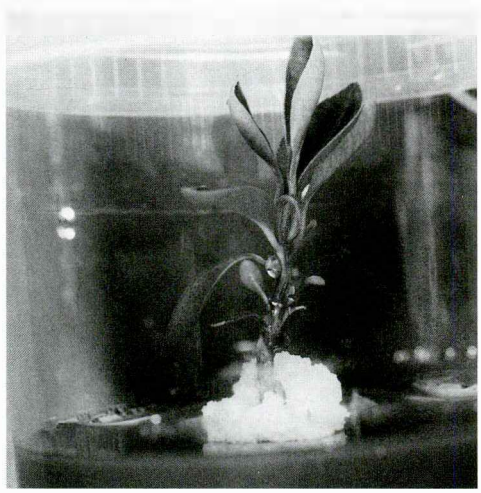

Photo 1
Formation of an embryogenic callus around the hypocotyl of a micropropagated somatic hybrid of C. deliciosa *and* F. japonica.

cryoconservation of embryogenic calli

A simplified technique for callus cryoconservation in liquid nitrogen has been developed (Engelmann *et al.*, 1994) to overcome callus induction problems with some genotypes and reduce somaclonal variations that could occur during successive subculturing. Calli are pretreated in a solution containing 0.15 M sucrose and 10% DMSO, placed in a small freezing module (Nalge Company) and then into a freezer set at −80°C. When the callus reaches −40°C, the cryotubes are plunged in liquid nitrogen. This technique is now routinely used for long-term callus conservation and can also be used to conserve duplicate fusion and transformation products during regeneration and evaluation processes.

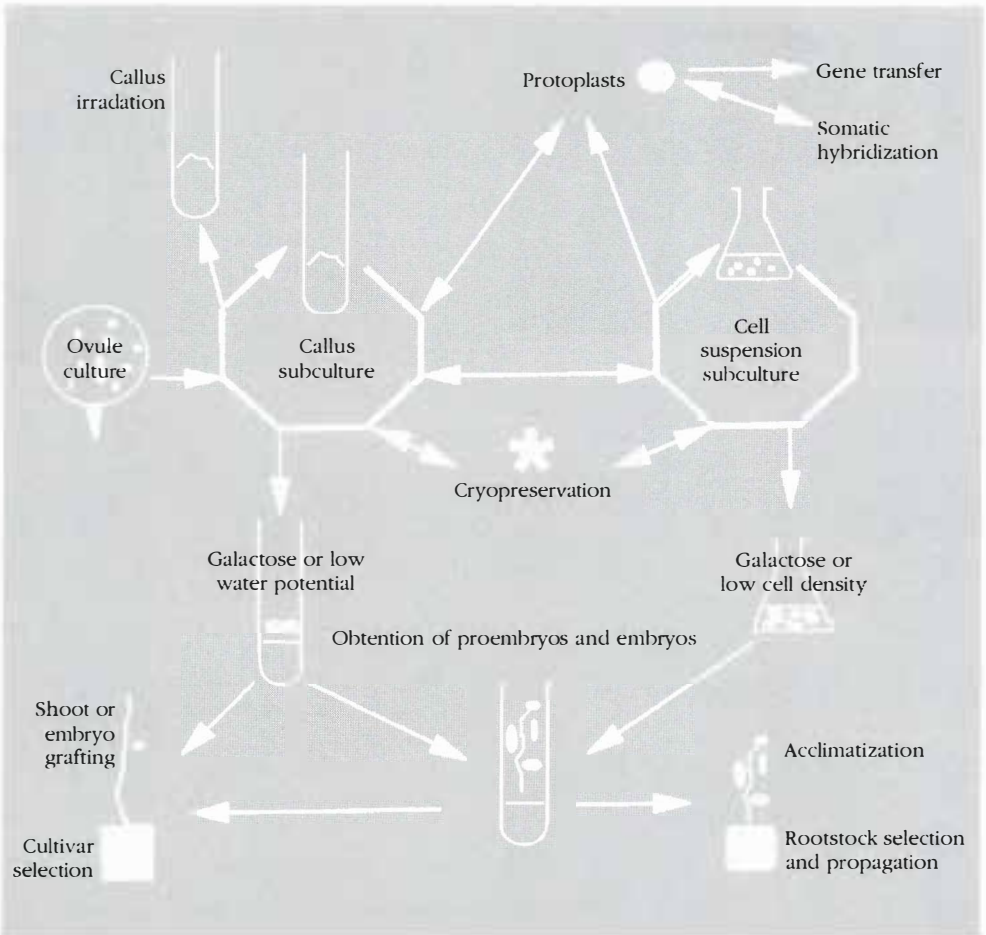

Figure 1
Management of embryogenic calli.

controlling embryo regeneration

Nucellar callus embryogenesis can be obtained on MURASHIGE and TUCKER medium (1969) without exogeneous hormones by modifying the form of the sugars contained in the medium (OLLITRAULT, 1992), or reducing the relative water content in the callus by increasing the gelling agent concentration (Fig. 2). With this original latter technique, embryos can be obtained for callus strains that do not respond to medium sugar modifications. Embryo development varies according to the callus strain and culture medium: cotyledonary embryos in cv Chios mandarin ("agar effect", Photo 2) and cv Sunki mandarin (galactose, Photo 3), and globular embryos in lemon (galactose, Photo 4). The observed suspensor-type structures (Photo 5) suggest that the embryos are of unicellular origin.

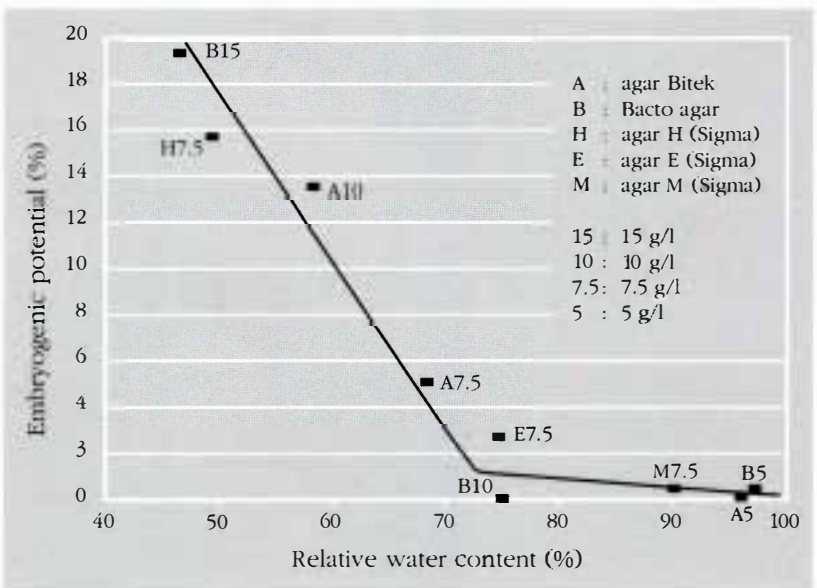

Figure 2
Control of embryogenesis in willow-leaf mandarin calli by modifying the type of agar and its concentration, in relation with the relative water content in the callus.

Photo 2
Cotyledonary embryos of cv Chios mandarin. Agar effect: MT medium (MURASHIGE & TUCKER, 1969) + 50 g/l sucrose + 4 g/l phytagel.

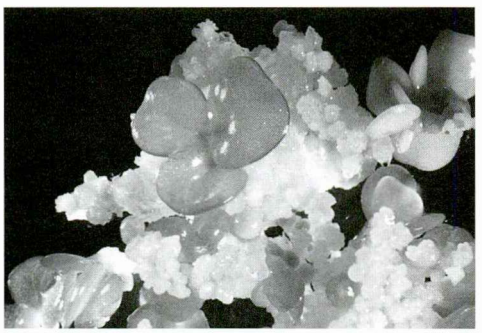

Photo 3
Cotyledonary embryos of cv Sunki mandarin. Galactose medium: MT medium + 30 g/l galactose + 2 g/l phytagel.

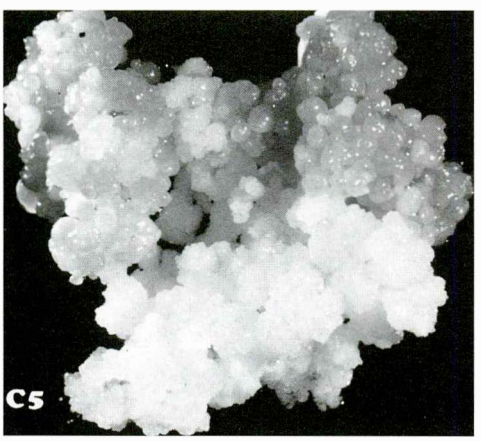

Photo 4
Globular embryos of lemon (galactose medium).

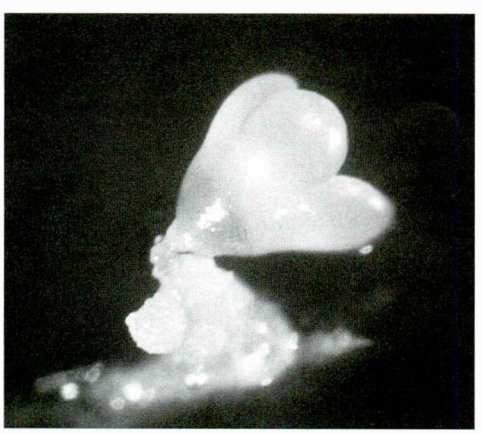

Photo 5
Embryo of C. deliciosa *attached to an embryogenic callus by a suspensor-type structure.*

isoenzyme characterization of calli

With the aim of obtaining very early detection of somatic fusion products, eight enzymatic systems (A.D.H., I.D.H., M.D.H., Sk.D.H., P.G.I., P.G.M. G.O.T. and L.A.P.) were analysed by electrophoresis in nucellar calli and embryos. This was the same as the technique used with leaf and bark samples (OLLITRAULT *et al.*, 1992a). In most cases, enough polymorphism is observed to enable detection of heterofusion products (Photo 6). For most of the systems, the callus and embryo profiles were identical to those obtained with leaves from adult trees. The profiles differed with M.D.H. and A.D.H., and their expression seemed to be associated with the embryo maturation level. Profiles for fully developed cotyledonary embryos obtained from calli were identical to those of seed embryos, while globular embryo profiles were identical to those of calli (Photo 7).

flow cytometry analysis of callus cell cycles and ploidy levels

Flow cytometry can be used to assess ploidy levels and relative proportions of cells in the G1 and G2 phases in organs and calli in the growth phase (OLLITRAULT and MICHAUX-FERRIERE, 1992). This latter information is important for isolating protoplasts to be used in somatic fusion and genetic transformation. Cytometry was used successfully to analyse protoplast nuclei obtained from embryogenic calli and stained with propidium iodide. In a preliminary study (Fig. 3), the highest levels of cells in the G2 phase (20%) were obtained 18 days after subculture. This technique is also useful for controlling ploidy stability of embryogenic calli formed around the hypocotyl of somatic tetraploid hybrids (Figure 1). This stability is necessary for mass propagation, involving somatic embryogenesis, of new rootstocks obtained in somatic hybridization programmes.

references

CABASSON C., 1993.
Régénération de la mandarine commune (*C. deliciosa* Ten.) par embryogenèse somatique en milieu liquide. Fusion somatique et essais de transformation génétique. PhD thesis, université de Montpellier II (U.S.T.L.), France, 124 p.

ENGELMANN F., DAMBIER D., OLLITRAULT P., 1994.
Cryopreservation of embryogenic cell suspensions and calluses of Citrus using a simplified freezing process. Cryo-Letters 15: 53-58.

MURASHIGE T. TUCKER DPH, 1969.
Growth factor requirement of citrus tissue culture. *In:* Proceedings of the First International Citrus Symposium, University of California, March 16-26, 1968. Riverside, USA, Chapman HD, vol. 3, p. 1155-1161.

OLLITRAULT P., 1992.
Research of seedless "willow leaf" mandarin by gamma irradiation of nucellar callus. *In*: Proc. of VII Int. Citrus Cong., Acireale, Italy, 3-8 March 1992. Int. Soc. of Citriculture, p. 113-116.

OLLITRAULT P., FAURE X., NORMAND F., 1992a.
Citrus rootstock characterization with bark and leaf isozymes; application for distinguishing nucellar from zygotic trees. *In*: Proc. of VII Int. Citrus Cong., Acireale, Italy, 3-8 March 1992. Int. Soc. of Citriculture, p. 338-341.

OLLITRAULT P., OLLITRAULT F., CABASSON C., 1992b.
Induction de cals embryogènes d'agrumes par culture d'ovules : détermination isoenzymatique de l'origine tissulaire des embryons. *Fruits* numéro spécial agrumes (47): 204-212.

OLLITRAULT P., MICHAUX-FERRIERE N., 1992.
Application of flow cytometry for Citrus genetics and breeding. *In*: Proc. of VII Int. Citrus Cong., Acireale, Italy, 3-8 March 1992. Int. Soc. of Citriculture, p. 193-198.

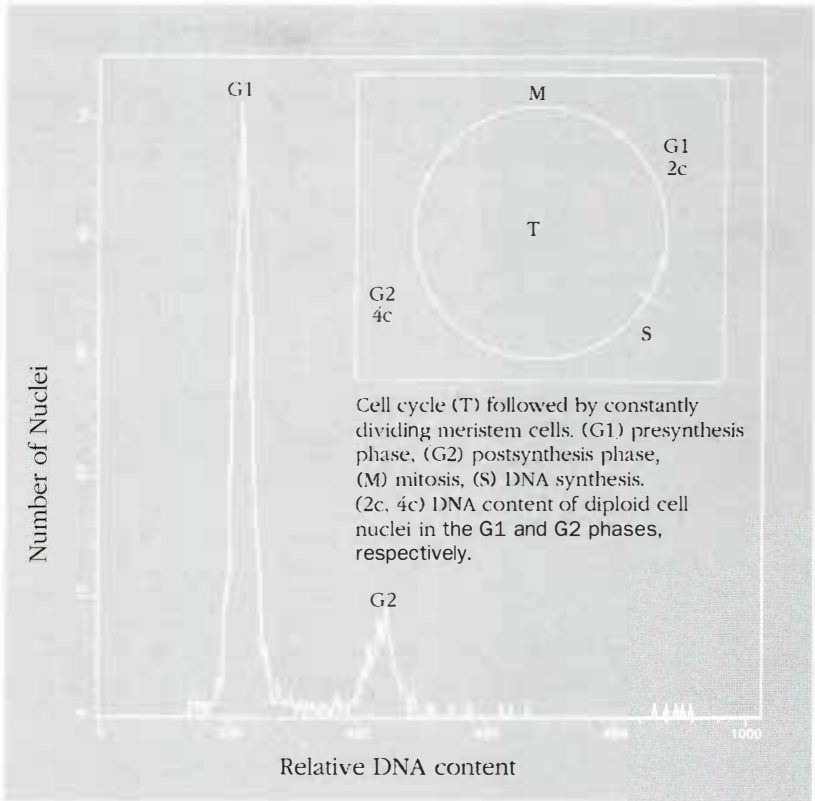

Figure 3
Analysis of the cell cycle of C. deliciosa *embryogenic calli (10 days after subculture).*

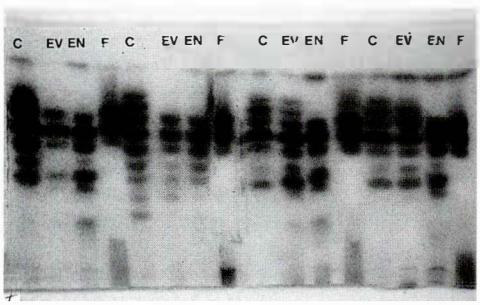

Photo 7
Comparison of MDH expression in calli (C), in vitro embryos (EV), nucellar seed embryos (EN), leaves (F), for four genotypes: cv Chios mandarin, cv Sunki mandarin, cv Shamouti orange and cv Star Ruby grapefruit.

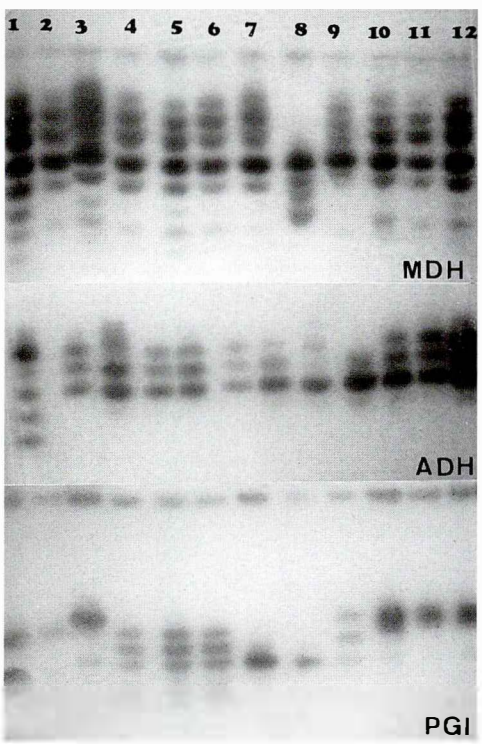

Photo 6
Enzymatic profiles for 12 callus strains:
1 *Sunki mandarin*
2 *Cleopatra mandarin*
3 *Sour orange*
4 *Shamouti orange*
5 *Navelate orange*
6 *Russ-Navel orange*
7 *Star Ruby grapefruit*
8 *Mexican lime*
9 *LAC lemon*
10 *Willow-leaf mandarin (G+)*
11 *Willow-leaf mandarin (G-)*
12 *Chios mandarin.*

Facultative Apoximis, Spontaneous Polyploidization and Inbreeding in *Citrus volkameriana* Seedlings

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The genetic status of 135 seedlings of Citrus volkameriana *and relationships with plant vigor were analysed.*

introduction

Citrus rootstocks are usually propagated by planting polyembryonic seeds that contain one zygotic embryo and several somatic embryos arising from the nucellus. Competition between these different embryos results in partial apomixis. The apomixis rate is dependent on the genotype and environmental conditions (Khan and Roose, 1988). Moreover, there can be a low percentage of polyploids due to fertilization of non-reduced ovules or spontaneous polyploidization of nucellar tissues (Esen and Soost, 1977; Iwamasa and Nito, 1989).

Citrus volkameriana is a very vigorous and highly heterozygous rootstock, as shown by isozyme analysis (Ollitrault *et al.*, 1992). It was therefore predicted that zygotic seedlings would show very marked diversity. However, *C. volkameriana* seedling populations are generally bimodal, i.e. a highly vigorous true-to-type population and, conversely, a very weak population.

In the present paper, we have analysed the genetic status (somatic or zygotic origin, and ploidy level) of *C. volkameriana* seedlings and relationships with plant vigor.

material and methods

The genetic origins of 135 *Citrus volkameriana* greenhouse-grown seedlings at the SRA San Giuliano station were analysed.

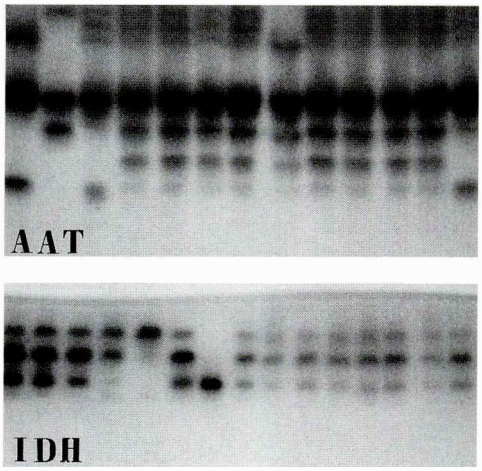
Isozyme polymorphism was used to differentiate zygotic and nucellar seedlings. Five heterozygous loci were analysed in *C. volkameriana* using four enzymatic systems (malate dehydrogenase, MDH; isocitrate dehydrogenase, IDH; phosphoglucose isomerase, PGI; aspartate amino transferase, AAT), as described by Ollitrault *et al.* (1992). Four of them are unlinked (Luro *et al.*, 1995 and our unpublished data), so more than 94% of the zygotic seedlings could be detected.

The ploidy level of each seedling was evaluated by flow cytometry, as described by Ollitrault and Michaux-Ferriere (1992). Samples were analysed at the INSERM Unit 291 laboratory in Montpellier under the supervision of C. Duperray.

Vegetative seedling vigor was estimated 1 year after planting according to three characters: seedling height, number of internodes and diameter of the second internode. A synthetic index of vigor was established from these characters by principal component analysis.

results

Twenty-nine zygotic plants were identified by isozyme analysis (Photo 1), while flow cytometry analysis revealed two tetraploid plants (Fig. 1). These two plants, which had enzymatic patterns identical to *C. volkameriana*, certainly arose through spontaneous tetraploidization of somatic cells. The enzymatic patterns of the zygotic seedlings suggested that they mainly



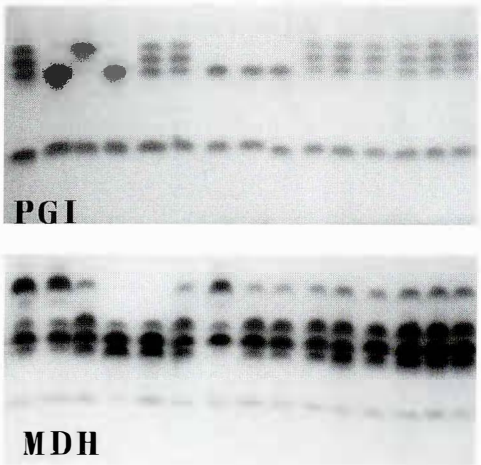


Photo 1
C. Volkameriana *(last sample) exhibits five heterozygous loci for the 4 analysed enzyme systems. From the combination of these systems it appears that samples n°1, 2, 3, 4, 5, 6, 7, 8, 9, 13 and 14 are zygotic seedlings. The others samples are considered as nucellars with a 3% risk (if the five heterozygous loci are unlinked).*

arose *via* self pollination. The enzymatic patterns and flow cytometry histograms of the 104 other plants were identical to *C. volkameriana*; they were thus considered to be somatic diploids of nucellar origin.

The three morphological characters studied were very highly correlated, and the vigor index established from the first axis in the principal component analysis represented more than 90% of the total variance. This vigor index was used to establish the vigor distribution between the three genetic groups (Fig. 2). The vegetative vigor levels of most of the zygotic seedlings (23/29) were substantially lower than those of plantlets of nucellar origin and, similarly, tetraploid plantlets showed very depressed development (Table 1).

discussion

The two main vigor classes in *C. volkameriana* seedlings could be associated with different genetic origins. The weak plants were diploid zygotic or somatic tetraploids, while the vigorous plants were mainly nucellar diploids.

Inbreeding was previously reported for other polyembryonic *Citrus* and *Poncirus* species (KHAN and ROOSE, 1988; SOOST and CAMERON, 1975). Apomixis certainly caused deleterious recessive mutations with respect to the heterozygous status, as noted in self-fertilized zygotic seedlings. The high proportion of depressed *C. volkameriana* seedlings suggested the

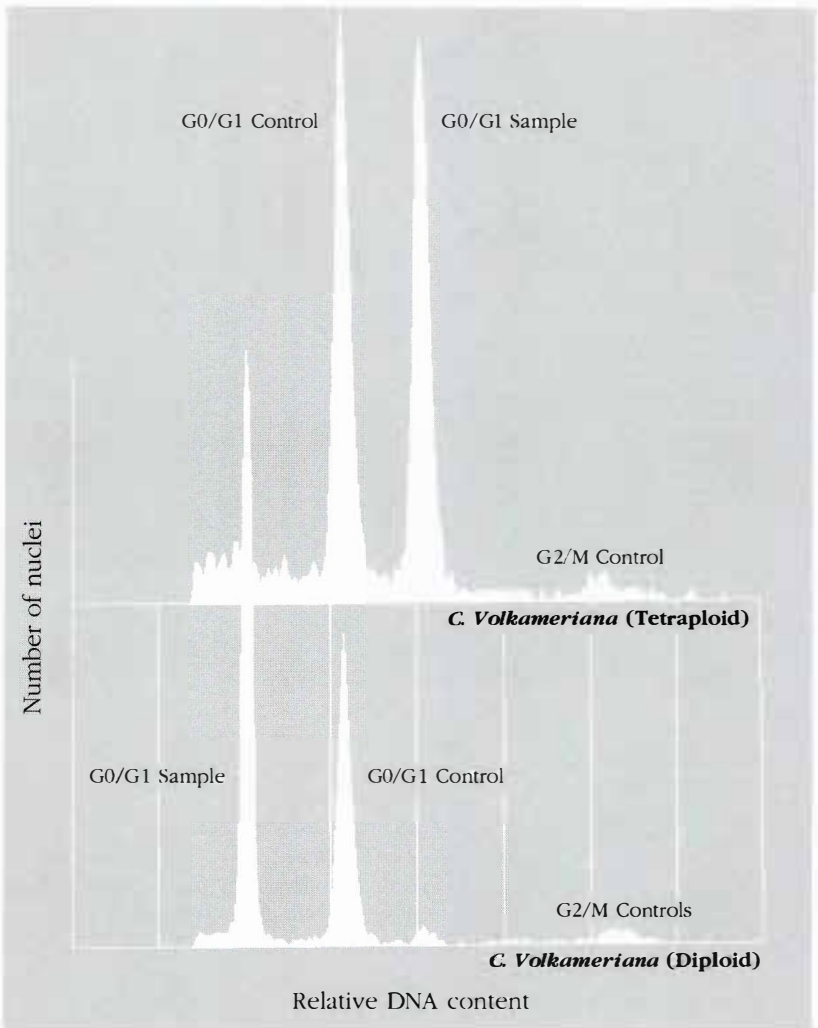


Figure 1
Flow cytometry analysis of ploidy levels in C. volkameriana *seedlings. Tahiti lime (triploid) was used as internal control.*

Table 1
Numbers and characteristics of nucellar, zygotic and tetraploid seedlings.

	Number of plants	%	DI Mean	DI CV	NI Mean	NI CV	H Mean	H CV
Nucellars	104	77.0	11.6	0.13	72.5	0.11	140	0.17
Zygotics	29	21.5	6.6	0.36	22.7	0.59	51	0.89
Tetraploids	2	1.5	5.6	0.20	24.5	0.10	30	0.04

DI: Diameter of the second internode (mm)
NI: Number of internodes
H: Hight of the seedling (cm)

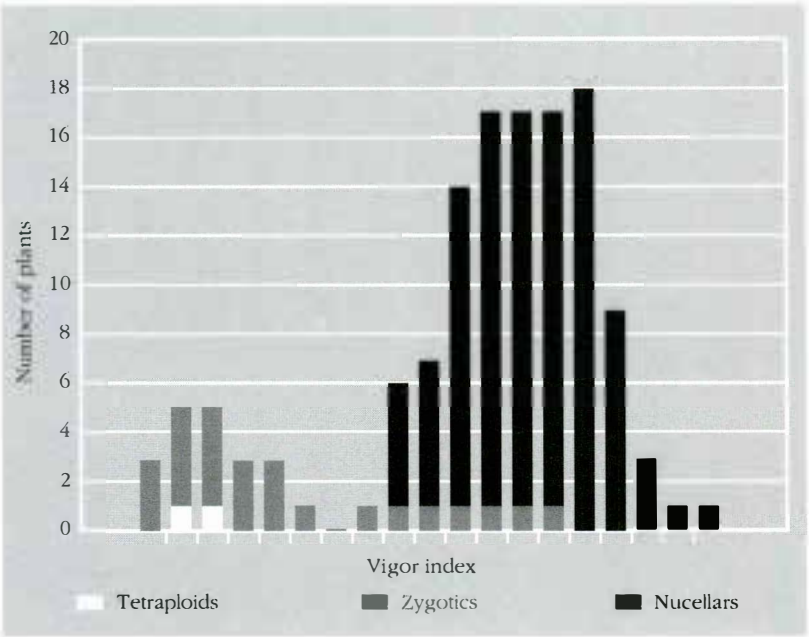


Figure 2
Vigor indexes for C. volkameriana *seedlings of three genetic origins.*

presence of several unlinked mutations of this kind. However, the morphology of some zygotic seedlings was very similar to the nucellar morphology. For agronomic or varietal tests, it is thus necessary to certify the nucellar origin of seedlings by molecular analysis (OLLITRAULT *et al.*, 1992).

The low proportion and vigor of spontaneous *C. volkameriana* tetraploids was in agreement with results obtained in other *Citrus* species (IWAMASA and NITO, 1989). Despite inbreeding, the proportion of zygotic seedlings was relatively high (>20%). This could indicate that the rate of spontaneous tetraploidization of nucellar tissues was higher than that evaluated for tetraploid plantlets. Indeed, the emergence of zygotic seedlings must be favoured by the very low vigor of tetraploid embryos.

references

ESEN A., SOOST R.K., 1977.
Relation of unexpected polyploids to diploid megagametophytes and embryo: endosperm ploidy ratios in *Citrus*. *In*: I. Congreso mundial de Citricultura, Murcia, Valencia, 29 April-10 May 1973. Vol. II, O. Carpena ed., International Society of Citriculture, p. 53-63.

IWAMASA M., NITO N., LING J.T., 1989.
Intra- and intergeneric hybridization in the orange subfamily, *Aurantioideae*. *In*: Proc. 6th Int. Citr. Cong. Middle-East, Tel Aviv, Israel, 6-11 March 1988. R. Goren and K. Mendel eds., Margraf Scientific Publishers, Germany, p. 123-130.

KHAN I.A., ROOSE M.L., 1988.
Frequency and characteristics of nucellar and zygotic seedlings in three cultivars of trifoliate orange. J. Amer. Soc. Hort. Sci. 113 (1): 105-110.

LURO F., LORIEUX M., LAIGRET F., BOVE J.M., OLLITRAULT P., 1995.
Genetic Mapping of an Intergeneric *Citrus* Hybrid using Molecular Markers. Fruits, vol. 49 (5-6): 402-406.

OLLITRAULT P., FAURE X., NORMAND F., 1992.
Citrus rootstock characterization with bark and leaf isozymes; application for distinguishing nucellar from zygotic trees. In: Proc. of VII Int. Citrus Cong., Acireale, Italy, 3-8 March 1992. Int. Soc. of Citriculture, p. 338-341.

OLLITRAULT P., MICHAUX-FERRIERE N., 1992.
Application of flow cytometry for *Citrus* genetics and breeding. In: Proc. VII Int. Citrus Congr., Acireale, Italy, 38 March 1992. Int. Soc. of Citriculture, p. 193-198.

SOOST R.K., CAMERON J.W., 1975.
Citrus. In: Advances in Fruit Breeding, Purdue University Press, Indiana, p. 507-540.

Protoplast Fusion in *Citrus*

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p. 481-482 (French)

Protoplast fusion, a prelude for regeneration of interspecific and intergeneric somatic hybrids and cybrids, is a promising area of research for the improvement of Citrus *rootstock and cultivars.*

introduction

Protoplast fusion is an increasingly important component of citrus breeding programmes (Ollitrault and Luro, 1995). It enables breeders to overcome some constraints linked with sexual hybridization and is applied to develop new rootstocks and cultivars for high quality, sustainable and environment-friendly citrus cropping.

Protoplast fusion can be used in rootstock improvement programmes to accumulate genes with resistance or tolerance to biotic and abiotic factors, irrespective of the heterozygosis level of the parents.

In addition, there is a very broad range of genetic resources that can be utilized since genomes from sexually incompatible species and genera can be combined by this fusion technique (Gmitter *et al.*, 1992).

Protoplast fusion also shows promise for diversification programmes through the development of triploid cultivars, especially in mandarin (Ollitrault *et al.*, 1995). The pool of tetraploid progenitors, used in sexual hybridization with diploids to produce triploid cultivars, could be enriched considerably.

Fertility has also been restored in somatic hybrids obtained from sterile elite cultivars (Ohgawara *et al.*, 1991). Results obtained by CIRAD[1] and INRA[4] in this area are presented.

obtaining intergeneric somatic hybrids

Research conducted in France over the past 5 years by CIRAD-FLHOR[2], CIRAD-BIOTROP[3] and INRA[4] (agricultural research station at San Giuliano, Corsica) on embryogenesis in citrus materialized in 1994 when the first *Citrus reticulata* (mandarin) + *Fortunella japonica* (kumquat) intergeneric hybrids were obtained in the CIRAD-BIOTROP laboratories. About a hundred plants were thus regenerated after electrofusion of *C. reticulata* embryogenic callus protoplasts and *F. japonica* leaf protoplasts (Photos 1-3).

Flow cytometry was used to determine ploidy levels (Fig. 1), and isoenzyme analysis confirmed their hybrid status. These tetraploid hybrids coud be sexually hybridized with diploid cultivars to introgress flavours, lateness, cold tolerance and kumquat bacterial canker resistance in mandarin-type triploid cultivars.

cybrid identification

As part of a cooperative project with IFAS[5] (Dr. J. Grosser, Florida, USA), diploid cybrids (nuclear genome from one species combined with cytoplasmic genomes of another species) were identified by two techniques: flow cytometry and RFLP marker analysis of nuclei and cytoplasm (Photos 4 & 5) from plants regenerated following fusions between *C. deliciosa* (mandarin) callus protoplasts

(1) CIRAD: Centre de coopération internationale en recherche agronomique pour le développement.

(2) CIRAD-FLHOR: Département des productions fruitières et horticoles.

(3) CIRAD-BIOTROP: Laboratoire des biotechnologies appliquées à l'amélioration des plantes tropicales.

(4) INRA: Institut national de la recherche agronomique.

(5) IFAS: Institute of Food and Agricultural Sciences (University of Florida).

and *C. sinensis* (sweet orange) leaf protoplasts, as well as between *C. deliciosa* callus protoplasts and *C. paradisi* (grapefruit) leaf protoplasts (LURO *et al.*, 1995).

The studies highlighted the systematic presence of nonrecombined mitochondrial and chloroplast genomes from the *C. deliciosa* parent (embryogenic calli) associated with nuclear genomes from *C. deliciosa*, *C. sinensis* or *C. paradisi*. The results were similar to those obtained by TUSA *et al.* (1990) and SAITO *et al.* (1993). They suggest that *Citrus* somatic embryogenesis regeneration capacity is under cytoplasmic control. Cybrids obtained in this way are ideal for assessing the involvement of cytoplasmic genomes and nucleus-cytoplasm interactions in determining phenotypic characters.

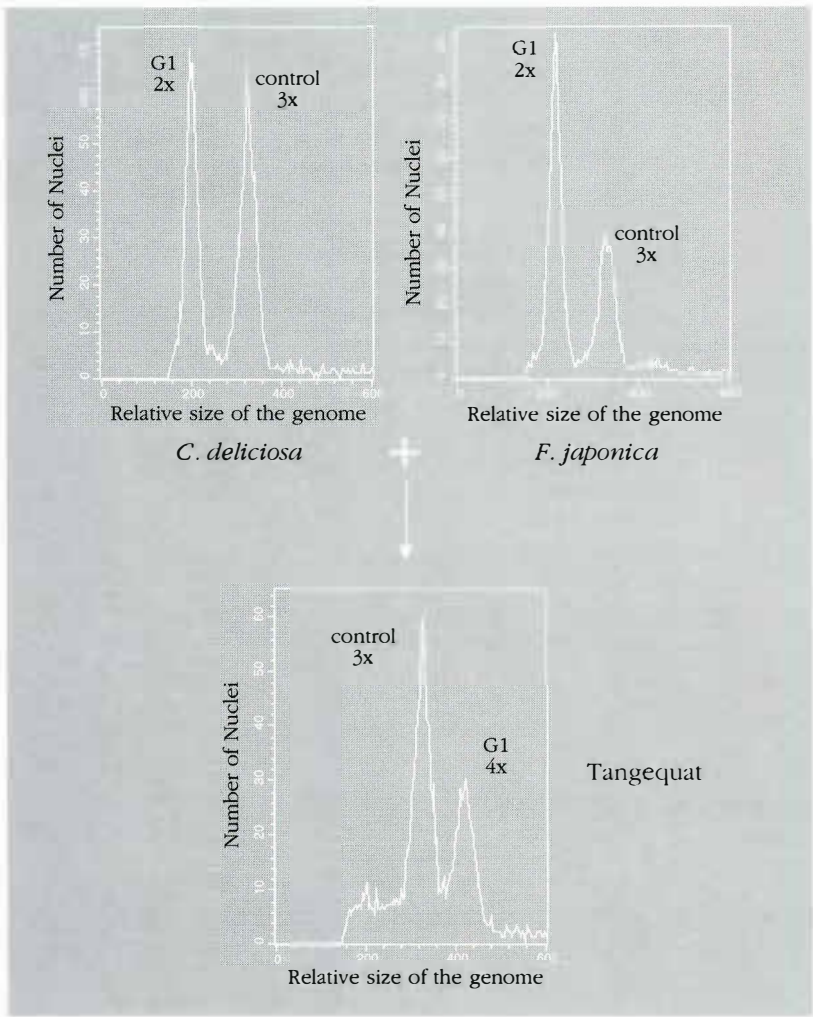

Figure 1
Analysis of ploidy levels of plants regenerated after somatic fusion between C. deliciosa *and* F. japonica.

prospects

Somatic hybridizations of various interspecific [*C. reticulata* + *C. sinensis*; *C. reticulata* + *C. paradisi*; *C. reticulata* + *C. lemon* (lemon); *C. reticulata* + *C. aurantifolia* (lime)] and intergeneric (*C. reticulata* + *Poncirus trifoliata* and *C. aurantium* + *Eremocitrus glauca*) combinations have been carried out and embryos are currently being propagated. These hybridizations are to be used in rootstock and cultivar improvement programmes and should also provide valuable information on polyploid genetics .

Fusions between diploid protoplasts and haploid protoplasts (derived from haploid plantlets obtained by induced gynogenesis) will soon be performed in order to synthesize triploids directly. The origins of plants regenerated in these different programmes will be checked with molecular markers and by flow cytometry. All plant material obtained by protoplast fusion will then be introduced in the CIRAD-FLHOR/INRA multilocation experimental network to assess their potential under Mediterranean and tropical conditions and their tolerance to the main diseases affecting such crops.

acknowledgements

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references

GMITTER F.G., GROSSER J.W., MOORE G.A., 1992. Citrus. *In*: Biotechnology of perennial fruit crops, Hammmerschlag and Litz ed., CAB International, p. 335-369.

LURO F., CABASSON C., GROSSER J., OLLITRAULT P., 1995. Utilisation des marqueurs RFLP et de la cytométrie en flux pour l'analyse génétique des plantules régénérées après fusion de protoplastes d'agrumes. *In*: Symposium méditerranéen sur mandarines, San Giuliano, France, 5-11 March 1995, (abstracts).

OHGAWARA T., KOBAYASHI S., ISHII S., YOSHINAGA K., OIYAMA I., 1991. Fertile fruit trees obtained by somatic hybridization: Navel orange (*C. sinensis*) and Troyer citrange *(C. sinensis x Poncirus trifoliata*). Theor. Appl. Genet. 81: 141-143.

OLLITRAULT P., LURO F., 1995.
Amélioration des agrumes et biotechnologie. Fruits (to be published).

OLLITRAULT P., F. LURO, ALLENT V., DAMBIER D., 1995.
Diversification des mandariniers : apport des biotechnologies pour la création de cultivars triploïdes aspermes. *In*: Symposium méditerranéen sur mandarines. San Giuliano, France, 5-11 March 1995, (abstracts).

SAITO W., OHGAWARA T., SHIMIZU J., ISHII S., KOBAYASHI, 1993.
Citrus cybrid regeneration following cell fusion between nucellar cells and mesophyll cells. Plant Science 88: 195-201.

TUSA N., GROSSER J.W., GMITTER F.G., 1990.
Plant regeneration of "Valencia" sweet orange, "Femminello" lemon, and the interspecific somatic hybrid following protoplast fusion. J. Amer. Soc. Sci. 116: 1043-1046.

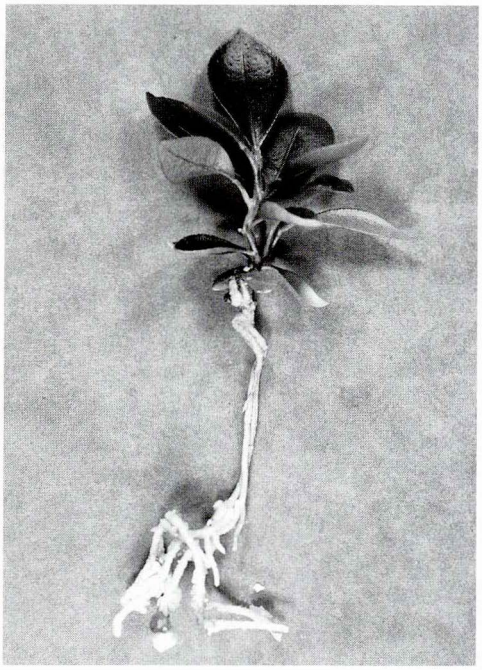

Photo 3
Somatic hybrids between C. deliciosa *and* F. japonica.

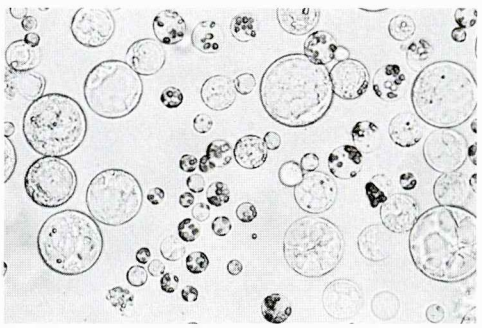

Photo 1
Mixture of Citrus deliciosa *embryogenic callus protoplasts and* Fortunella japonica *leaf protoplasts.*

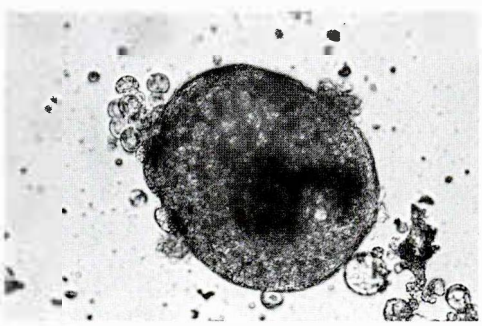

Photo 2
Proembryos 28 days after electrofusion of C. deliciosa *and* F. japonica *protoplasts.*

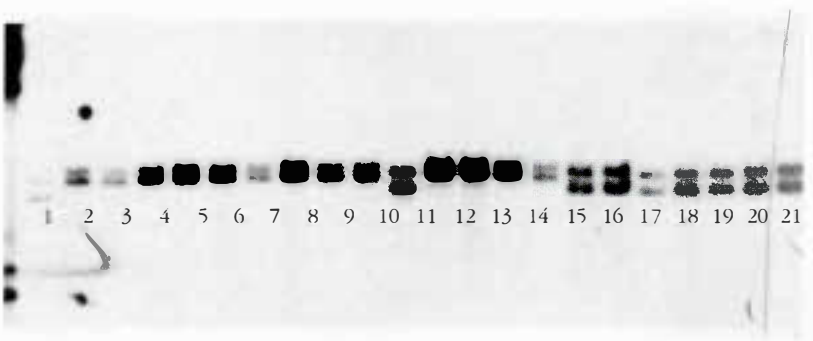

Photo 4
Checking the origins of nuclei from plants regenerated after protoplast fusion between C. deliciosa *and* C. sinensis.
1: C. deliciosa
2: C. sinensis.
Plants regenerated after fusion:
3-10 and 12-15: cybrids
11 and 16 to the end: plants regenerated from unfused C. deliciosa *protoplasts.*

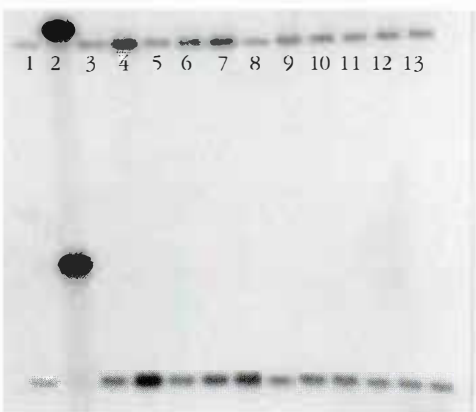

Photo 5
Checking the origins of cytoplasm (mitochondrial probe) from plants regenerated after protoplast fusion between C. deliciosa *and* C. sinensis.
1: C. deliciosa
2: C. sinensis
3-13: plants regenerated after fusion.

Genetic Mapping of an Intergeneric Citrus Hybrid Using Molecular Markers

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p. 483-485 (French)

A Citrus genetic linkage map was constructed: it can be used in interspecific and intergenetic hybrid heredity studies and for determining genes of agronomic interest.

introduction

Many problems are encountered when conducting genetic analyses of citrus hybrids, mainly for the following reasons: (1) high heterozygosity, (2) partial apogamy (polyembryonic seeds with embryos of nucellar origin and an embryo of zygotic origin), (3) the high numbers of progenies, and (4) the long juvenile phase (Gmitter *et al.*, 1992). The genetic improvement potential of cultivated citrus has been enhanced through biotechnological advances and the development of molecular marker techniques. Gene mapping has been carried out by several laboratories (Durham *et al.*, 1992; Jarrel *et al.*, 1992).

A citrus genetic linkage map was constructed using different types of molecular markers (isoenzymes, RFLP and RAPD), and the main applications are:
– investigate chromosomal heredity in interspecific and intergeneric hybrids,
– determine the number and assess the impact of detrimental or unsuitable mutations when crossing polyembryonic species,
– locate genes involved in the development of agronomically interesting characters. Markers associated with these genes could then be used for early selection of progenies and possible progenitors for breeding programmes (de Vienne, 1984; Stuber, 1989). Moreover, markers could potentially be used to isolate and transfer genes by genetic engineering (Ganal *et al.*, 1991).

A linkage map of a citrus genome from a hybrid obtained by a three-way cross is presented, focusing specifically on segregation distortions. The different analytical procedures are discussed in terms of the underlying biological models.

material and methods

hybridization

The progeny investigated (52 plants) were obtained by crossing a *Citrus grandis* (cv Seedless pummelo) female parent with an intergeneric hybrid male parent. The later was obtained through a *Citrus reshni* Hort. ex Tan. (cv Cleopatra mandarin) x *Poncirus trifoliata* L. Raf. (cv Swingle) cross.

markers

About one hundred markers were obtained. About half of these were RFLP markers from two cDNA banks (Luro, 1993). Forty probes were derived from a cDNA bank that we obtained from cv Valencia Late orange (*Citrus sinensis*) mRNA. Four other probes from a *Citrus jambhiri* bank were supplied by Dr. Roose of Riverside University, California (Jarrell *et al.*, 1992). Only cDNas with slightly repeated sequences or unique sequences showing polymorphism between the parents used in the cross were considered.

About forty amplified fragments segregating in the progeny were selected with a system involving RAPD markers (Williams *et al.*, 1990) using operon primers. Selection was based on the repetability of the amplifications and intensities of the amplified fragments. Heredity was also studied in a few fragments amplified by primers representing microsatellite sequences ([TCC]5; [GACA]4).

Seven isoenzyme systems were utilized: isocitrate dehydrogenase (ICD), malate dehydrogenase (MDH), phosphoglucose isomerase (PGI), endopeptidase (GOT) and phosphoglucomutase (PGM). Three isoenzymatic loci (LAP, GOT and PGI) were heterozygotic in pummelo and six (End, PGM2, LAP, GOT, ICD and MDH1) in the intergeneric hybrid (male).

genetic mapping

The genetic linkage maps were constructed using the Mapmaker software package (LANDER *et al.*, 1987). Several *Lod score* (logarithm of odds ratios) thresholds were tested to construct linkage groups. HALDANE's (1919) genetic mapping function was used. The recombination frequencies were calculated with the Mapmaker program.

The linkages and recombination frequencies (r) for each pair of markers were also calculated using the Genepop software program (OLLITRAULT, 1987). This program measures linkages by the chi-square test of independence (MATHER, 1957). This test takes segregation distortions into consideration relative to calculated theoretical frequencies for each class; it is based on marginal frequencies of the contingency table.

results and discussion

genetic linkage map

In all cases and for each individual hybrid, genetic compositions of male and female gametes for the intergeneric hybrid (*C. reshni* x *P. trifoliata*) were deduced from the genetic differences between parents used in the cross (Fig. 1). This progeny could thus be analysed for all markers as that of a test cross.

Forty-six fragments specific to the intergeneric hybrid (19 mandarin and 27 *Poncirus*) and 24 fragments specific to the maternal genome (pummelo) were amplified by 25 primers using the RAPD technique along with marker segregation in the progeny (Fig. 2).

The genetic linkage map constructed by the Mapmaker program included 95 markers distributed in 12 linkage groups (with a basic chromosome number of 9) (Fig. 3). Nine loci did not belong to any linkage group. The map was 1503 cM long (Haldane function), which is about two-thirds the total length of the genome (JARRELL *et al.*, 1992). The groups were established with a *Lod score* > 3 and maximum recombination frequency of 0.3 (corresponding to the approximate maximal detectable frequency for a backcross of 52 plants).

segregation distortions

Thirty-nine of the 104 markers mapped (37.5%) showed significant (chi^2 at 5% level) distortion as compared to the theoretical 1/1 segregation. In contrast, in pummelo, only 3 of 45 markers (6.5%) segregated in a non-Mendelian manner. Abnormal marker segregations have already been observed in citrus, especially in hybridizations of plants of different genera (TORRES *et al.*, 1985; OLLITRAULT & FAURE, 1992; DURHAM *et al.*, 1992; JARRELL *et al.*, 1992)

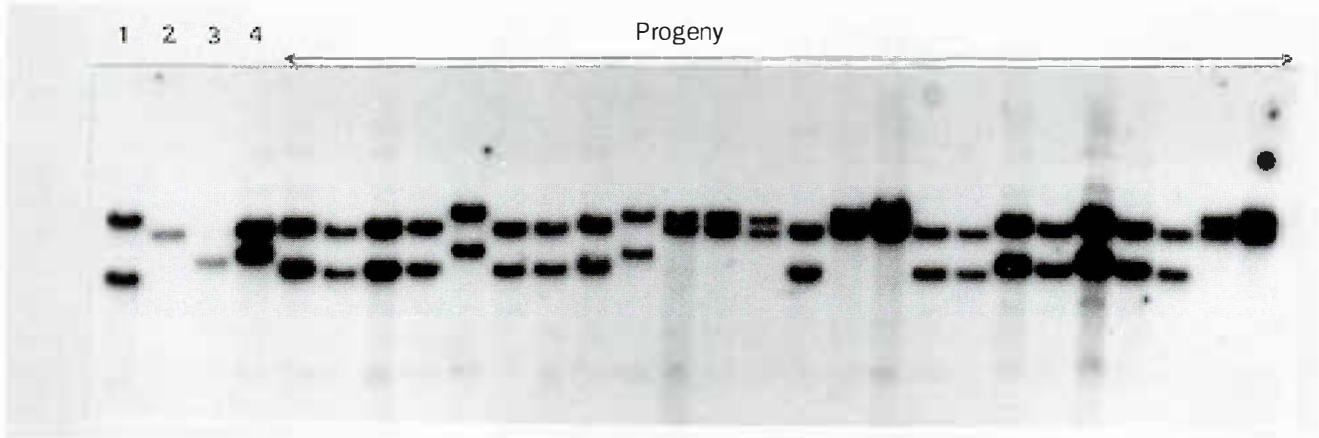

Figure 1
RFLP profile. Results of hybridization between DNA of parents and their progeny, digested by EcoRV and the cDNA probe 0.30.
1: cv Seedless pummelo
2: cv Cleopatra mandarin;
3: Poncirus trifoliata;
4: FAO 30573 (Cleopatra mandarin x Poncirus trifoliata*).*

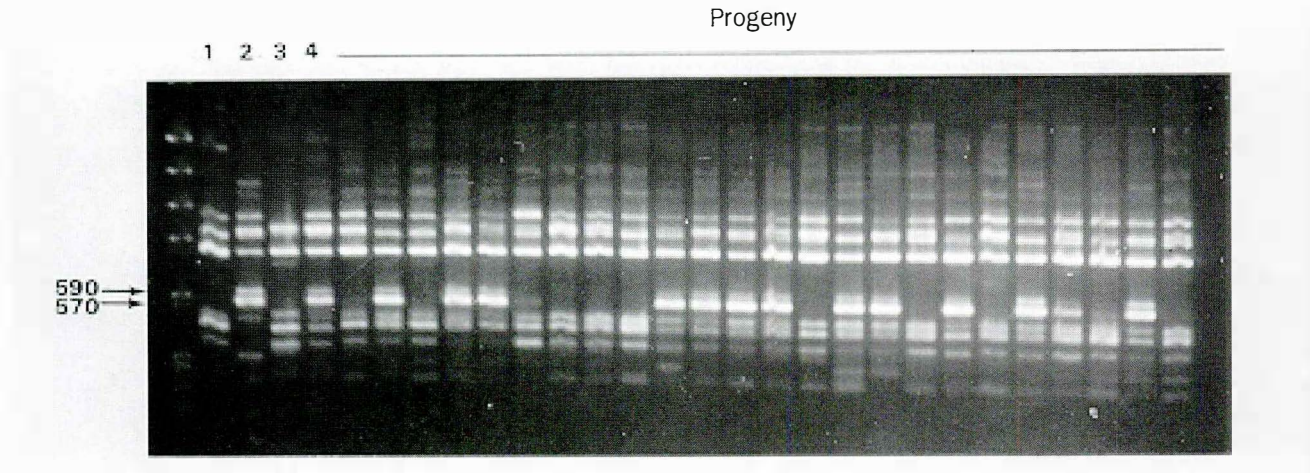

Figure 2
Segregation of RAPD markers. Results of amplification with primer OPK4, DNA from cv Seedless pummelo (1) x FAO 30573 (4) hybrids. The two 590 bp and 570 bp fragments were transmitted by cv Cleopatra mandarin (2). Lane 3: Poncirus trifoliata.

Note that linkage group 1 on the intergeneric hybrid genetic linkage map was constructed solely with markers showing segregation distortion, including almost half of all loci affected. Detailed analysis of distortions in linkage group 1 revealed that all of the markers had undergone selection in favour of the cv Cleopatra parent. Two hypotheses could be put forth:
– this is not a real group because the distortions caused false linkages;
– this group actually corresponds to a chromosome and thus the widespread distortion is probably partially due to structural heterozygosity of this chromosome set.

It is quite unlikely that there was a false linkage group since the chi^2 tests for independence, to assess possible linkages for each pair of markers, were always significant. Counter-selection of a whole chromosome could be the result of structural heterozygosity and gametic selection favouring one or several cv Cleopatra mandarin genes. At one of its ends, linkage group 3 included five markers showing segregation distortion. A unimodal distortion gradient was obtained, which peaked around markers VLc3.18 and VLc0.37. This pattern seems to indicate the presence of a single gene that was selected in the vicinity of these two markers.

The very marked differences, obtained for molecular marker segregation distortion levels that were much higher in the male intergeneric hybrid than in the female grapefruit parent, were in line with the biological data:

- data from the literature demonstrate that distortions are much more common in interspecific and intergeneric hybridizations than in intraspecific hybridizations (structural heterozygosity definitely has an important impact). The overall selection in linkage group 1 could be due to such structures;

- the two intergeneric hybrid parents of the intergeneric hybrid were polyembryonic whereas the pummelo was monoembryonic. It is therefore quite likely that the genetic load was lower in the pummelo parent. Indeed, facultative apogamy promotes buildup of mutations, in the heterozygotic state, that are detrimental or unsuitable in the homozygotic state. These mutations can induce abnormal segregations during crossing (gametic selection) and selfing (gametic and zygotic selections) (LURO *et al.*, 1995). The presence of structural heterozygosity can extend the effect of a locus selected to large chromosomal fragments or entire chromosomes. In such cases, the determined linkages can only be confirmed by comparisons with a map without any segregation distortions;

- due to pollen competition, it is quite likely that segregation distortions occurring in gametes are mainly the result of male parent input rather than that of the female parent.

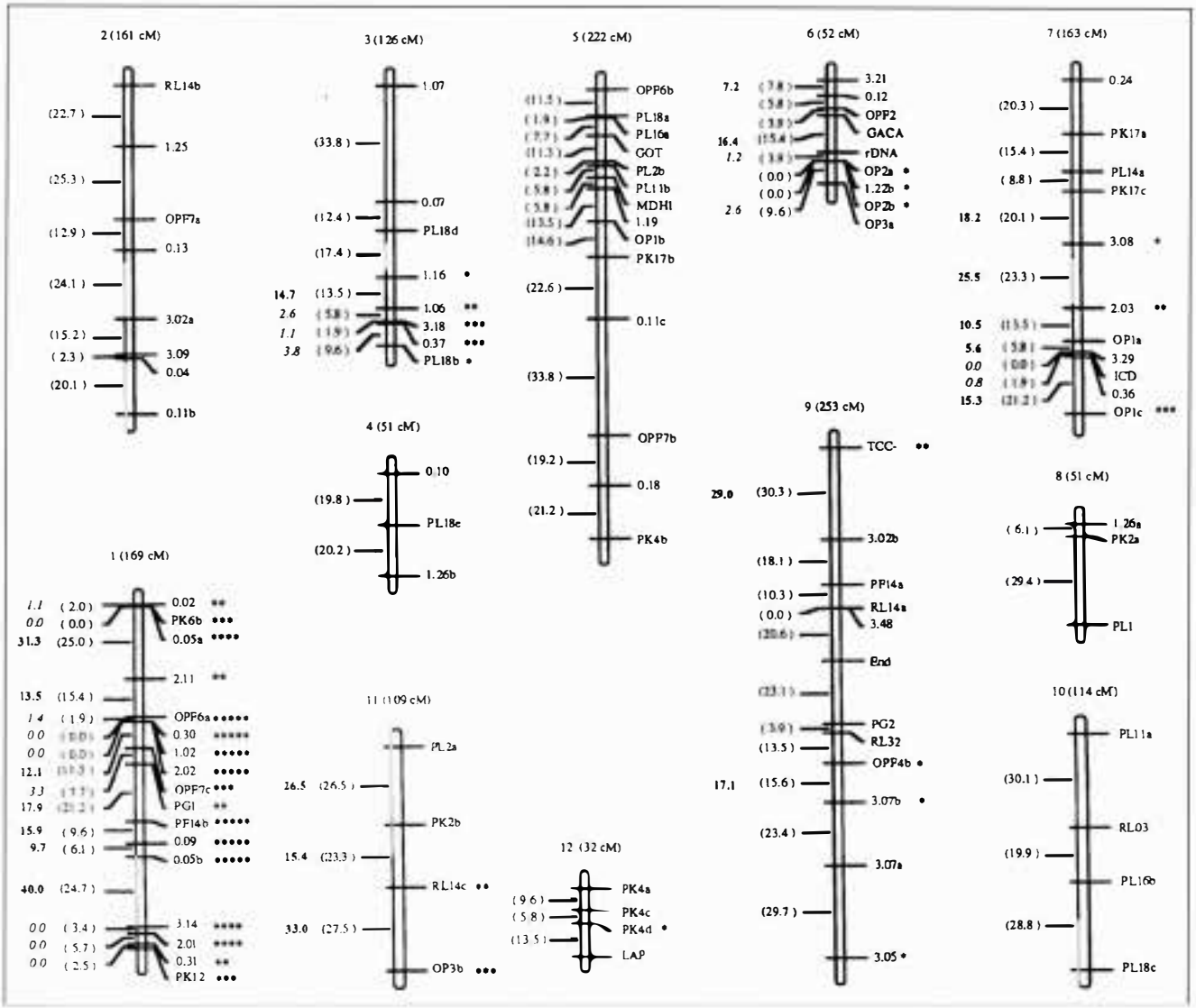

Figure 3
*Genetic linkage map for the intergeneric hybrid (*Citrus reshni *x* Poncirus trifoliata*). Numbers left of the linkage groups indicate the recombination frequencies calculated with the Mapmaker software package, the marker names are listed on the right.*

Asterisks indicate markers with segregation distortion:
**: chi² significance at 5%*
***: chi² significance at 1%*
****: chi² significance at 0.1%*
*****: chi² significance at 0.01%*
******: chi² significance at 0.001%.*

conclusion

Construction of a genetic linkage map from molecular markers is the first step towards fully understanding the underlying mechanisms involved in citrus reproduction. It also provides a means to locate genes of agronomic interest, e.g. showing disease resistance (tristeza, citrus bacterial canker, phytophtora, etc.). A partial genetic map containing one hundred markers divided into 12 linkage groups is still insufficient and should be supplemented with new markers. However, the presence of segregation distortions in specific genomic regions could jeopardize the use of these molecular markers for selection in plant breeding programmes. Chromosome inversions and the presence of false linkages have much more negative effects than simple distance estimate biases when attempting to locate genes or QTLs. Moreover, introgression of a chromosome fragment, promoted by a molecular marker with a distortion effect, leading to a false linkage with a sought-after trait, will result in breeding failures. It is thus essential to gain access to genetic information for the studied species in order to pinpoint the origins of distortions. This will facilitate choices of suitable assessment methods for future genetic mapping programmes. ●

references

DE VIENNE D., 1984.
Limites et perspectives des marqueurs moléculaires. Le sélectionneur français 33: 35-46.

DURHAM R.E., LIOU P.C., GMITTER F.G., MOORE G.A., 1992.
Linkage of restriction fragment length polymorphisms and isozymes in *Citrus*. Theor. Appl. Genet. 84: 39-48.

GMITTER F.G., GROSSE R.J.W., MOORE G.A., 1992.
Citrus. *In:* Biotechnology of perennial fruit crops. Hammerschlag et Litz. CAB International, pp 335-369;

GANAL M.W., BONIERBALE M.W., ROEDER M.S., PARK W.D., TANKSLEY S.D., 1991.
Genetic and physical mapping of the patatin genes in potato and tomato. Mol. Gen. Genet. 225: 501-509.

HALDANE J., 1919.
The combination of linkage values and the calculation of distance between the loci of linked factors. J. Genet. 8: 299-309.

JARRELL D.C., ROOSE M.L., TRAUGH S.N., KUPPER R.S., 1992.
A genetic map of *Citrus* based on the segregation of isozymes and RFLPs in an intergeneric cross. Theor. Appl. Genet. 84: 49-56.

LANDER E.S., GREEN P., ABRAHAMSON J., BARLOW A., DALY M.J., LINCOLN S.E., NEWBURG L., 1987.
Mapmaker: An interactive computer package for constructing primary genetic linkage maps of experimental and natural populations. Genomics 1: 174-181.

LURO F., 1993.
Utilisation des marqueurs moléculaires pour la cartographie du génome et les études génétiques chez les agrumes. PhD, Thesis, University of Bordeaux II, France, 187 p.

LURO F., LORIEUX M., LAIGRET F., BOVÉ J.M., OLLITRAULT P., 1995.
Cartographie du génome des agrumes à l'aide des marqueurs moléculaires et distorsions de ségrégation. *In*: Les colloques de l'INRA: Techniques et utilisations des marqueurs moléculaires. Montpellier, France, 29-31 March 1994. Paris, France, INRA, n° 72, p. 69-82.

MATHER K., 1957.
The measurement of linkage in heredity. London, UK, Methuen & Co, 149 p.

OLLITRAULT P., 1987.
Evaluation génétique des sorghos cultivés (*Sorghum bicolor* L. Moench) par l'analyse conjointe des diversités enzymatique et morphophysiologique. Relation avec les sorghos sauvages. PhD Thesis, Université de Paris XI, Orsay, France, 187 p.

OLLITRAULT P., FAURE X., 1992.
Système de reproduction et organisation de la diversité génétique dans le genre *Citrus*. *In*: Colloque international: Complexe d'espèces, flux de gènes et ressources génétiques des plantes. Paris, France, 8-10 January 1992. Paris, France, Lavoirier, Bureau des ressources génétiques, p. 135-151.

PERRIER X., OLLITRAULT P., DUBOIS C., 1992.
Cartographie du génome et QTL's. L'approche biométrique et les contraintes biologiques. Fruits, Special issue on *Citrus* 47: 135-144.

STUBER C.W., 1989.
Marker based selection for quantitative traits. Vorträge für Pflanzenzüchtung 16: 31-49.

TORRES A.M., MAU-LASTOVICKA T., WILLIAMS T.E., SOOST R.K., 1985.
Segregation distorsion and linkages of *Citrus* and *Poncirus* isozymes genes. J. Hered. 76: 289-294.

WILLIAMS J.G.K., KUBELIK A.R., LIVAK K.J., RAFALSKI J.A., TINGEY S.V., 1990.
DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. Nucleic Acids Res. 18: 6531-6535.

IV. Crop protection

VIROLOGY

Tristeza Survey in the West Indies. — C. BUJADOUX *et al.*

[Tristeza of citrus, identification, biological control, vectors, *Aphididae*, parasitoids, Caribbean] 410-414
[Tristeza des agrumes, identification, lutte biologique, vecteur de maladie, *Aphididae*, parasitoïde, Caraïbes]
[Tristeza de los agrios, identificación, control biológico, vectores, *Aphididae*, parasitoides, Caribe]

PHYTOPATHOLOGY

Serious Citrus Dieback in Colombia Caused by *Ceratocystis fimbriata*. — X. MOURICHON

[citrus fruits, *Ceratocystis*, identification, fungal diseases, symptoms, lesions, Colombia] 415-416
[agrume, *Ceratocystis*, identification, maladie fongique, symptôme, lésion, Colombie]
[frutas cítricas, *Ceratocystis*, identificación, enfermedades fungosas, síntomas, lesiones, Colombia]

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Research and Control Programmes Against Fruit Flies in Réunion. — S. QUILICI

[*Tephritidae, Ceratitis, Bactrocera* ...] 417-420
[... biology, ecology, insect control, biological control, oviposition, trapping, fruit trees, Réunion]
[... biologie, écologie, lutte antiinsecte, lutte biologique, ponte, piégeage des animaux, arbre fruitier, Réunion]
[... biología, ecología, control de insectos, control biológico, oviposición, caza con trampa, árboles frutales, Reunión]

The Fruit Fly Research Programme in New Caledonia. — J.M. LEMONTEY *et al.*

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[... distribución de la población, vigilancia de enfermedades, infestación, ganadería, control de plagas postcosecha, Nueva Caledonia]

Inventory of Insect Fauna Specific to Cultivated Fruit Trees of Northern Côte d'Ivoire. — K. N'GUETTA

[*Heteroptera, Coleoptera, Diptera, Hymenoptera, Orthoptera, Lepidoptera, Homoptera, Neuroptera, Dictyoptera* ...] 428-429
[... insect, fruit trees, surveys, Côte d'Ivoire]
[... insecte, arbre fruitier, enquête, Côte-d'Ivoire]
[... insectó, árboles frutales, encuestas, Côte d'Ivoire]

Inventory of Insect Fruit Pests in Northern Côte d'Ivoire. — K. N'GUETTA

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[Insectos depredadores de los frutos, frutas cítricas, mango, guayaba, papaya, anacardo, Côte d'Ivoire]

Tristeza Survey in the West Indies

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Fruits, vol. 49, n°5-6
p. 410-414 (English)
p. 488-490 (French)

A comprehensive indexing operation has been under way since 1993 in experimental orchards of Martinique and neighbouring islands to map the distribution of citrus tristeza virus in the West Indies. Behavioural studies on vectors of this disease have been conducted for potential biological control purposes.

introduction

Citrus cropping is expanding in the West Indies, mainly because of the increased demand for oranges to be processed for juice. Through its research, CIRAD-FLHOR is striving to promote citrus production that is fully adapted to local conditions. In 1988, an experimental orchard was thus set up at Rivière Lézarde (Martinique) to study citrus behaviour in a wet tropical climate and propagate indexed plant material.

However, there is a new citrus disease threat in the region, as signaled by the detection of the brown citrus aphid, *Toxoptera citricidus* Kirkaldy. This is the most efficient vector of citrus tristeza virus (CTV), which is transmitted semi-persistently.

The distribution range of *T. citricidus* recently extended considerably from its endemic zone in the southern hemisphere towards North America (Roistacher *et al.*, 1991).

In Central America, the vector was first noted in Panama in 1985, then in Costa Rica, Salvador and Honduras.

T. citridus colonized the West Indies within 5-6 years; it was first identified in Trinidad and Tobago in 1990, and then in Martinique and Guadeloupe.

In addition, CTV propagated and spread to new areas along with its most efficient vector. A serious infection broke out in Central America in 1992. The Caribbean islands were then contaminated, with severe tristeza strains detected in Trinidad and Tobago, Jamaica, the Dominican Republic and even Cuba.

CTV has a very high destructive potential in citrus orchards of the region since sour orange is the most common rootstock and its associations with orange, mandarin and grapefruit are very susceptible to the virus. The CTV front should thus be carefully monitored.

An indexing operation was set up by CIRAD-FLHOR at Fort-de-France (Martinique) in 1993 to deal with this situation. The operation is focused on trees from SRA lines, which are distributed as virus-free material. Some private citrus orchards in Martinique and hundreds of neighbouring islands have also been surveyed. The overall aim of this operation is to assess the CTV status in Martinique and surrounding islands. This operation has been stepped up in conjunction with the increased brown citrus aphid (*T. citricidus*) populations.

CTV control techniques mainly involve using resistant rootstock, cross protection and eradication. Eradication is used as a preventive strategy if the virus has not yet been propagated. Control programmes have not seriously focused on the insect vectors even though they represent the second most important means of transmission of CTV after grafting.

Studies have been carried out in the Mediterranean region on *Lysiphlebus tes-*

taceipes Cresson (Hym., Braconidae), an endoparasite of many different aphid species (Stary *et al.*, 1988a and 1988b) whose brown citrus aphid biocontrol potential looks promising (Yokomi, 1992). This endoparasite should therefore be further identified and investigated in full detail.

Studies on the behaviour of *Toxoptera citricidus* and *Lysiphlebus testaceipes* and their interactions are also under way.

materials and methods

phytosanitary situation

plant sampling

Sampling was done at two separate sites in the experimental Citrus orchard at Rivière Lézarde (CIRAD-FLHOR, Martinique). Half of the trees at the first site, which includes 167 different varieties, were tested. A quarter of the trees at the second site, comprising trial plots with replicates of four trees, were sampled. In surveyed private orchards of Martinique and neighbouring islands (Saint Lucia, Saint Vincent, Grenada, Dominica, Antigua, Nevis and Saint Kitts), samples were collected from the most susceptible trees: rootstock/susceptible variety associations, or highly susceptible Citrus trees showing specific symptoms (e.g. vein clearing in lime).

All samples were cut from young lignified shoots.

CTV detection

- ELISA-DAS technique

Indexing was performed using the ELISA-DAS technique with polyclonal antibodies from SANOFI diagnostic kits. The tests were carried out according to the manufacturer's instructions, and the conjugate was depleted with 33 µl of healthy control plant material/ml conjugate solution.

Mauritius papeda (*Citrus hystrix*) was preferentially used as control material for the depletion operation since the virus purified to develop the serum for the diagnostic kit had been obtained from this *Citrus* species. The ELISA plates were read on a spectrophotometer (405 nm) 45 min and 1 h after the substrate was plated.

- analysis of the results

The detection threshold was set 2- or 3-fold higher than the mean optical densities (OD) of the healthy controls (X).

Samples with OD levels lower than 2X were negative (healthy), while those higher than 3X were positive (contaminated). When the OD level was between these two levels, samples were tested a second time before determining the definitive result.

This detection threshold reduced the risks of making diagnostic errors for a disease with 0° tolerance.

insect rearing

aphids

T. citricidus aphids were reared on nursery Mexican lime plants. The plants were cut back regularly to promote the growth of shoots upon which the insect colonies were reared. The aphids had been identified and collected in the field.

Aphids were reared in an insectproof cage under a shaded plastic tunnel in natural conditions: 25-35°C, 12L/12D photoperiod and about 95% relative humidity during the rainy period.

The reared aphids were put in fine cotton sleeves placed around pretreated young shoots in cv Satsuma mandarin (*Citrus unshiu*) trees in the experimental orchard. The progeny of these aphids were then put in separate sleeves.

These aphid were observed on a daily basis to determine their characteristics and behaviour under the environmental conditions of Martinique.

parasitoids

The *L. testaceipes* aphid endoparasites were reared under the same conditions as the aphids on Mexican lime branches collected from the *T. citricidus* rearing cages; these branches were replaced regularly. Leaves with parasitized aphids (brown and mummy-like) were put in rearing boxes and placed in a room at constant temperature (25°C) under a 12L/12D photoperiod.

L. testaceipes insects hatching on the same day were grouped to determine the length of their adult life cycle.

Two-day-old *L. testaceipes* adults from the rearing boxes were put in the cotton sleeves containing aphids of different ages (3-10 days old) and densities (10-30 aphids).

These parasitoids were removed after 24 h with the host. After 4 days, they were monitored daily to assess the length of their growth cycle and parasitism rates.

The fine cotton sleeves were placed on cv Navel orange trees.

results and discussion

indexing

None of the 665 samples from Martinique were found to be contaminated with CTV (Table 1).

These results confirm the good health status of the experimental orchard at Rivière Lézarde (CIRAD-FLHOR, Martinique) where many samples had been collected. The station can thus continue its plant propagation activities under close supervision.

No general conclusions can be drawn from the present results because of the very low number of samples collected from *Citrus* growers' orchards (two were surveyed); they only apply to the trees tested.

Table 1
Results of CTV indexing analyses using the ELISA-DAS technique.

Origin	Total trees	Trees tested	Healthy trees	Infested trees
Martinique				
Repository orchard	838	420	420	0
Trial plots	956	220	420	0
Plantations	18 250 [1]	25	25	0
Caribbean				
Saint Lucia		10	9	1
Saint Vincent		11	11	0
Grenada		8	8	0
Dominica [2]		18	18	0
Antigua		13	12	1
Nevis		11	11	0
Saint Kitts		7	7	0

(1) estimated
(2) no samples were found to be positive, despite observed CTV symptoms in the field.

Martinique still seems to be CTV-free, but the survey carried out in the West Indies revealed the presence of the virus on two of the seven monitored islands, i.e. Antigua and, closer to Martinique, Saint Lucia. Table 2 illustrates CTV propagation patterns in the West Indies, which are closely correlated with the vector distributions.

Although the sample sizes were small for these areas, CTV seemed to be widespread because of the broad distribution range of its vector. It seems that the introduction of CTV-infected plants was responsible for spreading the virus to the West Indies; it was then transmitted by *T. citricidus*.

This hypothesis is supported by the fact that in Martinique, where only SRA-type citrus material is present (originating from the repository at San Giulano, Corsica, an island that is also virus-free), all ELISA results were negative.

In contrast, CTV has been introduced on neighbouring islands through budwood or plants originating from Florida, a region that has long been known to harbour tristeza.

The arrival of *T. citricidus* should accelerate CTV transmission on islands that until now have only been partially contaminated, and also boost between-island transmission. A 24-h CTV watch is thus required on Martinique and Guadeloupe since they both seem to be virus-free even after *T. citricidus* outbreaks.

insect biology

aphids

- life cycle length

The mean life cycle length of *T. citricidus*, as determined from a sample of 40 apterous aphids, was 17 days (± 2.47) under the environmental conditions of Martinique (Fig. 1).

- breeding rates

The mean number of offspring produced by an apterous female aphid, as determined from a sample of 30 aphids, was 50 aphids (49.6 ±11.3), peaking at almost 60 aphids (59 ± 8) (Table 3).

The first aphids were hatched after 6 days, with maximums at 9-12 days (Fig. 2).

The high standard deviations for these results could be explained by variations in the rearing system.

Nevertheless, the breeding efficiency confirmed field observations, indicating that *T. citricidus* was widely distributed. It seemed to be propagated at the expense of *Toxoptera aurantii*, the main aphid present prior to the arrival of *T. citricidus* but which is now rarely observed.

The high parthenogenic breeding rates of *T. citricidus* enabled it to quickly colonize the West Indies. It has now become the most serious aphid citrus crop pest because of the size of its colonies and the direct crop damage it causes.

The geographic extension of this aphid is also promoted by its marked ability to adapt to various climatic conditions; it is found in wet tropical regions (Asia, South America, Africa south of the Sahara), and in temperate areas (South America, Australia, New Zealand (LECLANT *et al.*, 1992).

parasitoids

- life cycle length

In natural conditions, the mean life cycle length of *L. testaceipes* in the aphid is about 10 days (9.4 ± 1.46), as determined from a sample of 41 insects.

The mean length of the adult *L. testaceipes* life cycle was found to be more than 3 days (3.38 ± 0.9), as determined from a sample of 120 insects placed in rearing boxes under unnatural conditions.

Parasitism rates assessed from field data were too heterogeneous to be interpreted. Nevertheless, it seems that *L. testaceipes* biocontrol could not alone reduce aphid populations to low enough levels to hinder the spread of CTV.

conclusion

The present results indicated that CTV was not yet present in Martinique, despite the arrival of its vector *T. citricidus* at the end of the 1980s. However, further in-depth analyses should now be carried out with more efficient techniques such as immunoprinting, PCR, etc.

Table 2
Citrus production and variation in *T. citricidus* and CTV distributions in the Caribbean Basin (from AUBERT, 1992; CAO VAN, 1992, updated in 1993).

Country	Citrus output	September 1991			September 1992			September 1993	
		CTV MS	CTV SS	*T. citricidus*	CTV MS	CTV SS	*T. citricidus*	CTV S?	*T. citricidus*
Costa Rica	34	+	+	+	+	+	+	+	+
Panama	86	+	+	+	+	+	+	+	+
Nicaragua	66	+	+	+	+	+	+	+	+
El Salvador	99	+	–	–	+	?	–	+	–
Honduras	97	–	–	–	+	+	–	+	–
Guatemala	135	–	–	–	+	–	–	+	–
Belize	87	+	–	–	+	+	–	+	–
Mexico	3 081	–	–	–	–	–	–	–	–
Trin. & Tobago	16	–	–	–	+	+	+	+	+
Saint Lucia	–	–	–	–	?	?	+	+	+
Martinique	2	–	–	–	–	–	+	–	+
Dominica	20	–	–	–	?	?	?	?	+
Guadeloupe	4	–	–	–	–	–	+	–	+
Puerto Rico	33	–	–	–	+	+	+	+	+
Dominican Rep.	84	–	–	–	+	+	+	+	+
Jamaica	104	–	–	–	+	?	+	+	+
Cuba	898	–	–	–	(–)	(–)	+	?	+
Grenada	2							–	+
Saint Vincent	1							–	+
Antigua	–							+	+
Nevis	–							–	+
Saint Kitts	–							–	+

CTV = citrus tristeza; MS = mild strain; SS = severe strain; S? = severity unknown.

Figure 1
Length of the T. citricidus *life cycle.*

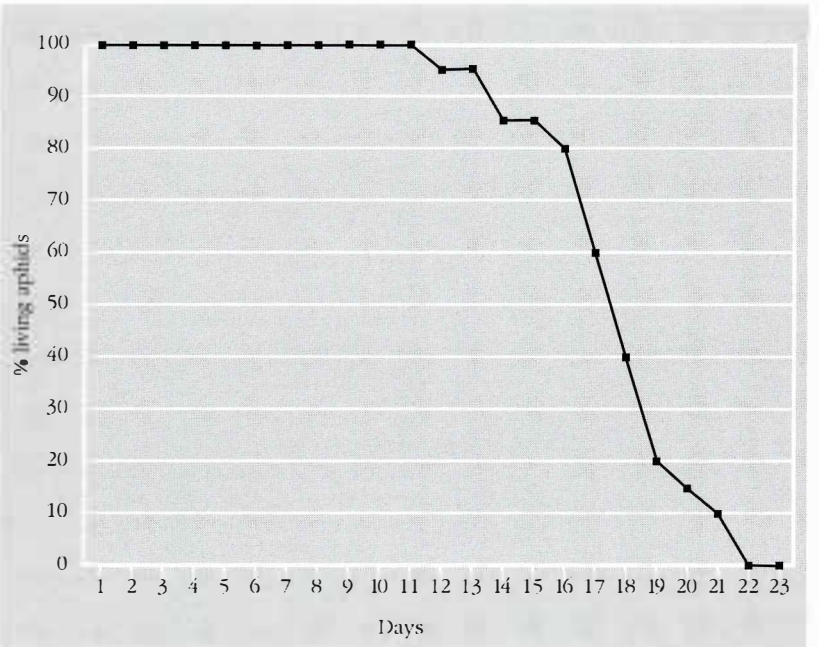

Table 3
Cumulated offspring for an apterous *T. citricidus* female.
The results were calculated from the offspring of 30 female aphids.

Life cycle length (days)	Total number of hatched aphids	
12	34.7	(8.44)*
13	40	(9.17)
14	45.5	(9.75)
15	49.6	(8.25)
16	53.2	(7.94)
17	57.6	(6.18)
18	58.2	(5.76)
19	59	(8)

* (x) = standard deviation

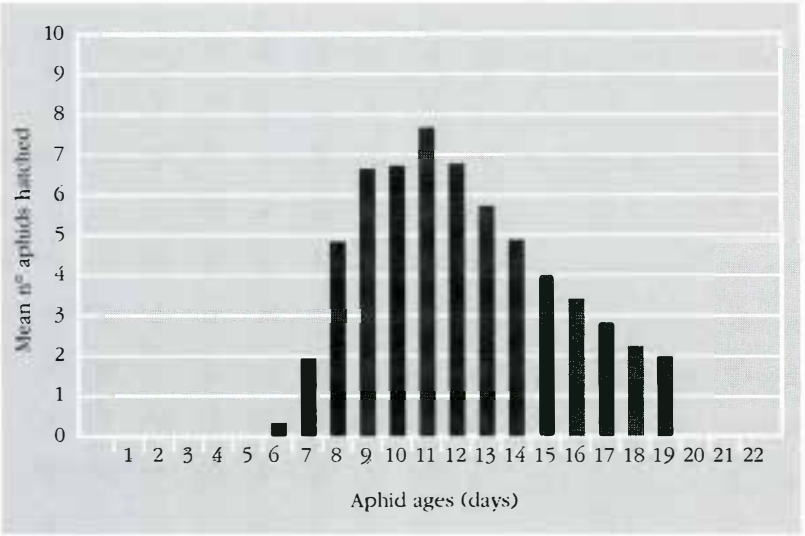

Figure 2
T. citricidus *breeding (mean number of aphids hatched/day/parent).*

references

AUBERT B., 1992.
Le programme agrumes du CIRAD-FLHOR. *Fruits,* Special issue on *Citrus* 47: 99-102.

AUBERT B., ETIENNE J., COTTIN R., LECLANT F., CAO VAN Ph., VUILLAUME C., JARAMILLO C., BARBEAU G., 1992.
Citrus Tristeza disease, a new threat for the Caribbean Basin. Report of a survey to Colombia, Dominican Republic, Guadeloupe, Martinique and Trinidad. Fruits 47 (3): 393-404.

CAMINADE J.M., 1992.
Le virus de la Tristeza des agrumes (CTV): transmission par *Toxoptera citricidus* (Kirkaldy) (*Hemipterae: Aphididae*) en conditions semi-contrôlées. Facteurs influençant la concentration des plantes hôtes en parasites viraux. Thesis. Cergy-Pontoise, France, ISTOM, 77 p.

CAO VAN P., 1992.
Citrus Tristeza virus/*Toxoptera citricidus*: situation in Martinique, Guadeloupe (French West Indies) and St Lucia. *In*: CTV and *T. citricidus* in Central America. Development of management strategies and use of biotechnology for control, September 14-19 1992, Maracay, Venezuela, 287 p. CATIE (Costa Rica), University of Florida (USA), INIFAP-SARH (Mexico), Universidad Central de Venezuela, USDA (USA), p. 102.

GILLETT J.M., MORRISSEY S.M., RAMSDELL D.C., 1986.
Interpreting ELISA data and establishing the positive-negative threshold. Plant Disease 70 (8): 722-726.

LECLANT F., ETIENNE J., AUBERT B., 1992.
Alerte à la Tristeza en verger d'agrumes. Le puceron vecteur *Toxoptera citricidus* envahit l'arc Caraïbe. Phytoma (440): 32-34.

ROISTACHER C.N., GUMPF D.G., DODDS J.A., LEE R.F., 1991.
The threat of «the citrus killer». Citrograph 76 (10): 4-10.

STARY P., LYON J.P., LECLANT F., 1988a.
Post-colonisation host range of *Lysiphlebus testaceipes* in the Mediterranean area (*Hymenoptera, Aphidiidae*). Acta Entomol. Bohemoslov. 85: 1-11.

STARY P., LYON J.P., LECLANT F., 1988b.
Biocontrol of aphids by the introduced *Lysiphlebus testaceipes* (Cress.) (*Hymenoptera, Aphidiidae*) in Mediterranean France. J. Appl. Ent. 105 : 74-87.

WALLACE J.M., 1978.
The Tristeza disease complex. The citrus industry. University of California, USA. W. Reuther, E.C. Calavan and G.E. Carman, eds, Volume IV, p. 87-109.

YOKOMI R.K., 1992.
Potential for biological control of *Toxoptera citricidus* (Kirkaldy). *In*: CTV and *T. citricidus* in Central America. Development of management strategies and use of biotechnology for control, September 14-19 1992, Maracay, Venezuela, 287 p. CATIE (Costa Rica), University of Florida (USA), INIFAP-SARH (Mexico), Universidad Central de Venezuela, USDA (USA), p. 194-198.

Serious Citrus Dieback in Colombia Caused by *Ceratocystis fimbriata*

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A new citrus disease in Colombia: symptoms and characteristics of the cultured fungus.

introduction

A very worrisome canker disease was recently detected in about 10% of citrus crops in Colombia, but the actual damage toll is probably even higher. Serious dieback has been observed over the last 3-4 years and threatens overall citrus production in the Colombian coffee-growing region. At the joint request of citrus growers in this region (Pereira, Manizales), the Centro nacional de investigaciones de cafe (CENICAFE) and the Instituto colombiano agropecuario (ICA), a task force was sent to assess the causes of this canker disease.

symptoms

The greatest canker damage was noted on cv Tahiti lime (Photo 1) and orange trees (Photo 2). The initial symptoms appear on certain vegetative organs or the whole tree; the leaves yellow and dry up to various extents. The symptoms are similar to those noted during *Phytophthora* attacks.

This disease features internal spread of different colours of rot in parts of the trunk or main branches or throughout most of the ligneous tissues of the tree. Comparisons with other diseases can thus only be made by analysing trunk or branch cross-sections.

Internal rotting quite often spreads from the base of the trunk (above the graft) to the top of the tree. Lesions are mainly located in the stele; they then spread centrifugally in a black flame shape (especially in lime, Photo 1), or much more extensively with a yellow serrated front.

External lesions are sometimes noted on various parts of the tree. The first disease symptoms (leaf wilt) often correspond to widespread underlying internal cankers.

diagnosis

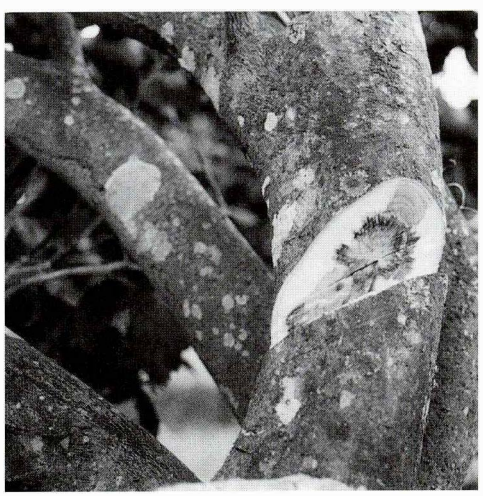
The fungus was isolated *in vitro* on various media from samples collected at different sites. Almost all cultures were derived from specimens cut from areas around lesions. Three genera of fungi were identified and their proportions evaluated:

– *Ceratocystis* sp. alone, 22% of the samples,
– *Ceratocystis* sp. + *Fusarium* sp., 8%,
– *Fusarium* sp. alone, 40%,
– *Diplodia* sp., 30%.

Morphological analysis of *Ceratocystis* in culture indicated that it belonged to *C. fimbriata*:

a - typical perithecium and ascospore morphology,
b - conidial stage *Chalara* (endospores/endoconidia),
c - many chlamydospores (alieuspores) (Photo 3).

Photo 1 and 2
Internal damage observed in parts of a citrus trunk or main branches.



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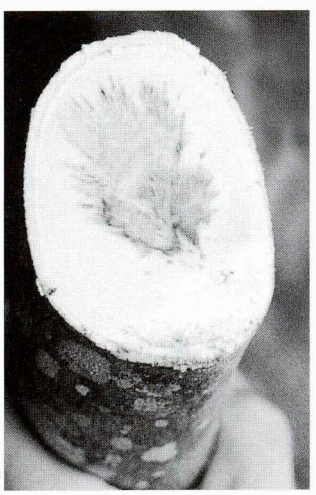

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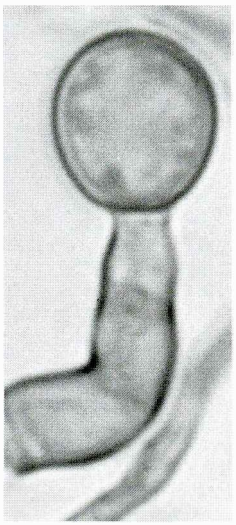


Photo 3
Chlamydospore (alieuspore) observed in Ceratocystis *culture derived from specimens cut from areas around lesions.*

Microscopy analyses of ligneous tissue fragments cut behind the growth front revealed many typical *C. fimbriata* chlamydospores in the pitted vessels. However, very few mycelial or endospore elements were detected.

discussion

The observed symptoms were very reminiscent of those described on plane trees in USA and Europe, and on some fruit trees infested by *Ceratocystis fimbriata* (plum, apricot and peach), especially in California (DEVAY *et al.*, 1968; MOLLER & DEVAY, 1968; MOLLER *et al.*, 1969; BOSTOCK & MIDDLETON, 1987).

In plane trees, the fungus penetrates the host through wounds in its aerial parts. *C. fimbriata* mainly develops in the medullary rays of the infested tree (thus explaining its flame-like appearance) and spreads to the pith. It then spreads in various directions and becomes deeply implanted in the host. The lesions spread rapidly, i.e. from 10 to 100 cm/month. The fungus is transmitted through dispersion of various kinds of debris from infected trees, e.g. sawdust from diseased trees is highly infectious. Fungal inocula are most commonly transmitted on tools used on different trees. Transmission by a few potential insect vectors has also been reported in USA (CRONE & BACHELDER, 1961), but this mode seems to be relatively limited.

In stone fruit trees, *C. fimbriata* is reportedly transmitted from the soil to pruning wounds or other injuries by insects (MOLLER & DEVAY, 1968).

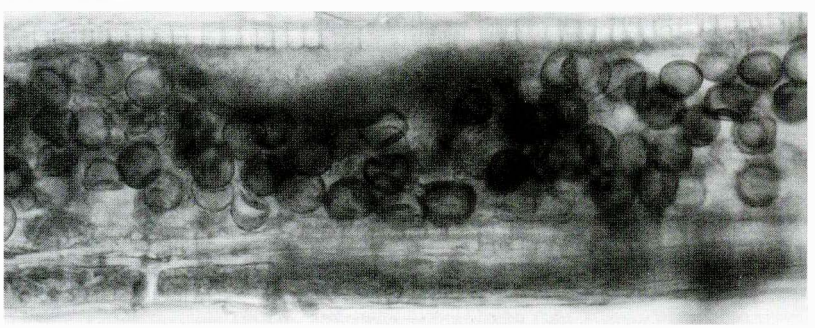
In the Colombian situation, *C. fimbriata* seems to be maintained as chlamydospores in the tree tissues, particularly in the xylem vessels (Photo 4). Identical images in plum trees were published by DEVAY *et al.* (1968).

The problems encountered in isolating this fungus in culture and the low isolation rates as compared to two other genera (*Fusarium* and *Diplodia*), considered to be secondary parasites in this particular situation, could have been due to the fact that *C. fimbriata* was mainly present as chlamydospores in the ligneous tissues.

conclusion

This is the first description of these quite unique symptoms in *Citrus* crops. *C. fimbriata* seems to be the causal agent of this new disease. The present results should now be confirmed by pathogenic analysis of *C. fimbriata* in *Citrus*, e.g. after experimental inoculation. Studies aimed at stalling the progress of this new parasitic threat are under way to further determine some epidemiological components of the disease (etiology and propagation).

Photo 4
C. fimbriata *chlamydospores observed in the xylem vessels of tree tissues.*



references

BOSTOCK R.M., MIDDLETON G.E., 1987.
Relationship of wound periderm formation to resistance to *Ceratocystis fimbriata* in almond bark. Phytopathology 77 (8): 1174-1180.

CRONE L.J., BACHELDER S., 1961.
Insect transmission of canker stain fungus, *Ceratocystis fimbriata* F. *platani*. Phytopathology 51: 576 (Abs.).

DAVIS S.H., PETERSON J.L., 1973.
A tree wound dressing to prevent spread of the *Ceratocystis* causing canker stain disease of the plane tree. Plant Dis. Rep. 57: 28-30.

DEVAY J.E., LUKEZIC F.L., ENGLISH H., TRUJILLO E.E., MOLLER W.J., 1968.
Ceratocystis canker of deciduous fruit trees. Phytopathology 58: 949-954.

MOLLER W.J., DEVAY J.E., 1968.
Insect transmission of *Ceratocystis fimbriata* in deciduous fruit orchards. Phytopathology 58: 1499-1508.

MOLLER W.J., DEVAY J.E., BACKMAN P.A., 1969.
Effect of some ecological factors on *Ceratocystis* canker in stone fruits. Phytopathology 59: 938-942.

Research and Control Programmes Against Fruit Flies in Réunion

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The bioecology of the Natal fly, a fruit crop pest, is now almost fully characterized and supervised pest control techniques have been improved, thus prompting certain development-oriented activities in Réunion, i.e. public awareness campaigns and the distribution of control compounds to fruit producers.

introduction

In recent years, the CIRAD-FLHOR entomology laboratory in Réunion has refocused its activities on fruit flies, a group of pests that have a major economic impact. The Natal fly, *Ceratitis (Pterandrus) rosa* Karsch, causes the most fruit crop damage on the island by far; this could be explained by the fact that it is highly polyphagous and widely distributed.

Three types of activity on this topic have been under way since 1991:
– baseline research, aimed at further characterizing the bioecology of this pest,
– applied research, aimed at improving supervised control techniques against fruit flies,
– development activities, aimed at fully informing fruit producers as to the situation and distributing control compounds and equipment.

In 1991, a new Tephritidae species, *Bactrocera (Bactrocera) zonata* Saunders, was identified on the island. A control programme focusing on this pest was immediately set up in conjunction with several other organizations.

baseline research

These studies are specifically focused on defining the underlying mechanisms that guide *C. rosa* females in choosing oviposition sites and on the reproductive potential of this species.

The importance of some visual stimuli, e.g. host colour and size, in determining female oviposition site choices, was clarified in the initial studies. Artificial wax hemispheric domes (Boller, 1968; Prokopy & Boller, 1971) of given size and colour were presented to females in choice experiments. Wild larval fruit flies of the same origin were collected from infested guavas. The female fruit flies used in most of the tests were naive with no prior contact with an oviposition substrate.

The results showed a significant effect of host size on the extent of ovipositions in *C. rosa*, i.e. there were more eggs laid in large-sized domes. Colour was also found to influence oviposition site choices; females generally preferred yellow and red, and black to a lesser extent. Of all seven colours tested, the highest numbers of eggs were laid in yellow domes. The results also indicated no significant effect of background colour (white or black) in the females' host colour choices. Moreover, it was found that preconditioning females on a red substrate had little effect on their ultimate substrate colour preferences.

The studies also highlighted an important effect of olfactory stimuli in *C. rosa* oviposition site choices. In these trials, fruit

extracts were placed under the wax domes out of the fruit flies' reach. In choice experiments with odourless domes and those smelling of peach (pulp) or orange (peel), almost all eggs were laid in the latter domes. It seemed that other factors such as dome colour and size did not limit the high attractivity of the orange-odoured domes, indicating that olfactory stimuli are more important than visual stimuli.

The female fruit flies were also very attracted to other fruits such as rose apples, *Sizygium jambos* (L.) Alston. Bilberries (*Solanum auriculatum* Ait.) were not as attractive, and the odour of guava (*Psidium cattleianum* Sabine) was not at all attractive to females. Otherwise, grape, which is not infested by *C. rosa* in field conditions, induced some response under experimental conditions; damaged grapes were more attractive than sound fruit.

In other tests, females did not respond, at the tested concentrations, to different chemical compounds used separately (acetic acid, limonene, linalool and fluorene). Laboratory studies analysing changes in volatile discharges from citrus fruits (mandarin) during ripening (i.e. fruit odours at different maturity stages) relative to female fruit fly responses are currently under way. They are aimed at fully defining the relationships between *C. rosa* and various host plants.

Studies have also been carried out on other biological and behavioural aspects of *C. rosa*. The effects of temperature on the reproductive potential of the species has thus been investigated. For pre-adult stages, the thermal constant and zero-point of egg and pupa development have been determined, i.e. 32.8 degree-days-11.1°C and 141.5 degree-days-12.6°C, respectively. Other studies revealed that female fecundity was maximal at 20°C.

Natal fly behaviour under semi-natural conditions (large cage) was also studied. Some preliminary data were thus obtained on the fly's activities and positions on the plant during the day. Studies on the sexual behaviour of the pest, especially the pheromonal marking of males, revealed similarities with the known behaviour of *C. capitata*. However, in *C. rosa*, pheromonal marking generally begins late in the afternoon, around 1700 hours. The lek phenomenon that has already been reported in various Tephrididae species, was observed for the first time in *C. rosa*.

An ecological study on Tephritidae host plants in Réunion, aimed at updating data obtained about 20 years ago by ETIENNE (1982), has also been under way for 2 years. Samples are being collected from a wide range of fruit hosts at many locations and at different times of the year. This survey revealed new host plants and dominant fruit fly species on the whole range of host plants.

In addition, there has been an IOBC[1] task force study on the responses of local *Ceratitis (Ceratitis) capitata* Wiedemann strains to pheromone marking (BOLLER *et al.*, 1994).

Biological control studies were first focused on optimizing methods for mass rearing local Tephritidae strains. In preparation for acclimatization experiments, bioethological studies have been conducted with an ovo-pupal parasitoid, *Biosteres arisanus* Sonan (Hym.: Braconidae), that was imported from Hawaii in early 1993 (generously donated by Dr. E. Harris, USDA[2]).

applied and development-oriented research

Various tests have been carried out in recent years to improve supervised control techniques. The first were focused on perfecting sexual trapping techniques to monitor fruit fly populations. The efficacies of various types of traps, slow-release sexual attractant dispensers, and different sizes of dichlorvos insecticide strips (DDVP) were thus compared.

The results of several orchard tests carried out since 1991 have confirmed the efficiency of the spot treatment technique (protein + malathion hydrolysate) against local fruit fly species present in *Citrus* and mango orchards. To assess the limitations of this method, experiments were undertaken with other more susceptible fruit species (loquat, strawberry guava

(1) IOBC: International Organization for Biological Control of Noxious Animals and Plants.

(2) USDA: United States Department of Agriculture.

and peach); the results so far are not very convincing. Moreover, several orchard tests were carried out to determine optimal hydrolysate and insecticide concentrations. Mortality rates at different compound concentrations were estimated by hanging sticky trays in the foliage of treated trees.

A parallel programme was launched in 1991 to extend the use of supervised fruit fly control to all potentially applicable situations. The advantages of this type of pest control over the techniques currently used by fruit producers are: fewer treatments (with the use of sexual trapping), lower control costs (reduced insecticide volumes, quantities and labour), thus reducing harmful effects on non-target fauna.

A widespread public awareness campaign (leaflets, posters, radio and TV ads and videos), conducted in collaboration with the chamber of commerce of Réunion, was able to reach many farmers and much of the general public. Essential equipment and products (traps, attractants, etc.), which were partly funded by local governmental agencies (i.e. regional and county councils), were distributed in conjunction with many agricultural cooperatives. In 1992, sexual trapping was used to control about 450 ha of susceptible crops, and fruit flies were controlled on about 115 ha with spot treatments.

A fruit fly pest watch network, involving sexual trapping with methyleugenol, was set up in Réunion by the mid-1990s. It aims at early detection of infiltrations by *Bactrocera (Bactrocera) zonata* Sanders, an Indian species that has been infesting fruit crops in neighbouring Mauritius over the past few years. A few flies of this species were actually detected near the airport in February 1991. A control program was immediately set up jointly with various collaborating organizations (Service de la protection des végétaux, Fédération des groupements de défense contre les ennemis des cultures, Chambre d'agriculture de l'île de la Réunion) to try to eradicate this new pest. The sexual trapping network was substantially reinforced in the zone and extended over the whole island. Simultaneously, an intensive campaign involving chemical control and destruction of susceptible host fruits was carried out around the outbreak area. Network captures decreased progressively during the second half of 1991 and were nil by February 1992. Only three flies were trapped in 1993 and no new upsurges were noted. At the end of 1993, the species was considered to have been completely eradicated from Réunion. Nevertheless, the fruit fly watch network must be kept up to enable very quick interventions if any more of these pests are detected.

conclusion

Studies carried out over the last few years in Réunion by the CIRAD-FLHOR entomology laboratory have aimed at fully characterizing the bioecology of Tephritidae fruit crop pests on the island, particularly the Natal fly. Insect-plant relationships, pest behaviour and their natural enemies are priorities for future research.

Supervised control techniques are currently being extended in Réunion. They will eventually be combined with biological control, which could be very useful for treatment of areas with communities of wild host plants, and with biotechnical control, which will require further experiments. ●

acknowledgements

This paper provides a brief summary of the research focuses of the CIRAD-FLHOR entomology laboratory team in Réunion. We would like to express our sincere gratitude to the technicians A. Franck, R. Manikom and C. Simiand, and to the following trainees who worked in our laboratory from 1991 to 1993: K. Bonacina, A. Bonhomme, V. Bunge-Vivier, E. Haug, P. Labarrière, J.M. Martin-Teissère, C. Norosomahefa, A. Peppuy, A. Pierru, L. Rivry, G. Rossolin and V. Sourdri.

references

BOLLER E., 1968.
An artificial oviposition device for the European cherry fly, *Rhagoletis cerasi*. J. Econ. Ent. 61: 850-852.

BOLLER E.F., HIPPE C., PROKOPY R.J., ENKERLIN W., KATSOYANNOS B.I., MORGANTE J.S., QUILICI S., DE CRESPO DE STILINOVIC, ZAPATER M., 1994.
Response of wild and laboratory reared *Ceratitis capitata* Wied. (*Dipt., Tephritidae*) flies from different geographic origins to a standard host-marking pheromone solution. J. Appl. Ent. 118: 84-91.

ETIENNE J., 1982.
Etude systématique, faunistique et écologique des Téphritides à la Réunion. PhD thesis, Paris, France, Ec. Pratique Hautes Etudes, 100 p.

PROKOPY R.J., BOLLER E.F., 1971.
Artificial egging system for European cherry fly. J. Econ. Ent. 63: 1413-1417.

QUILICI S., 1989.
Aménagement de la lutte chimique contre les mouches des fruits à la Réunion. *In*: Fruit Flies of Economic Importance, Proc. CEC / IOBC Intern. Symp., Rome, Italy, 7-10 April 1987. Rotterdam, Netherlands, R. CAVALLORO ed., A.A. Balkema, p. 515-524.

QUILICI S., TRAHAIS B., 1993.
Improving fruit fly trapping systems in Reunion Island. *In*: Fruit Flies: Biology and Management, New-York, USA, M. ALUJA et P. LIEDO eds, Springer-Verlag, p. 235-242.

QUILICI S., RIVRY L., ROSSOLIN G., 1994.
Visual stimuli influencing the choice of oviposition site in *Ceratitis rosa* Karsch (*Diptera: Tephritidae*). *In*: Current Research on Tropical Fruit Flies and their Management, Proc. Symp. on Tropical Fruit Flies, 18-20 May 1992, Kuala Lumpur, Malaysia, H.S. YONG and S.G. KHOO eds, p. 9-21.

The Fruit Fly Research Programme in New Caledonia

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An important fruit fly research programme was set up in New Caledonia following the recent ban on ethylene dibromide treatments. It is aimed at revitalizing the fruit and vegetable export sector. A progress report is presented.

introduction

A fruit fly research programme has been set up in New Caledonia (Map p. 362) to address recent quarantine restrictions on the export of local fruits and vegetables, especially to countries such as New Zealand which are free of pest fruit fly species (Diptera: Tephritidae). Exports from New Caledonia to New Zealand were authorized until 31 December 1993 on condition that the produce was pre-treated with ethylene dibromide (EDB). Fruit flies can be efficiently eliminated at different development stages (e.g. eggs, larva) by treatment with this pesticide. However, New Zealand legislation has now set the permissible EDB residue level at 0.1 ppm, thus representing an overall ban on the use of this product.

Only fruits and vegetables with a confirmed non-host status for different fruit fly species, or those that have undergone an authorized alternative treatment (heat, cold, etc.), can currently be exported to New Zealand. The French Territory of New Caledonia has assigned the CIRAD-FLHOR fruit research station at Pocquereux the task of solving this produce export problem.

A 4-year research programme (1993-1996) has been set up under mixed financing (CIRAD/Territory of New Caledonia). The present paper summarizes this programme, with emphasis on the first two well-established phases, i.e. the sexual trapping network and *Bactrocera tryoni* (Froggatt) breeding project.

Tephritidae inventory in New Caledonia

Eleven fruit fly species have been identified in New Caledonia, including seven endemic species (Cochereau, 1970; Drew, 1989; White & Elson-Harris, 1992). All of these species, their known fruit hosts, susceptibilities to different sex attractants, and South Pacific distributions are summarized in Table 1. Two complementary strategies have been developed to certify the detection of all fruit flies and collect further information on the full range of plant hosts, these are: a sexual trapping network and systematic collection of susceptible fruits and vegetables.

sexual trapping network

The sexual trapping network was set up in 1990 and gradually extended throughout New Caledonia; there are now 118 traps at 41 different sites. Each Lynfield trap comprises a plastic container (1 l) with four holes, cotton soaked with a liquid sex attractant and a dichlorvos insecticide strip. The traps are attached at human height under the tree foliage. Three sex attractants are used (Cue-lure, Methyl-eugenol and Trimedlure); the first two are known to effectively attract some fruit fly species present in New Caledonia, and Trimedlure is used to detect accidental introductions of Mediterranean fruit flies (*Ceratitis capitata* Wiedemann).

Although fruit fly captures are not always representative of the actual field situation,

Table 1
Inventory of fruit flies (*Tephritidae*) in New Zealand
(from WHITE & ELSON-HARRIS, 1992; DREW, 1989 and DREW, pers. comm.).

Species	Known host fruit	Attractant	Distribution
Bactrocera tryoni (Froggatt)	very many	Cue-lure	Australia, N.C. Polynesia
Bactrocera psidii (Froggatt)	citrus fruits, guavas, peaches, mangoes, etc.	Cue-lure	endemic N.C.
Bactrocera curvipennis (Froggatt)	citrus fruits, guavas, peaches, mangoes, etc.	Cue-lure	Vanuatu, N.C.
Bactrocera mucronis (Drew)	unknown	Cue-lure	endemic N.C.
Bactrocera umbrosa (Fabricius)	breadfruit, jackfruit	Methyl-eugenol	Vanuatu, N.C., Micronesia, East Asia
Bactrocera ebenea (Drew)	unknown	Methyl-eugenol	endemic N.C.
Bactrocera aneuvittata (Drew)	unknown	unknown	endemic N.C.
Bactrocera perpusilla (Drew)	unknown	Cue-lure (?)	endemic N.C.
Bactrocera fulvifacies (Perkins)	unknown	unknown	endemic N.C.
Bactrocera caledoniensis	unknown	Cue-lure	endemic N.C.
Bactrocera sp.*	*Diospyros fasciculosa* (*Ebenaceae*)	unknown	endemic N.C. (?)
Bactrocera near *xanthodes**	unknown	Methyl-eugenol	Vanuatu (?), N.C.
Dirioxa pornia (Walker)	citrus fruits, peaches, (secondary pest)	unknown	Australia, N.C.

* identification in progress.

the sexual trapping network provides information on the distributions and relative population densities of different fruit fly species (Fig. 2). *B. tryoni* (Froggatt) and *B. psidii* (Froggatt) are often trapped in high numbers, i.e. 55% and 39% respectively; note that these trapping figures are means for all sites, but there are marked between-site variations. *B. tryoni* seems to be spreading rapidly as it was captured in 98% of cases in Nouméa; nevertheless, only a few have been trapped on the Loyalty Islands (Maré, Lifou) which are still relatively free of this species. The *B. tryoni* risk potential should be stressed in the light of its rapid spread subsequent to an accidental introduction from Australia in 1970 (COCHEREAU, 1970).

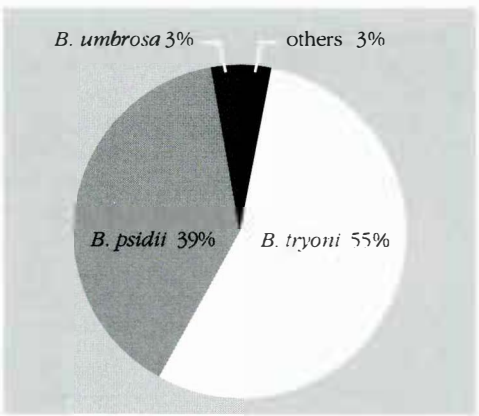

Figure 2
Percentages of fruit flies trapped in New Caledonia (mean of 108 traps).

The bimonthly collections also provide data on fruit fly population dynamics. Trapping results at the Pocquereux station are summarized in Figure 3, highlighting the clear correlations between population peaks and summer heat spells. The curves are similar for each region, except for the urban zone around Nouméa where fruit fly populations remain high throughout the year. This could be explained by the island-like location of Nouméa and the fact that climatic variations are not as extreme as elsewhere in New Caledonia. All 11 characterized fruit fly species are captured regularly in the traps, even though there are very few specimens of some species, i.e. *B. fulvifacies* (Perkins) and *Dirioxa pornia* (Walker). A few flies of a species close to *B. xanthodes* (Broun) have been trapped in the network set up on Maré Island. It is now being fully identified with the assistance of the entomology laboratory of the

Queensland Department of Primary Industries (Dr. R.A.I. Drew).

fruit and vegetable collection

The trapping network provides a relatively easy means for drawing up a partial fruit fly inventory. However, the list obtained should not be considered exhaustive since species that do not respond to the different sex attractants used are not detected. This shortcoming was highlighted by the fact that some specimens of a seemingly new *Bactrocera* species (Drew, pers. comm.) were collected separately on *Diospyros fasciculosa* (Ebenaceae) fruits, but they have never been found in the traps.

Wild and cultivated fruits and vegetables thus have to be collected at all sites throughout the year. They are placed in "hatching boxes" on a wet bed of sawdust. The sawdust is sifted regularly to collect fruit fly pupa and adults, which are then identified.

This campaign to detect fruit fly species that are not attracted by the sexual traps is also useful for determining different species of host plants. The fruit hosts of six fruit fly species are still completely unknown.

This list is being drawn up in collaboration with the New Zealand Ministry of Agriculture and Fisheries (MAF). Economically important fruit fly species, i.e. those that infest exportable fruits and vegetables, are thus being identified. In practice, MAF considers that all fruit species belonging to the same plant family as a known fruit host could be infested and thus should be tested. For instance, *B. umbrosa* (Fabricius) has been observed on *Momordica* sp., which means that it should be tested on all other Cucurbitaceae species present (e.g. zucchini, squash).

The list is needed as a basis for discussions on the exclusion of some species from future host status studies. *B. tryoni* (Froggatt), *B. psidii* (Froggatt), *B. curvipennis* (Froggatt) and *B. umbrosa* (Fabricius) are so far the only species chosen; a programme has thus been set up to rear these pests.

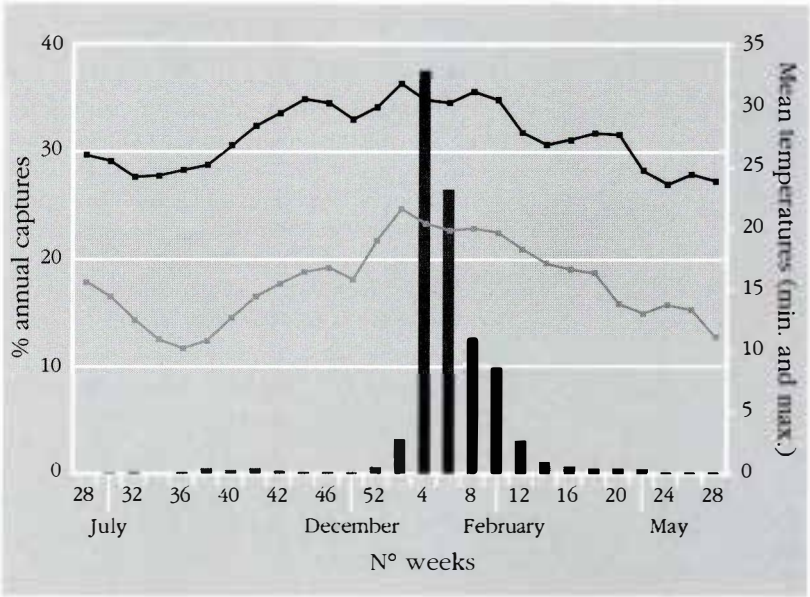

Figure 3
Variations in fruit fly trapping rates at the Pocquereux research station (July 1993 June 1994; mean of 3 traps).

B. tryoni, *B. psidii*, *B. curvipennis* and *B. umbrosa* rearing

A rearing programme for the above-mentioned pest species was considered necessary to produce enough flies for year-round reproducible and fully-controlled experiments.

Fruit fly colonies were created from infested peaches (*Prunus persica*) for *B. tryoni* and *B. curvipennis*, guavas (*Psidium guajava*) for *P. psidii* and jackfruit (*Artocarpus heterophyllus*) for *B. umbrosa*.

B. tryoni rearing conditions

About 2 000 adults/cage were kept in a temperature-controlled room (25°C ± 1°C) at about 70% relative humidity, under natural lighting with supplementary strong artificial lighting. The flies had a regular supply of water, sugar, yeast hydrolysate and the bacterial strain *Klebsiella oxytoca*. This latter enterobacterium is commonly used in rearing *Tephritidae* fruit flies (LLOYD, pers. comm.); it provides a protein supplement which promotes the production of high quantities of viable eggs and sexual maturation (DREW & LLOYD, 1989).

Eggs are collected on artificial oviposition domes made of perforated plastic cylinders (photographic film capsules), coated

inside with a larval medium containing fresh banana (88.6%), Torula yeast extract (11.1%) and nipagine (0.25%), an antimicrobial agent that effectively stimulates egg laying in female fruit flies. The eggs are collected in water and deposited on this larval medium. Larval pupation occurs in wet sawdust spread under the larval containers. The fruit fly rearing procedures were extensively described in a manual (CLARE and LEMONTEY, 1994).

B. psidii, B. curvipennis and *B. umbrosa* rearing

Conditions for rearing these three species are not as well established as for *B. tryoni*. There are differences with respect to a number of factors, especially the yeasts used to feed adult flies, the potato/dehydrated carrot-based larval medium used for *B. umbrosa*, and the lighting conditions in the rearing rooms.

B. curvipennis and *B. umbrosa* rearing conditions are gradually being perfected and functionalized. So far very few *B. psidii* flies have been successfully reared in the laboratory. Nevertheless, mass numbers of these fruit flies should be collected from infested fruit during the next hot season; further rearing trials could then be undertaken.

B. Tryoni life cycle

Fruit fly life cycles have to be fully understood in order to meet specific needs for insects at different development stages. Three thousand eggs that had been oviposited in 2 h were thus deposited on 600 g larval medium. After hatching, 100 larvae were randomly collected from the medium every 12 h for 2 weeks and their development stages were specified (1st, 2nd and 3rd instars). Changes in the mean composition of the different larval stages on the nutrient medium are shown in Figure 4. Table 2 provides various biological data on *B. tryoni*.

Control of *B. tryoni* rearing and critical information that has been obtained on its life cycle will facilitate further studies with this species. The same biological studies will be conducting with other species once they can be efficiently reared.

Figure 4
Bactrocera tryoni *life cycle at 25°C ± 1°C (on banana medium).*

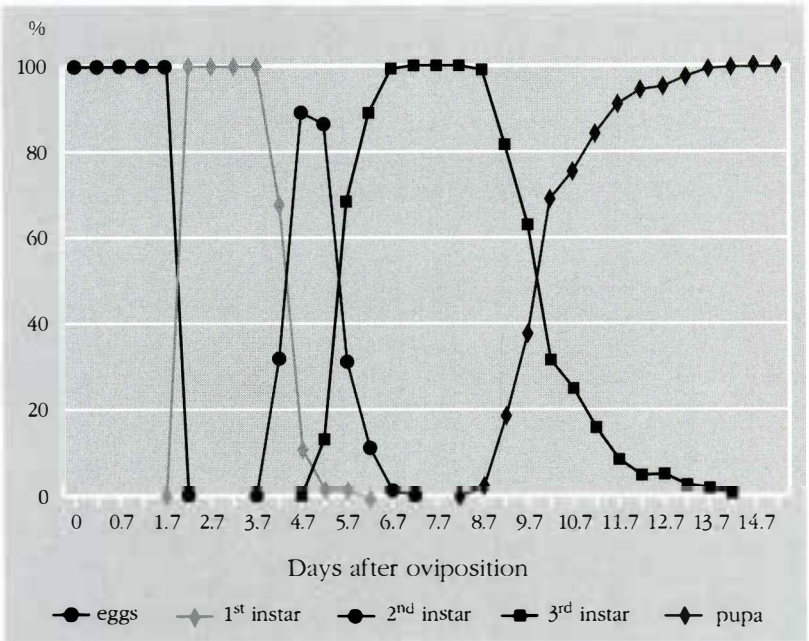

Table 2
Biological characteristics of *B. tryoni* (at 25°C ± 1°C).

N° eggs/female/24 h	about 15 (15-30 days after oviposition)
Hatching rate	about 70%
Hatching	41-53 h after oviposition
Pupation	8-14 days after oviposition
Emergence of adults	21-29 days after oviposition
Sexual maturity	about 15 days after emergence
Length of the life cycle	about 40 days

host and non-host status of plants

MAF drew up a list of different fruits and vegetables to test on the basis of data collected through the sexual trapping network and from collected wild and marketed fruit (Table 3).

Tests concerning *B. tryoni* and *B. curvipennis* were staggered to coincide with the November 1994-February 1995 fruiting period so as to obtain high numbers of available gravid adult females. For the two other species, the number of tests carried out was dependent on the rearing success rates. Details on the studies conducted for each fruit and vegetable with each fruit fly species are given in Figure

5; they met with the MAF specifications for the determination of fruit fly host status (ANONYMOUS, 1991).

Fruits and vegetables that were found to be non-hosts for all concerned fruit fly species can be exported again without any type of postharvest treatment. Alternative nonchemical treatments will be required for those that host fruit flies, e.g. mango was found to be a host for *B. tryoni, B. psidii* and *B. curvipennis*.

Table 3
MAF list of fruits and vegetables for testing.

Fruits and vegetables (varieties)	Species to test
lime (Tahiti SRA 58)	*B. tr., B. cur., B. ps., B. um.*
litchi (local variety)	*B. tr., B. cur., B. ps.*
mango (Kensington)	*B. um.*
pineapple (Queen Tahiti)	*B. tr., B. cur., B. ps., B. um.*
zucchini (Diamant)	*B. um.*
eggplant (Black beauty, Zébrina)	*B. tr., B. cur., B. ps.*
squash (New Zealand variety)	*B. um.*

B. tr.: Bactrocera tryoni — *B. cur.: Bactrocera curvipennis*
B. ps.: Bactrocera psidii — *B. um.: Bactrocera umbrosa.*

heat-treatment of mango

The efficiency of hot-air and vapour heat treatments to eliminate various fruit fly stages that infest fruit has been investigated with several different fruit species. ARMSTRONG *et al.* (1989) thus demonstrated the effect of high-temperature forced-air treatments of papayas infested with *Ceratitis capitata* (Wiedemann), *Dacus cucurbitae* (Coquillett) and *D. dorsalis* (Hendel) in Hawaii. Similar disinfestation studies with *Bactrocera xanthodes* (Broun) and *B. melanotus* (Coquillett) were carried out in the Cook Islands and led to a lifting of the ban on papaya exports to New Zealand (WADDELL *et al.*, 1992 and 1993). In mangoes (cv Kensington), HEARD *et al.* (1992) demonstrated the efficiency of vapour heat treatment of *B. tryoni* in Australia. In New Caledonia, disinfestation studies should be carried out with *B. tryoni, B. psiddi* and *B. curvipennis* infesting cv Kensington mango; *B. umbrosa* should also be assessed in this context if the host status of mango for this fruit fly is found to be positive.

The first phase in the heat-treatment research involved comparing the resistances of different fruit fly species at all development stages (i.e. egg, larva, 1st, 2nd and 3rd instars) over an increasing temperature gradient. This was carried out by immersing eggs and larvae in hot water baths for increasing periods of time, thus obtaining 0-100% mortality.

MAF considers that the vapour heat treatment developed in Australia could be used without modification, whereas our preliminary tests indicated high resistance of *B. tryoni*. The treatment has not yet been checked for effectiveness, but this will soon be done. Further analyses should be carried out if any of the other three species shows higher resistance. There are several phases to these analyses:
– confirming lethal hot water bath treatment temperatures and times with artificially infested fruits;
– checking that the temperatures used are not phytotoxic to the treated fruit;
– checking treatment efficiency in large-scale tests. This involves exposing high numbers of insects (30 000) to heat to certify that lethal temperatures established in previous tests actually cause 100% fruit fly mortality.

Our research is now focused on determining comparative resistances and the completed results for *B. tryoni* will be published later.

conclusion

In New Caledonia, postharvest treatments are essential for export fruit and vegetable crops because of the presence of fruit flies in this country. Fruit fly pest research carried out at the Pocquereux station (New Caledonia) is fully in line with current world trends to develop alternative nonchemical postharvest treatment techniques. Scientific collaboration with the Horticulture and Food Research Institute of New Zealand (Hort+Research,

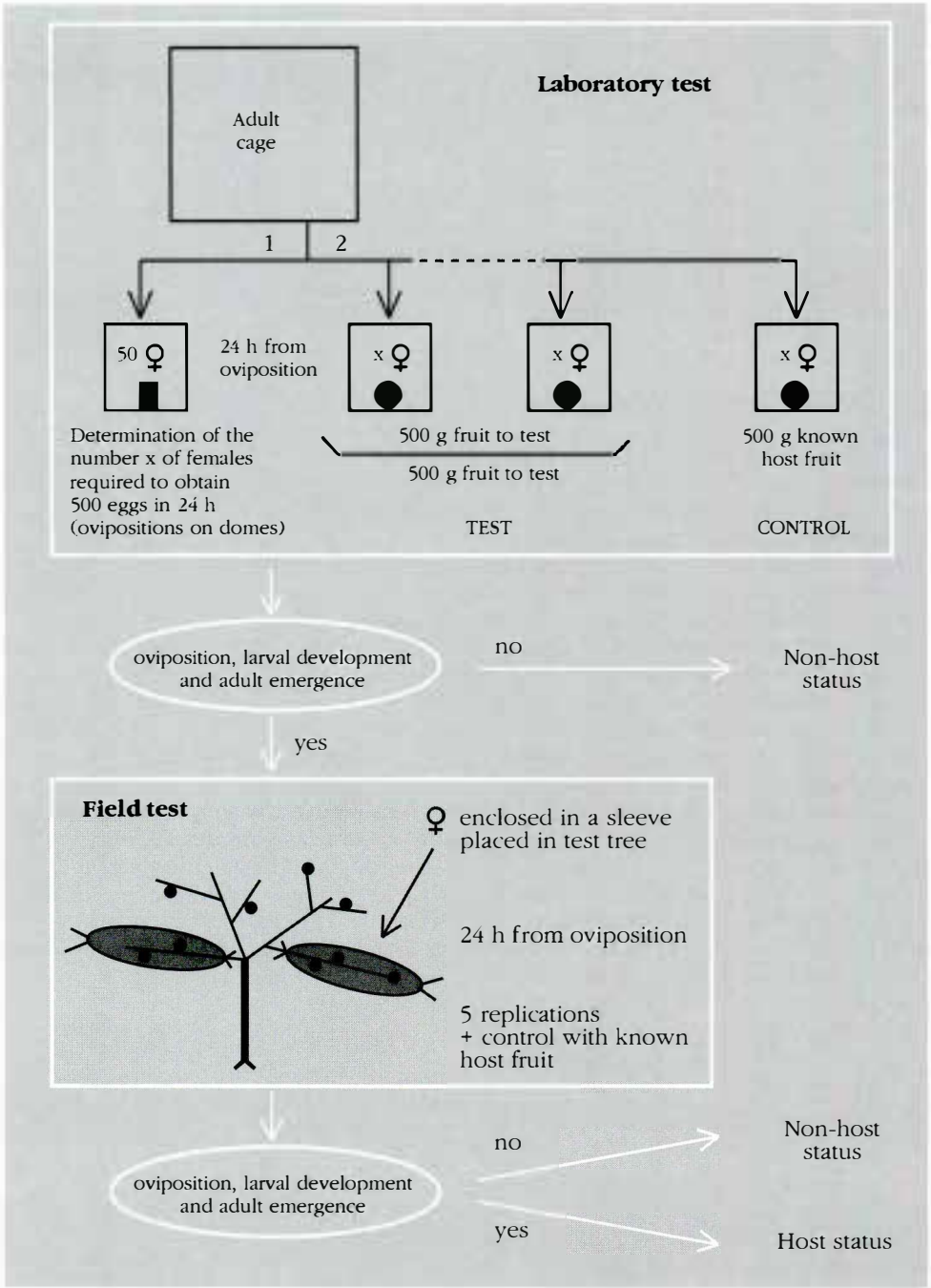

Figure 5
Procedure for determining the fruit fly host status of various fruits and vegetables.

ex-DSIR) will enable CIRAD-FLHOR to benefit from their research experience in a similar disinfestation programme on papayas in the Cook Islands.

Official policies in New Caledonia and economic imperatives have prompted fruit and vegetable producers to export their crops to other markets in the South Pacific region. The know-how acquired through the present research and the credibility obtained by penetrating the renowned demanding market of New Zealand should facilitate future exports of various fruits and vegetables to other markets in the region, especially Japan.

references

Anonymous, 1991.
NASS Standard 155.02.01.08: Specification for Determination of Fruit Fly Host Status as a Treatment. New Zealand Ministry of Agriculture and Fisheries, 17 p.

ARMSTRONG J.W., HANSEN J.D., HU B.J.K., BROWN S.A., 1989.
High-Temperature, Forced-Air Quarantine Treatment for Papayas Infested with Tephritid Fruit Flies (*Diptera: Tephritidae*). Journal of Economic Entomology 82 (6): 1667-1674.

CLARE G., LEMONTEY J.M., 1994.
Fruit fly Rearing Management Manual for *Bactrocera tryoni, B. curvipennis, B. psidii* and *B. umbrosa*. HortResearch Client Report No. 94/65. Auckland, New Zealand, 36 p.

COCHEREAU P., 1970.
Les mouches des fruits et leurs parasites dans la zone indo-australo-pacifique et particulièrement en Nouvelle-Calédonie. Cahiers ORSTOM, série Biologie, 12, 15-50.

DREW R.A.I., 1989.
The Tropical Fruit Flies (*Diptera: Tephritidae: Dacinae*) of the Australasian and Oceanian Regions. *In*: Memoirs of the Queensland Museum, Brisbane, 26, 521 p.

DREW R.A.I., LLOYD A.C., 1989.
Bacteria associated with Fruit Flies and their Host Plants. *In*: World Crop Pests: Fruit Flies - Their Biology, Natural Enemies and Control. Amsterdam, Netherlands, ROBINSON A.S. et HOOPER G. (eds), Elsevier Science Publishers, 3A, p. 131-140.

HEARD T.A, HEATER N.W., PETERSON P.M., 1992.
Relative Tolerance to Vapor Heat Treatment of Eggs and Larvae of *Bactrocera tryoni* (*Diptera: Tephritidae*) in Mangoes. Journal of Economic Entomology 85 (2): 461-463.

WADDELL B.C., CLARE G., MAINDONALD J.H., 1992.
Postharvest Disinfestation of *Bactrocera melanotus* and *B. xanthodes* in the Cook Islands: Reports 2. HortResearch Client Report No.92/89. Auckland, New Zealand, 41 p.

WADDELL B.C., CLARE G., MAINDONALD J.H., 1993.
Postharvest Disinfestation of *Bactrocera melanotus* and *B. xanthodes* in the Cook Islands: Reports 3. HortResearch Client Report No.93/270. Auckland, New Zealand, 70 p.

WHITE I.M., ELSON-HARRIS M.M., 1992.
Fruit Flies of Economic Significance: Their Identification and Bionomics. Oxon: C.A.B. International, 601 p.

Inventory of Insect Fauna Specific to Cultivated Fruit Trees of Northern Côte d'Ivoire

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p. 500-501 (French)

The highly diversified insect fauna colonizing five types of fruit trees in northern Côte d'Ivoire was inventoried.

aims

The present study was aimed at:
– identifying all species of insects living on cultivated fruit trees in northern Côte d'Ivoire,
– determining the distributions of each species on the main fruit trees cropped in the region.

materials and methods

insect collection

Insects were collected with sweep nets in experimental plots at the Lataha research station (Korhogo region, Côte d'Ivoire). They were sampled from five different types of host fruit trees: mango, citrus, guava, papaya and cashew.

The insects were collected in the foliage, between rows of plants in nurseries and between rows of adult trees in orchards.

Collected insects were killed with acetic ether and identified by the naked eye or under a dissecting microscope.

criteria assessed

species identification

For each sampling, collected insects were given a code number corresponding to various morphological features. They were then temporarily referred to as "species".

These insects were first identified from available documents or collections and then confirmed or characterized by a specialist.

The insects were prepared and classified in a collection.

species distributions on different host fruit trees

Host fruit trees were noted for each insect species at each sampling. A table was drawn up with each insect species and their hosts.

results

Table 1 provides a list of insect species identified during the present survey and the fruit trees from which they were collected.

The insect species were either collected on one specific type of fruit tree (Table 2), or on two, three or four of the five types of trees.

Very few insect species were specific to only one type of fruit tree. They were generally specific to one or two trees; heteropterans and coleopterans were exceptions, with more than two species from these orders collected on more than one type of the fruit trees studied. The distributions were as follows:
– six heteropterans and three coleopterans collected on both mango and citrus,
– three coleopterans on mango and papaya,

– three coleopterans on citrus and guava,
– four heteropterans on papaya and cashew,
– eight heteropterans on mango, citrus and guava,
– six heteropterans on mango, citrus, guava and papaya.

The distributions of insect species collected on the five fruit trees studied were as follows:
– four heteropterans: *Nezara viridula* (Pentatomidae), *Agonoscelis versicolor* (Pentatomidae), *Aspavia armigera* (Pentatomidae) and a Coreidae species,
– one coleopteran: *Lagria villosa* (Lagriidae),
– one dipteran: *Hermetia* sp. (Stratiomyidae),
– one orthopteran: *Zonocerus variegatus* (Acrididae).

One-third of the insect fauna observed on cultivated fruit trees in northern Côte d'Ivoire were heteropterans, next came coleopterans, dipterans and hymenopterans. Species of these orders were found on all of the fruit trees studied, but seemed to prefer mango and citrus. The last quarter of the insect fauna was represented by six other species that seemed highly specific to certain fruit trees.

Species collected in this survey are not all pests; some are predators of other insects, for instance:
– Reduviidae and Lygaeidae (*Geocoris* sp.) bugs,
– Coccinellidae (*Exochomus* sp., *Cydonia vicina*) coleopterans,
- Asilidae (*Promachus* sp.) and Syrphidae (*Xanthogramma aegyptium*) dipterans,
– various hymenopteran species,
– Libellulidae odonatan species, Chrysopidae neuropteran species, Mantidae dictyopteran species, etc.

Other insect species lick or suck nectar or other plant exudates. These are generally dipterans (Bombyliidae) or various hymenopterans involved in flower pollination.

Table 1
Insect species collected on five different types of fruit trees in northern Côte d'Ivoire. The results are pooled on an insect order basis.

	Mango	Citrus	Guava	Papaya	Cashew	N° different species
Heteroptera	50	49	31	32	25	96
Coleoptera	26	17	15	10	10	53
Diptera	18	12	8	9	14	44
Hymenoptera	16	20	10	7	7	51
Orthoptera	1	1	2	1	2	3
Lepidoptera	5	4	3	0	1	11
Homoptera	8	4	2	2	3	13
Odonata	0	1	4	0	0	5
Neuroptera	2	3	0	0	0	3
Dictyoptera	0	1	0	0	1	2

Table 2
Insects specific to different types of cultivated fruit trees of northern Côte d'Ivoire.

	Mango	Citrus	Guava	Papaya	Cashew
Heteroptera	10	16	6	8	5
Coleoptera	13	6	5	6	5
Diptera	14	9	5	3	8
Hymenoptera	13	14	7	5	5
Orthoptera			1		1
Lepidoptera	4	3	2		1
Homoptera	5	1	1		3
Odonata		1	4		
Neuroptera		1			
Dictyoptera		1			

conclusion

This preliminary study highlighted the insect fauna that colonize the main cultivated fruit trees in northern Côte d'Ivoire. This fauna mainly comprises heteropterans (dominant group), coleopterans, dipterans and hymenopterans. Low numbers of orthopteran, lepidopteran, homopteran, odonatan, neuropteran and dictyopteran species were also detected.

The insect species are generally pests, predators or pollinators.

Further studies are to be carried out to supplement the present preliminary results; they will focus on:
– identifying further species,
– assessing insect population densities on different host plants,
– evaluating the economic impact of various insects on fruit crops.

Inventory of Insect Fruit Pests in Northern Côte d'Ivoire

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Fruits, vol. 49, n°5-6
p. 430-431 (English)
p. 502-503 (French)

Many insects that develop in fruits were inventoried and identified following preliminary studies that were carried out in northern Côte d'Ivoire.

aims

The present study had three main objectives:
– to inventory all insect fauna of the region that develop in fruit,
– to identify their specific natural enemies,
– to determine population sizes for each species on different host plants.

materials and methods

insect collection

The insects were collected on infested fruit harvested in experimental plots at the Lataha research station (Korhogo region, Côte d'Ivoire). They were collected from five different types of fruit: mango, citrus, guava, papaya and cashew apples.

insect rearing

Ripening orchard fruits were placed in the front compartment of larval rearing cages until completely decomposed. Eggs and larvae in the fruit continued their development.

Fully developed larvae left the fruit and pupated in a layer of sand in the second compartment of the cage. The sand was sifted to collect nymphs and other preadult insects. These developing insects were put in emergence cages and reared to adulthood.

criteria assessed

species identification

The insect species were identified as described by N'Guetta (1995).

species quantification

The total number of insects obtained at each sampling was noted for each species and host plant.

results

species distributions

Twenty-seven insect species were collected on fruit, most were dipterans, lepidopterans and hymenopterans.

Of 16 dipteran species collected:
- eleven belonged to the Tephritidae family:
  – *Ceratitis* species: *C. (Pterandrus) anonae, C. (Ceratalaspis) cosyra* (Walker), *C. (Pardalaspis) punctata* (Wied), *Ceratitis* spp.,
  – one *Dacus* sp.,
- one belonged to the Stratyomiidae family: *Hermetia* sp.,
- four have not yet been identified.

Of four lepidopteran species collected:
- one belonged to the Oletheutidae family: *Cryptophlebia leucotreta*,
- the three others (two collected on citrus and one on guava) have not yet been identified.

The six hymenopteran (Microhymenoptera) species collected have not yet been

identified. They are probably parasitoids and/or hyperparasitoids.

The fruit-host distribution of the 11 Tephritidae species collected was as follows:
- six species on mango only, four of these were *Ceratitis* species,
- one species was found on mango and guava: *C. capitata*,
- one species on guava and papaya: *Dacus* sp.,
- two species on mango, guava and papaya: *C. (Pterandrus) annonae* and an unidentified species,
- one species was found on all of the fruit hosts: *C. (Ceratalaspis) cosyra*.

One lepidopteran species, *Cryptophlebia leucotreta* (Oletheutidae), was collected on citrus and guava. The other still unidentified species seemed to be specific to fruit hosts.

The microhymenopteran species were specific to mango, guava and papaya; only one species was found on both mango and papaya.

Insect quantities/species /host plant

Only dipteran species on two fruit hosts were considered in this analysis: papaya (cv Solo) and guava (cvs Beaumont and Huek-Now).

On cv Solo papaya, *Dacus* sp. (Tephritidae) was found in the highest quantities in all harvested fruit, it thus seemed to be the most important and constant papaya fruit pest. A still unidentified Stratiomyidae species (*Hermetia* sp.) was also detected in high quantity. The larvae seemed to feed by scavenging since they were found in decomposing fruit waste. However, the exact fruit pest roles of these species have not yet been determined.

Two Tephritidae species were found to be the main guava pests, i.e. *Ceratitis cosyra* and *C. annonae*. *C. capitata*, another species of this family, was only detected in the last cv Beaumont guava harvest; its role should now be determined.

conclusion

In the present study, the types of insects that develop in fruit harvested in northern Côte d'Ivoire were determined, along with their preferred fruit hosts. Further studies are under way to supplement and/or confirm the present results, they focus on:
– identifying and studying collected insect species,
– assessing the sizes of all insect populations collected,
– analysing the population dynamics of each species,
– defining various storage techniques,
– identifying parasitoids and their hosts. ●

references

N'GUETTA K., 1995.
Inventory of insect fauna specific to cultivated fruit trees of northern Côte d'Ivoire. *Fruits,* 49 (5-6): 428-429.