Use of the *Poncirus trifoliata* Flying Dragon as dwarfing rootstock for citrus under tropical climatic conditions

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Abstract — Introduction. Citrus fruit trees grown under tropical climatic conditions have a high level of vigour, and, consequently, late fruit-bearing and low productivity. Using *Poncirus trifoliata* Flying Dragon (P*t*FD) rootstock, which makes it possible to obtain smaller trees and earlier production, could solve this problem. **Materials and methods**. Trials comprising eight commercial varieties were begun in December, 1992, in an irrigated plot on Grande-Terre Island, New Caledonia. Growth of the trees was observed over a 5 year period through twice-a-year measurements of tree height, of frondescence between and in the rows and of trunk diameter at a point 10 cm above that of grafting. Production was weighed as of fruit development 2 years after planting. **Results**. Under the climatic and pedological conditions at the experimental site, trees grafted onto P*t*FD could, depending on the variety, be planted in densities of from 800 to 1,400 trees·ha^{-1}. Cumulative planting and maintenance costs over the 5 years were 1.8 time those of traditional orchards for a density 5 times as great and a level of productivity per hectare 5.2 times that of a standard orchard. **Conclusion**. Using P*t*FD, which is seldom used in the Mediterranean zone due to its dwarfing effects in this climatic region, could prove interesting in tropical zones. Further observation will make it possible to assess tree longevity and fruit quality granted by this rootstock. © Éditions scientifiques et médicales Elsevier SAS

New Caledonia / *Citrus* / variety trials / dwarf / rootstocks / crop yields / plant response

Utilisation de *Poncirus trifoliata* Flying Dragon comme porte-greffe nanifiant des agrumes sous climat tropical.

Résumé — Introduction. Les agrumes cultivés sous climat tropical présentent une vigueur importante et, par conséquent, une mise à fruits retardée et une faible productivité. L'utilisation du porte-greffe *Poncirus trifoliata* Flying Dragon (P*t*FD), qui permet d'obtenir des arbres d'un volume réduit et une production précoce, pourrait pallier ce problème. **Matériel et méthodes**. Un essai comprenant huit variétés commerciales a été implanté en décembre 1992 sur une parcelle irriguée de l'île de la Grande-Terre en Nouvelle-Calédonie. La croissance des arbres a été suivie pendant 5 ans par la mesure, deux fois par an, de la hauteur de l'arbre, du diamètre de la frondaison entre rangs et sur le rang et du diamètre du tronc à 10 cm au-dessus et au-dessous du point de greffe. Les récoltes ont été pesées dès l'apparition des fruits 2 ans après la plantation. **Résultats**. Dans les conditions climatiques et pédologiques du site expérimental, les arbres greffés sur P*t*FD autorisent, selon les variétés testées, des densités de plantation de 800 à 1 400 arbres·ha^{-1}. Les coûts d'implantation et d'entretien cumulés sur 5 ans dépassent de 1,8 fois ceux d'un verger traditionnel, pour une densité 5 fois plus élevée et une productivité à l'hectare égale à 5,2 fois celle d'un verger standard. **Conclusion**. L'utilisation de P*t*FD, peu développée en zone méditerranéenne en raison de l'effet nanifiant trop important de ce porte-greffe sous ce climat, pourrait donc être intéressante en zone tropicale. Les observations futures permettront d'évaluer la longévité de ces arbres et la qualité des fruits induites par le porte-greffe. © Éditions scientifiques et médicales Elsevier SAS

Nouvelle-Calédonie / *Citrus* / essai de variété / nain / porte-greffe / rendement des cultures / réponse de la plante

1. introduction

In tropical climatic zones, the vigour observed in citrus fruit trees represents a handicap for orchard development and limits yield increase of cultivated surface area. This situation obliges nurserymen to plant in low densities – 150 to 200 plants·ha^{-1} – leading to poor sanitary conditions linked to the sizes of the trees to treat; pruning and harvesting operations for such trees result in high culture costs. Such constraints become particularly troublesome when site topography hinders mechanical harvesting techniques.

To solve this problem of excess vigour, various procedures based on the use of pathogenic agents, of specific horticultural or cultural techniques, or of certain dwarfing rootstock are all apt to reduce tree development.

1.1. pathogenic agents

Use of pathogenic agents was developed in Australia [1] and Israel [2]. It involves using the tristeza (CTV) virus and the exocortis (CEV) causal agent. The results obtained after inoculation vary substantially depending on the rootstock used and the variety associations / rootstock sensitivity. This technique presents numerous drawbacks and is not transposable, particularly, to zones in which tristeza is not present. Moreover, one cannot ignore the risk of pathogenic agent mutation towards more virulent forms.

1.2. horticultural and cultural techniques

Tree development can be reduced by using the so-called "sandwich" (interstock) method which consists in placing a piece of stem from a third variety between the rootstock and the scion. This procedure is used for training certain temperate-zone fruit trees and makes it possible to insert a dwarfing variety between a well adapted rootstock and a commercially interesting variety. In the case of citrus fruit trees, trials in Florida [3] have shown the efficiency of the technique. The approach has not yet, however, been exploited by nurserymen.

In Israel [2], tree development has been reduced by rationing irrigation, thus making it possible to provoke early and abundant production. Such a technique, however, cannot be transposed to zones with a humid climate.

Other techniques, such as pruning or angle planting of trees, can be used, but up to now they have not resulted in the training of trees with sufficiently reduced development to facilitate the establishment of very high density orchards [4].

1.3. use of dwarfing rootstock

The term 'dwarfing' can only be applied to rootstock which reduces tree volume by at least 75%, thus limiting tree height to 2.5 m at adult age. The *Poncirus trifoliata* Flying Dragon cultivar would be one such dwarfing rootstock [5].

The first trials using this cultivar were run in 1972 at the South coast field station in California. In 14 years, Valencia Late orange trees grafted onto this rootstock reached a height of 1.9 m and a foliation diameter of 1.8 m for an average yield of 33 kg per tree. The fruit is of good quality [6]. In Florida, the Flying Dragon, tested in comparison with the Cleopatre mandarin tree, reduced the canopy volume of Minneola tangelo trees by 30%.

The Flying Dragon originated in Japan, where it is used to produce ornamental potted plants. Introduced in the U.S.A. by Walter S. Swingle in 1915, it long remained a botanical curiosity. Thereafter, economic considerations led researchers to identify dwarfing rootstock which would make it possible to increase planting densities and, consequently, yield. Like the *Poncirus trifoliata*, of which it is a mutant [7], the Flying Dragon has tolerance traits towards the tristeza virus, resistance traits towards *Phytophthora* spp. and citrus fruit nematodes, as well as a good level of tolerance for culture in heavy soils. It also allows production of good quality fruit [5]. Its use requires the selection of scions which are free of exocortis, a degenerative illness to which *Poncirus* and their hybrids are very sensitive.

This overall set of characteristics was used in defining a trial protocol which made it possile to test Flying Dragon dwarfing rootstock in New Caledonia, under the conditions at the Pocquereux fruit research station.

2. materials and methods

2.1. presentation of the environment

New Caledonia, an archipelago situated in the north of the Tropic of Capricorn between 19° and 23° south latitude and 158° and 172° east longitude, is at 18,000 km from metropolitan France (*figure 1*). Its total surface area of 19,100 km^2 is approximately twice that of Corsica. The archipelago is composed of a principal island orientated north-west by south-est – the Grande-Terre, 16,900 km^2 – and of dependencies: Pins Island, the Loyalty Islands, the Bélep Islands, together covering 2,200 km^2 [9].

Grande-Terre, approximately 400 km long and 50 km wide, has a mountainous central zone peaking at 1,628 m and sliced by deep valleys running perpendicular to the east and west coasts. These valleys are at low altitudes (less than 200 m) and are longer near the east coast than near the west coast. The dependencies are composed of coral atolls built up on volcanoes.

The Pocquereux station, in the La Foa commune, is at 15 km from the sea and at an altitude ranging from 18 m to 50 m. Situated in the middle of one of the Grande-Terre coastal valleys with an east-west orientation, it is 120 km to the north-west of Noumea.

2.1.1. climate

The archipelago has a transitional climate between that of a tropical zone and that of a Mediterranean zone. One part of the year it is under the influence of the intertropical convergence zone (ITCZ) and the rest of the year it is under the influence of temperate lows:

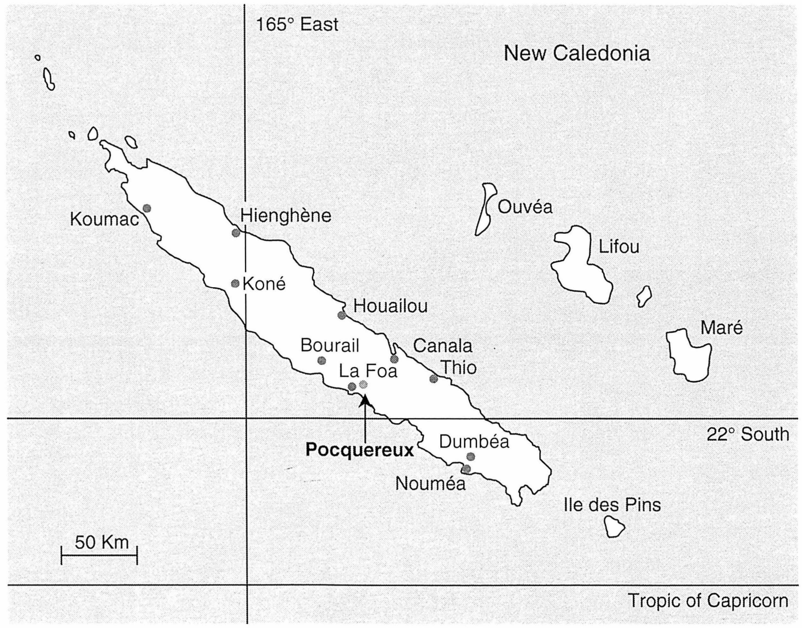


Figure 1.
Map of New Caledonia.

– The period from mid-December to mid-April corresponds to the season of tropical lows and cyclones. This is the major hot, humid season which ends in February-March.

– From mid-April to mid-May, there is a short dry season during which the precipitation and temperature decrease due to the rising of the ITCZ towards the north.

– From mid-May to mid-September, there is a cool season which is sometimes rainy due to the rising of polar cold fronts which can provoke temperate lows.

– During the major dry season from mid-September to mid-December, the temperature rises as the ITCZ begins its descent towards the south.

2.1.2. temperatures

The temperature curve is a determining element in the study of citrus fruit tree behaviour as this parameter influences both the internal and external quality of the fruit, particularly the colour. Temperatures collected at the La Foa weather station are very contrastive. Over 34 years of observation (1956 to 1991), the annual average was 22.5 °C, with an average maximum of 28.5 °C and a minimum of 16.4 °C (*figure 2*). Such temperatures, which have a relatively

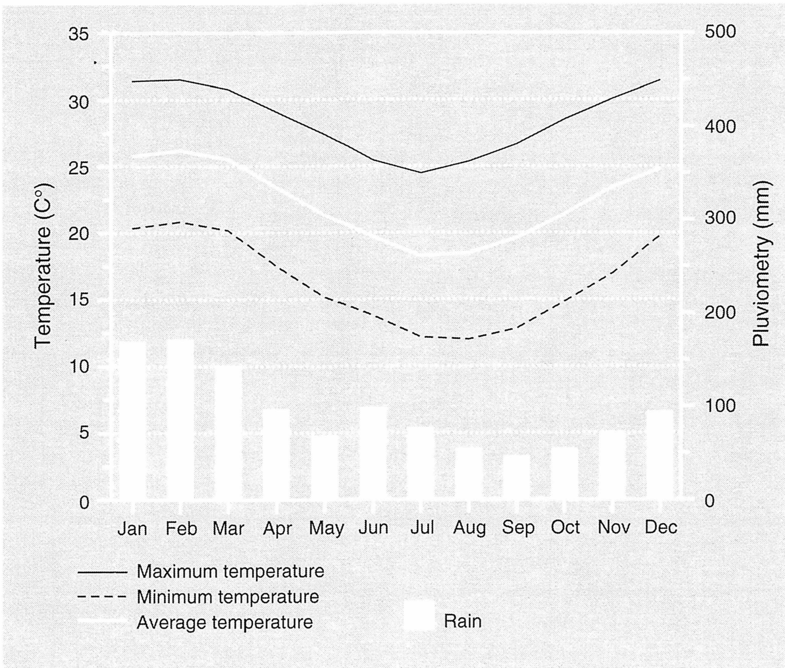
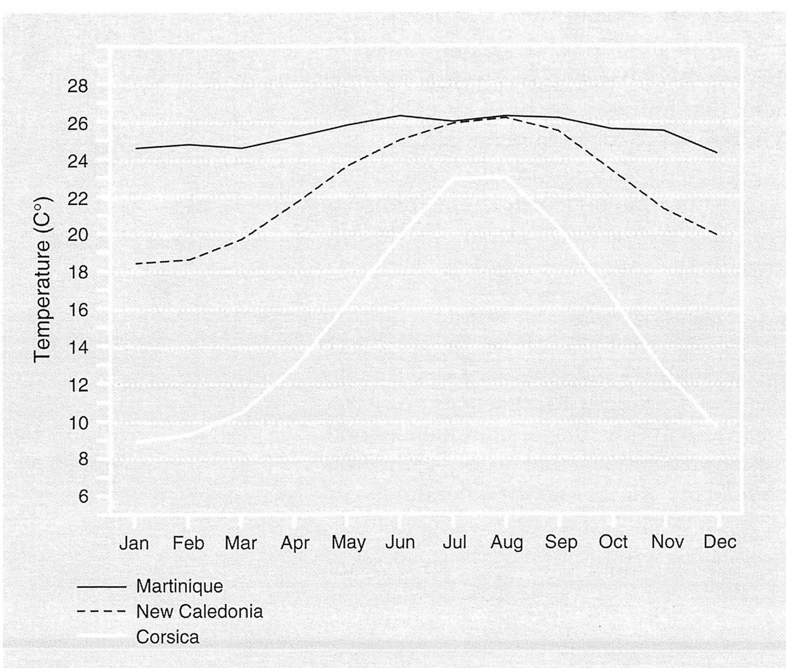


Figure 2.
Pluviometric and temperature averages recorded from 1956 to 1991 at the La Foa experimental site (alt. 18 m, lat. 21°40' S, long. 169°49' E) in New Caledonia.

Figure 3.
Comparison between average temperatures in La Foa (New Caledonia), in Martinique (Antilles, humid tropical climate) and in Corsica (France, Mediterranean climate).



low minimum level in spite of the low altitude, the geographical position and the insularity, are intermediary between those of a tropical climate and those of a Mediterranean climate (*figure 3*).

2.1.3. hygrometry, evaporation and precipitation

Average hygrometry varies from 40 to 96%. The average annual evapotranspiration potential is 1,463 mm with a minimum level of 65 mm in June and a maximum level of 177 mm during the month of December. The pluviometric annual average is 1,155 mm, but this parameter varies extensively as, in 1967, the annual pluviometric level dropped to just 610 mm while, in 1973, it reached 2,292 mm.

The precipitation is grouped into an 84 d period. This insufficient yearly distribution makes it necessary to use irrigation techniques.

2.2 soils

The trees observed during the experimentation were planted on a hilly, piedmont plot in non-climatic, poorly developed soil with colluvial deposits. The soil texture was heavy (sandy-loam clay) with the clay-loam combination equalling 66%. Such soil is average (2%) in organic substance content, very rich in magnesium, but very poor in potassium and calcium. It contains no sodium and the pH is 5.6.

2.2.1. cultural technique

Before improvement, the chosen, flat plot had been covered by a dry forest composed of niaouli (*Melaleuca quinquenervia*). After bulldozer clearing, the soil was strongly enriched with 6 t·ha^{-1} of lime crusts giving a 48% calcium oxyde (CaO) dosage. The basic fertilisation consisted of a 2 t·ha^{-1} deposit of NPK 0–32–16 fertiliser. The ground was subsoiled with a ripper to a depth of 1 m (three teeth 1 m apart). Tilling was carried out to a depth of 45 cm with a four blade plow, then the planting bed was banked up by positioning the soil in the planting rows through repeated runs with the four blade plow.

The double rows of trees were situated in beds which were 4 m long and 80 cm high along the central axis. The soil of the banked beds was heavily strawed (10 cm) every year, in August, using bales of "Rhodes grass" (*Chloris gayana*) produced on specially designed plots at the experimental station.

2.2.2. fertilisation

The annual fertilisation of 1,500 g urea and 2,500 g NPK 13–13–21 fertiliser for the 5-year-old trees was divided into three segments per year:

– 50% of the fertilisation was deposited in July, that is to say 1 month before flowering,

– 25% was deposited 2 months later, in September,

– 25% 4 months later, in November.

2.3. experimental design

The experimentation was put in place in December, 1992. *Poncirus trifoliata* Flying Dragon cultivar rootstock seeds had been supplied for the testing by Willits and Newcomb (U.S.A.) in 1990.

Trial groups were made up of eight varieties grafted onto this rootstock. These varieties were introduced in New Caledonia by the San Giuliano, Corsica Inra-Cirad agronomic research station (ARS). Testing concerned Lisbon lemon trees (*Citrus limon* (L.) Burm. F.) (ARS 16), Tahiti lime trees (*C. latifolia* Tan.) (ARS 58), Washington Navel (ARS 203) and Valencia Late (ARS 105) orange trees (*C. sinensis* (L.) Osb.), Saint John satsuma mandarin trees (*C. unshiu* Marc.) (ARS 108), Star Ruby grapefruit trees (*C. paradisi* Macf.) (ARS 293), Ortanique tangor trees (*C. reticulata* Blanco × *C. sinensis* (L.) Osb.) (ARS 110) and Orlando tangelo trees (*C. reticulata* Blanco × *C. paradisi* Macf.) (ARS 46).

Control trees were made up using the *Citrus volkameriana* species as rootstock for lemon and lime trees and the Troyer citrange as rootstock for the other varieties.

Citrus fruit tree rootstock can be multiplied by sowing when the plants are apomictic. In the case of the Flying Dragon cultivar, however, zygotic original plants are frequent. Their percentage, varying from 0 to 75%, runs at an average of 50% [6]. Even if visual sorting makes it possible to distinguish nucellar subjects (bent thorns and spiral growth of shoots), certain zygotic plants as well have phenotypic features like those of nucellar plants. Identification of atypical subjects can be made very reliably on the basis of isoenzymatic polymorphism since the *Poncirus trifoliata* species has four heterozygotic loci on its enzymatic system: malate dehydrogenate (MDH), phosphoglucose isomerase (PGI), aspartate transaminase (GOT) and phosphoglucomutase (PGM) [10]. Enzymatic analysis carried out at the Pocquereux station laboratory in 1997 made it possible to identify five zygotic subjects out of the 149 plants of the trial a posteriori, that is to say 2.7% of the plants. Visual sorting in the nursery, is, thus, relatively efficient.

Planting density was 1,000 trees·ha^{-1}. Trees were planted in twin rows: 5 m separated each double row, with 3 m between rows and 2.5 m between plants in each row. The eight groups were distributed in complete random blocks in four repetitions. Each block was made up of four trees. The global unit was surrounded by rows of trees made up of plants which were identical to those in the groups.

2.4. observations carried out

2.4.1. production characteristics

Every 6 months, from January to July, beginning with planting, five measurements were taksen:

– canopy diameter along the planting line (D_{line}),

– canopy diameter perpendicular to the planting line (D_{perp}),

– trunk diameter at 10 cm above the level of the graft,

– trunk diameter at 10 cm below the level of the graft,

– tree height (H).

Canopy volume was calculated using the results of these measurements in the formula:

$V = 1/6\ \pi H D^2$ [11], where $D = (D_{line} + D_{perp})/2$

Weighing of the production harvests began as of appearance of the first fruit at the end of the second year after planting.

2.4.2. fruit quality characteristics

Quality analyses were run on the harvested fruits using parameters laid out in international specifications [12]. These analyses were made on samples made up of 10 fruits per tree, picked every 3 weeks.

After the harvest, all the fruits from the trial trees were calibrated in order to judge the commercial interest of the harvest. Batches of 30 fruits per variety made it possible to characterise these calibration classes.

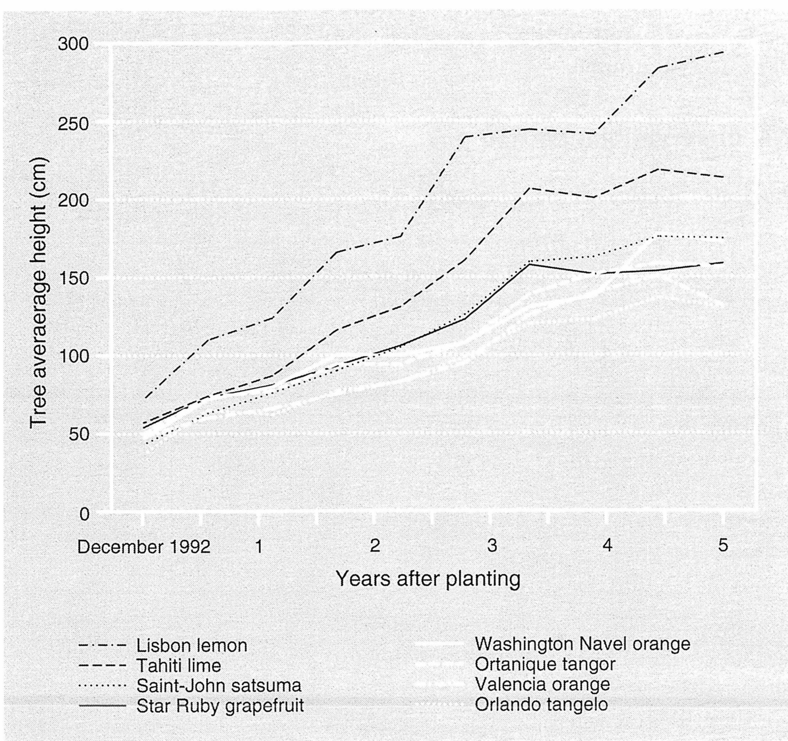
3. results

Tree growth was slow over the 5 years of observation (*figure 4*).

At 5 years of age, the dwarfing effect is obvious, no matter what variety has been grafted onto Flying Dragon rootstock. Canopy volume of the trees from [Valencia Late orange / Flying Dragon] and [Orlando tangelo / Flying Dragon] couples is reduced from 11 to 16 times, respectively, in comparison to the control couples (*table I*). The reduction is approximately 6 times for the Star Ruby grapefruit, Ortanique tangor and Washington Navel varieties and 4 times for the Tahiti lime, the Saint John satsuma and the Lisbon lemon.

Twin-row planting is not the most appropriate technique because inter-row interventions cannot be mechanised. This is especially true as far as weeding is concerned. On the basis of the ratio between tree volume and occupied ground surface and considering single row planting, the measurements make it possible to recommend specific planting densities according to the varieties chosen (*table II*).

Figure 4.
Development of average height over the first 5 years after planting for trees from citrus tree commercial varieties grafted onto dwarfing *Poncirus trifoliata* cv. Flying Dragon rootstock (New Caledonia).



3.1. effect of the climate

To bring to light any possible incidence of climatic conditions on the Flying Dragon cultivar dwarfing effect, growth measurements obtained for the [Tahiti lime / Flying Dragon] crossing in New Caledonia were compared to those for a similar variety / rootstock crossing made in the Antilles in 1988 under humid tropical climatic conditions (50 m of altitude, lat. 14°40' N and long. 61°01' E) [13]. This comparison shows that reduction of the development of trees grafted onto the Flying Dragon is more extensive in New Caledonia than in Martinique (*figure 5*) due to the climate.

3.2. productivity

3.2.1. yield

The comparison of the cumulated harvests per tree from the second to the fifth years on trees grafted onto the Flying Dragon and those resulting from the production of control trees shows a ratio varying from 0.4 to 1.1 (*table III*). Flying Dragon rootstock leads to early production, thus compensating for the reduced development of the trees.

Shifting these yields per tree to those which would be obtained with planting

Table I.
Canopy volume (in m^3), for 5-year-old trees of citrus commercial varieties grafted onto dwarfing rootstock (*Poncirus trifoliata* cv. Flying Dragon), under New Caledonian climatic conditions.

Variety grafted	Rootstock		Reduction in volume (m^3)
	Control[1]	Flying Dragon	
Lisbon lemon	64.0	17.0 a	3.8
Tahiti lime	48.1	11.1 b	4.3
Saint John satsuma	20.9	5.4 c	3.9
Washington Navel orange	19.8	3.6 d	5.5
Star Ruby grapefruit	19.4	3.3 d	5.9
Ortanique tangor	17.9	3.2 d	5.6
Orlando tangelo	29.6	1.8 e	16.4
Valencia Late orange	17.8	1.6 e	11.1

[1] Control: *Citrus volkameriana* for lemons and limes, Troyer citrange for the other varieties. The values which are not followed by the same letter are different at a 5% threshold, using the Newman Keuls test.

densities in orchards using Flying Dragon rootstock (1,000 plants·ha^{-1}), the cumulative harvest results put the usage of the Flying Dragon into a much more favourable light (*table IV*). Five years after planting, the cumulative harvest results, calculated at the level of the planted surface, would be 2 to 5.7 times as much for the varieties grafted onto the dwarfing rootstock.

Thus, for example, yield from trees from the [Tahiti lime / Flying Dragon] association were 1.5 kg, 7.4 kg, 40.4 kg and 45.7 kg per tree for the years 2, 3, 4 and 5, leading to a cumulative result of 94 t·ha^{-1} for an orchard planted at high density, whereas, in a conventional orchard, the same citrus tree variety grafted onto *C. volkameriana* produces 9 kg, 37 kg and 54 kg per tree in the years 3, 4 and 5, that is to say a cumulative harvest result of 20.8 t·ha^{-1}.

Another parameter displaying the efficiency of the Flying Dragon is the calculation of the ratio between fruit production and tree canopy volume (*table V*). Production per surface unit varies from 2.5 to 9.8 kg·m^{-3} for varieties grafted onto the Flying Dragon, whereas it varies from 1 to 4.8 kg·m^{-3} for the control trees. Graftings using the Flying Dragon as rootstock are thus from 1.4 to 5.8 times more productive than those concerning the *C. volkameriana* and Troyer citrange graftings.

Table II.
Surface occupied at 5 years of age by trees from commercial varieties of citrus fruit trees grafted onto dwarfing rootstock (*Poncirus trifoliata* cv. Flying Dragon) and proposed planting density (New Caledonia).

Variety grafted	Surface occupied (m^2)	Proposed planting density (plants·ha^{-1})
Lisbon lemon	8.8	800
Tahiti lime	6.9	800
Saint John satsuma	4.7	1 000
Washington Navel orange	3.4	1 200
Star Ruby grapefruit	3.1	1 200
Ortanique tangor	3.1	1 200
Orlando tangelo	2.0	1 400
Valencia Late orange	1.9	1 400

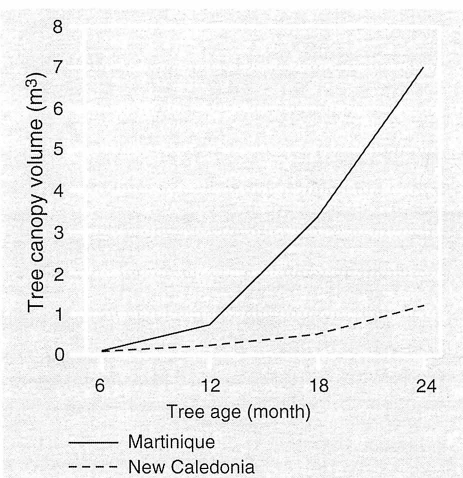


Figure 5.
Climatic effect on the growth of Tahiti lime trees grafted onto Flying Dragon dwarfing rootstock through the comparison of canopy volumes for trees planted in Martinique (humid tropical climate, lat. 15° N, alt. 50 m) and in New Caledonia.

Table III.
Cumulated harvest for 5-year-old trees from citrus fruit commercial varieties grafted onto dwarfing rootstock (*Poncirus trifoliata* cv. Flying Dragon) and ratios of comparison with the production of conventional orchards (New Caledonia).

Variety grafted	Cumulated harvest (kg per tree)		Ratio Flying Dragon / control
	onto Flying Dragon	onto control[1]	
Saint John satsuma	57	50	1.1
Tahiti lime	94	100	0.9
Lisbon lemon	74	103	0.7
Ortanique tangor	39	67	0.6
Valencia Late orange	28	48	0.6
Star Ruby grapefruit	76	122	0.6
Orlando tangelo	40	80	0.5
Washington Navel orange	28	66	0.4

[1] Control: *Citrus volkameriana* for lemors and limes, Troyer citrange for the other varieties.

Table IV.
Theoretical harvest for 5-year-old trees from citrus fruit commercial varieties grafted onto dwarfing rootstock (*Poncirus trifoliata* cv. Flying Dragon) and planted at high densities made possible by the reduced canopy expanse, and ratios of comparison with the production of conventional orchards (New Caledonia).

Variety grafted	Cumulated harvest ($t \cdot ha^{-1}$)		Ratio Flying Dragon / control
	onto Flying Dragon	onto control[1]	
Saint John satsuma	57	10	5.7
Tahiti lime	94	21	4.5
Washington Navel orange	74	21	3.5
Star Ruby grapefruit	76	25	3.0
Ortanique tangor	39	14	2.8
Valencia Late orange	28	10	2.8
Orlando tangelo	40	17	2.4
Lisbon lemon	28	14	2.0

[1] Control: *Citrus volkameriana* for lemons and limes, Troyer citrange for the other varieties.

It should be noted that using Flying Dragon rootstock had no derogatory effect on fruit size (results not shown).

3.2.2. fruit quality

For graftings using varieties producing sweet fruits (oranges, satsumas, tangelos, tangors) grafted onto the Flying Dragon, the maturing of fruits was slowed down but the fruits themselves were sweeter and juicier (results not shown).

3.3. costs

As the goal of the experimentation was to increase the profitability of New Caledonian citrus fruit tree orchards by using new rootstock, a comparison was made between implementing and running a high density orchard (1,000 plants$\cdot$ha^{-1}), foreseeable using the dwarfing rootstock, and a traditional orchard (208 plants$\cdot$ha^{-1}) for the Tahiti lime.

Table V.
Production per unit of volume, 5 years after planting, for trees from grafts of commercial varieties of citrus fruit trees onto dwarfing rootstock (*Poncirus trifoliata* Flying Dragon cultivar) and ratios of comparison with the production of conventional orchards (New Caledonia).

Variety grafted	Harvest (kg) / foliation volum (m^3)		Ratio Flying Dragon / control
	onto Flying Dragon	onto control[1]	
Orlando tangelo	9.8	1.7	5.8
Tahiti lime	4.1	1.1	3.7
Valencia Lateorange	7.3	2.2	3.3
Saint John satsuma	4.8	1.7	2.8
Star Ruby grapefruit	9.5	4.8	2.0
Lisbon lemon	2.5	1.0	2.5
Ortanique tangor	5.2	3.1	1.7
Washingtonl Navel orange	3.6	2.5	1.4

[1] Control: *Citrus olkameriana* for lemorls and limes, Troyer citrange for the other varieties.

Table VI.
Comparison of installation costs (in US $) for a Tahiti lime tree pedestrian orchard at a high planting density (1,000 plants·ha^{-1}) and for a conventional orchard at a low density (208 plants·ha^{-1}) in New Caledonia.

Considered expenditure	Pedestrian orchard cost (C_{po})	Conventional orchard cost (C_{co})	(C_{po}) / C_{co})
Soil preparation	290	290	1.0
Basic fertilisation	2,180	2,180	1.0
Banked bed construction	237	211	1.1
Plant costs	10,500	2,140	5.0
Planting	2,318	464	5.0
Irrigation	5,596	4,889	1.1
Global costs	21,121	10,174	2.1

3.3.1. installing a pedestrian orchard

The dwarfing effect of Flying Dragon rootstock makes it possible to obtain trees of reduced size on which technical interventions are simplified. Orchards composed of such trees are called "pedestrian orchards".

When creating a pedestrian orchard, soil preparation costs – basic fertilisation and ground works – remain the same no matter what planting density is adopted. Direct costs proportional to the number of trees planted thus concern only the works related to installing tree supports and planting the plot. Moreover, costs for installing an irrigation network increase only 1.1 time, given the modification of the network to use one microjet for four trees (*table VI*).

On the basis of the costs analysis of the different posts considered, it thus appears that the implementation of a pedestrian orchard is 2.1 times more expensive than that of a traditional orchard, whereas its density is 5 times higher.

Table VII.
Comparison of the maintenance costs (in US $) cumulated over 5 years for a Tahiti lime tree pedestrlan orchard at a high density (1,000 plants·ha^{-1}) and for a conventional orchard at a low density (208 plants·ha^{-1}) in New Caledonia.

Considered expenditure	Pedestrian orchard		Conventional orchard		$(C_{po}) / C_{co})$
	cost (C_{po})	% of global cost	cost (C_{co})	% of global cost	
Labour	8,105	34	5,297	35	1.5
Products	6,503	17	4,613	30	1.4
Tilling	4,638	19	4,295	28	1.1
Harvesting	4,700	20	1,040	7	4.5
Global costs	23,946	100	15,245	100	1.6

3.3.2. maintenance of a pedestrian orchard

For an orchard made up of varieties grafted onto the Flying Dragon (pedestrian orchard), maintenance cost components do not increase proportionally to plant density. They are:

– maintenance and weeding of the plot, where the number of aisles to maintain is the same as with normal density,

– plant pruning, which amounts to \$1,446 for the pedestrian orchard and \$1,175 for a conventional orchard, a cost multiplied by a factor of only 1.2,

– phytosanitary protection, where the difficulty to properly treat the crowns of trees in a plot with normal density is compensated for by the reduced size of the trees in a pedestrian orchard, the volume of spray thus remaining practically the same.

On the other hand, fertilisation costs, which increase by a factor of 6.1, and harvest costs, multiplied by 4.5, are two cost components which increase significantly. They are not, however, proportional to density, if the 5 year observation period is taken into account.

Globally, maintenance costs of a pedestrian orchard, cumulated over 5 years, are 1.6 time, higher than those of a normal orchard (*table VII*).

When the costs of orchard installation and the cumulative maintenance costs over 5 years (*table VII*) are added up, per hectare costs for a high density or pedestrian orchard (\$45,066) are 1.8 time higher than those of a conventional orchard (\$25,417) for a 5 times higher plant density. At the same time, the quantity of production is 4.5 times higher with a pedestrian orchard than with a conventional orchard. These

Table VIII.
Comparison of the gross margin per hectare (in US $) cumulated over 5 years for a Tahiti lime tree pedestrian orchard planted at a high density (1,000 plants·ha^{-1}) and for a conventional orchard at a low density (208 plants·ha^{-1}) in New Caledonia.

Considered expenditure	Pedestrian orchard (PO)	Conventional orchard (CO)	(PO) / (CO) cost ratio
Costs	45,066	25,417	1.8
Products	184,240	40,768	4.5
Gross margin per ha for 5 years	139,174	15,351	9.1
Direct cost per kg for 5 years	0.48	1.22	–2.5

results give a gross margin per hectare, cumulated over 5 years, 9 times higher for the high density orchard than for that with usual density (*table VIII*).

The development of the gross margin (*figure 6*) indicates that the threshold of profitability is reached during the fourth year of exploitation for the [Tahiti lime / Flying Dragon] association, on the basis of an average selling price of $1.96 per kg [source: *Institut territorial de la statistique et des études économiques* (ITSEE)]. It should, however, be noted that this rough estimate concerns only the direct costs for the plot, which are parameters to integrate into the exploitation structure case by case.

4. conclusion

To make up for the excessive vigour of trees grown under tropical climatic conditions, using rootstock resulting in less volume while meeting sanitary requirements can be promising as it makes it possible to improve:

- fruit yield per hectare,
- harvested fruit quantity per surface unit,
- intervention efficiency,
- labour yield.

Adopting Flying Dragon rootstock, a cultivar of the *Poncirus trifoliata* species, makes it possible to plant in densities of 800 to 1,400 trees·ha^{-1} according to the variety. The approach contributes to the installation of "pedestrian" orchards in which interventions are simplified and the beginning of production is early, thus resulting in rapid depreciation of installation and maintenance costs.

Even though this rootstock has not experienced extensive commercial development in the Mediterranean zone due to its excessive dwarfing effect in this climate, it would seem interesting for a tropical zone. Further observations will make it possible to assess the longevity of these trees as well as the effect of this rootstock on fruit quality (size, juice and sugar content, acidity) according to the tree age.

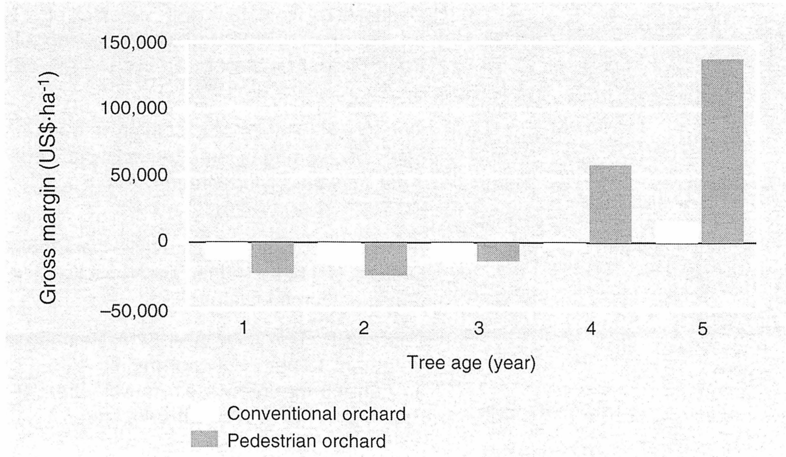


Figure 6.
Comparison of the gross margins cumulated from the first year to the fifth year after planting for a pedestrian orchard made up of Tahiti lime trees grafted onto dwarfing Flying Dragon rootstock and an orchard using conventional rootstock (New Caledonia).

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references

[1] Broadbent P., Forsyth J.B., Bevington K.P., Hutton R.J., Citrus tree size control with dwarfing agents, Citrograph 72 (1986) 8–10.

[2] Golomb A., High density planting of intensive citrus groves: a challenge and realization, In: Proc. Int. Soc. Citriculture, ISC, Tel Aviv, Israel, 1988, pp. 921–930.

[3] Krezdorn A.H., Interstocks for tree size contol in citrus, Proc. Fla. State Hort. Soc. 91 (1978) 50–52.

[4] Piner G.F., Planting citrus at ultra high densities. A review of developments in Southern Africa with special reference to angle planting, In: Proc. Int. Soc. Citriculture, ISC, Tel-Aviv, Israel, 1988, pp. 931–940.

[5] Bitters W.P., Cole D.A., McCarthy C.D., Facts about dwarf citrus trees, Citrograph 64 (1979) 54–56.

[6] Roose M.L., Dwarfing rootstocks for citrus, In: Proc. Int. Soc. Citrus Nuserymen, ISCN, Riverside, USA, 1986, pp. 1–8.

[7] Castle W.S., Rootstock and interstock effects on the growth of young Minneola tangelo trees, Proc. Fla. State Hort. Soc. 105 (1992) 82–84.

[8] Cheng F.S., Roose M.L., Origin and inheritance of dwarfing by the citrus rootstock *Poncirus trifoliata* Flying Dragon, Am. Soc. Hortic. Sci. 120 (2) (1995) 286–291.

[9] Anonymous, Atlas de Nouvelle-Calédonie, Orstom, Hachette Calédonie, Nouvelle-Calédonie, édition du Cagou, 1989, 91 p.

[10] Ollitrault P., Isozymes and DNA Restriction Fragment Length Polymorphisms (RFLP's) as genetic markers in citrus selection, In: Proc. Asia-Pacific Int. Conf. Citriculture, 1990, pp. 57–68.

[11] Castle W.S., Growth, yield, and cold hardiness of seven-year-old Bears lemon trees on twenty-seven rootstocks, Proc. Fla. State Hortic. Soc. 96 (1983) 23–25.

[12] Anonymous, Descriptors for citrus, IBPGR, FAO, Rome, Italy, 1988, 27 p.

[13] Mademba-Sy F., Rapport annuel d'activités, Document interne, Irfa, centre de Martinique, Fort-de-France, France,1989, pp. 93–104.

Utilización de *Poncirus trifoliata* « Flying Dragon » como porta-injerto que vuelve enanos los agrios en clima tropical.

Resumen — **Introducción**. Los agrios cultivados en clima tropical presentan un gran vigor y, por consiguiente, una puesta en frutos atrasada y una baja productividad. El uso de portainjerto *Poncirus trifoliata* Flying Dragon (P*t*FD), que permite lograr árboles de un volumen reducido y una producción precoz, podría paliar este problema. **Material y métodos**. Un ensayo incluyendo ocho variedades comerciales fue instalado en diciembre de 1992 en una parcela irrigada en la isla de la Grande-Terre en Nueva-Caledonia. El crecimiento de los árboles fue vigilando durante 5 años mediante medición, dos veces por años, de la altura del árbol, del diámetro de la fronda entre rangos y en el rango y del diámetro del tronco a los 10 cm encima y abajo del punto de injerto. Las cosechas se pesaron a partir de la aparición de los frutos 2 años después de la siembra. **Resultados**. En las condiciones climáticas y pedológicas del sitio experimental, los árboles injertados sobre P*t*FD autorizan, acorde a las variedades sometidas a test, densidades de siembra de 800 a 1.400 árboles·ha^{-1}. Los costos de implantación y de mantenimiento cumulados sobre 5 años son superiores de 1,8 veces a los de un vergel tradicional, para una densidad 5 veces más elevada y una productividad por hectárea igual a 5,2 veces a la de un vergel estándar. **Conclusión**. El uso de P*t*FD, poco desarrollado en zona mediterránea debido al demasiado gran efecto reductor de tamaño de este porta-injerto en este clima, podría pues resultar interesante en zona tropical. Las observaciones futuras permitirán evaluar la longevidad de estos árboles y la calidad de los frutos inducidos por el porta-injerto.

Nueva Caledonia / *Citrus* / ensayos de variedades / enano / portainjertos / rendimiento de cultivos / respuesta de la planta