Characterization and Performance of 51 Citrus Varieties in New Caledonia

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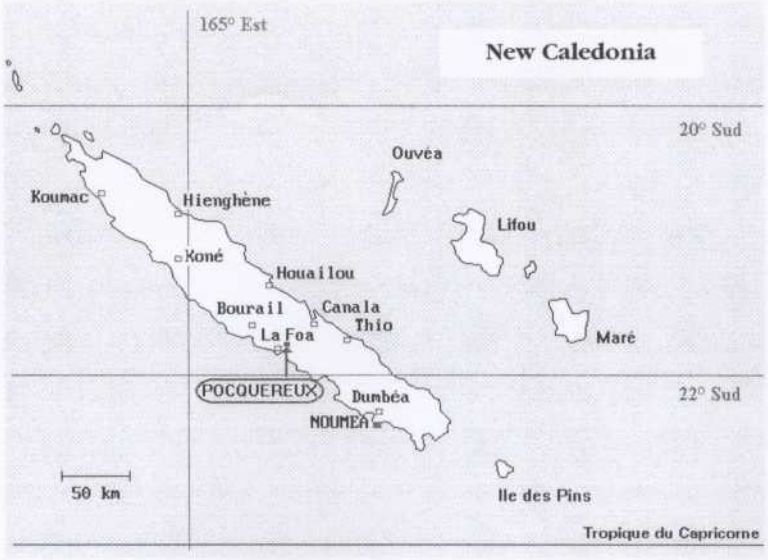
Although citrus fruits are not yet widely grown in New Caledonia, interesting results were obtained in analyses of recently-introduced grapefruit, orange and mandarin varieties.

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).

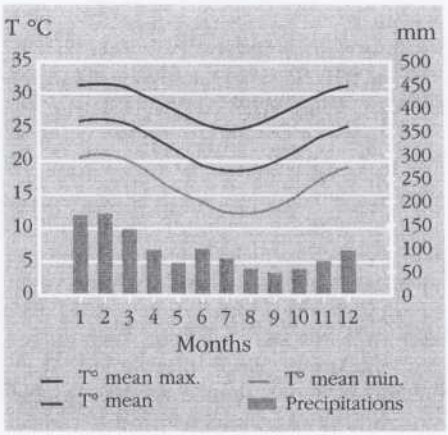


Figure 1
Climatic data for La Foa. Elev. 18m, Lat. 21°40'S, Long. 169°494E.

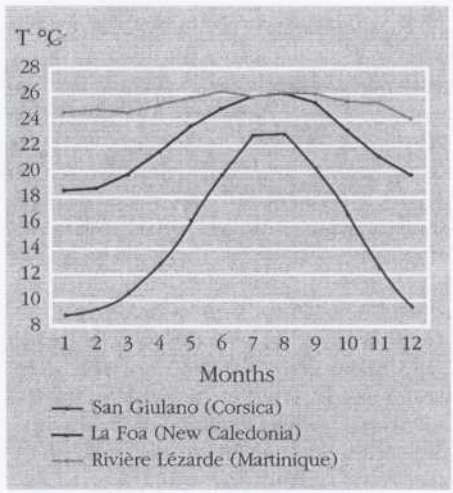


Figure 2
Comparison fo mean temperatures for La Foa, Martinique and Corsica.

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).

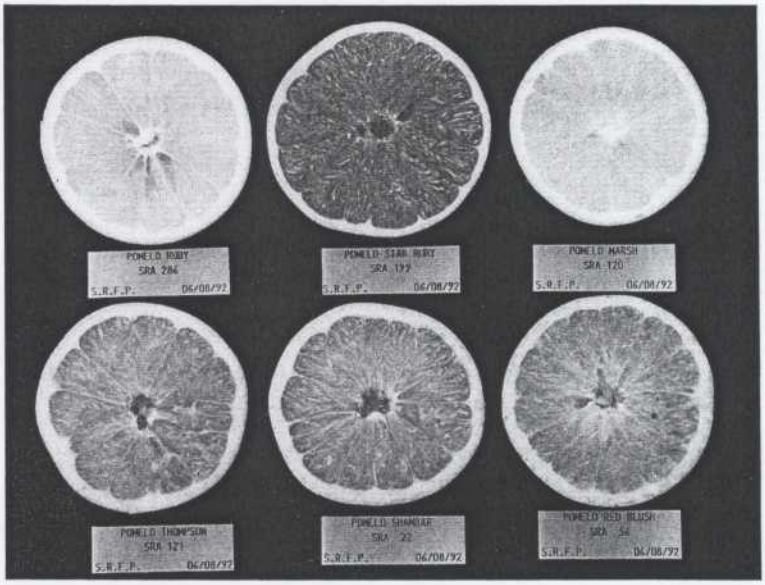


Photo 1
The six varieties of grapefruit studied in New Caledonia.

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.

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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).

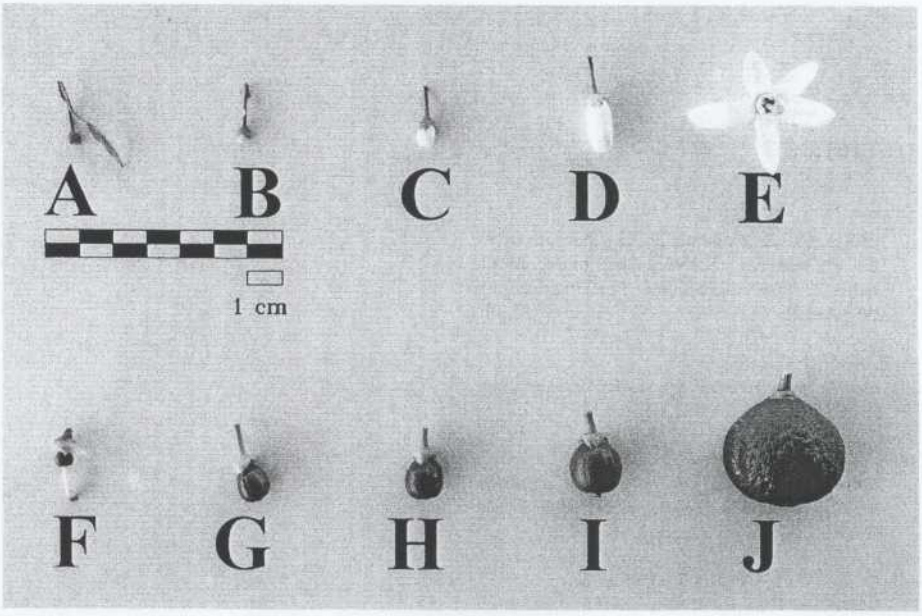
Juice content (SDE): percentage juice relative to the fruit weight.

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.