Coconut (Cocos nucifera L.) genetic improvement in Vanuatu: overview of research achievements from 1962 to 2002

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Résumé : From 1963 to 2002, at the Saraoutou research station on the island of Santo in Vanuatu, genetic improvement work was undertaken to increase the productivity of coconut plantations, which, through copra exports, were the country's main wealth in the last century. Beginning with two Vanuatu Tall (VTT) populations collected near the station, four mass selection cycles by open pollination or intercrossing have resulted in Elite Vanuatu Tall populations intended for distribution to farmers. The study sums up how the different VTT populations perform in terms of germination rate, flowering precocity, and yield components (copra per nut, number of nuts). It highlights the efficiency of these breeding methods in increasing nut copra content and in reducing within-population variance of phenotypic traits. Flowering precocity, the number of nuts, and consequently copra production per plot, remain highly dependent upon growing conditions, and on the care taken in the nursery. It also confirms that selection too exclusively based on the search for a high copra content is reflected in a drop in the number of nuts and a very slight gain in copra production per palm.Compared to higher-yielding hybrids, the improved VTT populations offer the advantage of being totally tolerant of coconut foliar decay and of being reproducible by farmers themselves. The merits of setting up decentralized seed gardens in the Vanuatu archipelago from improved populations at the research station, or from locally surveyed material, are discussed.

Mots-clés : pacific, vanuatu, coconut, genetic improvement, copra, seeds, heritability, mass selection

ARTICLE

Located in the Pacific northeast of New Caledonia, Vanuatu is an archipelago of around 80 islands and islets of volcanic origin straddling the 13th and 22nd parallels, over a distance of about 850 kilometres. Coconut is a traditional crop used by rural populations for highly varied purposes (nutritional, medical, ritual) and for making domestic articles and constructing dwellings. Since 1870, coconut has become a cash crop through exports of a single product, copra, obtained by drying the kernel of the coconut fruit. Throughout the twentieth century, this commodity was the main source of income for the Condominium of the New Hebrides, which became the Republic of Vanuatu after the proclamation of independence in 1980. The latter years of the last century were marked by a slow but steady decline in copra production, though it still reached 29,500 tonnes in 2001, despite record low prices and damage by two cyclones that year. Ninety percent of production is ensured by smallholders farming a few hectares, the rest being supplied by ageing estates. Around half this production is processed locally into oil. These two products, copra and oil, still account for 26% of the country's total export earnings [1].Agricultural research on coconut is relatively recent in Vanuatu. The Saraoutou research station was founded in 1962 on the island of Santo and placed under the authority of the Institut de recherches pour les huiles et oléagineux (IRHO), then of the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), a French State-run research establishment, in 1985. In 2002, the coconut research station was integrated into the Vanuatu agricultural research and technical centre (VARTC).The first research work involved coconut breeding and agronomy, along with the improvement of livestock grazing under coconut [2]. In the context of the 1960s, the aim of research was to increase productivity in coconut plantings, expressed in tonnes of copra per hectare, by improving the yield potential of planting material and developing modern and cost-effective management techniques.The geographical dispersion of Vanuatu and the diversity of its soils and climates would suggest substantial genetic diversity but, until recently, all the Tall coconut populations in the country were grouped under the generic name New Hebrides Tall, then Vanuatu Tall (VTT) after independence. The common trait of these populations is the large number of small nuts, as reported by several observers and scientists as early as the 1960s [3, 4]. The Vanuatu Tall should be classed among coconut palms with high phenotypic variability. Manciot [5] gave the following average values for the different production parameters:

- – Number of nuts/palm/year = 88 (c.v. = 44.2 %)
- – Copra weight/nut = 148 g (c.v. = 17.9 %)
- – Number of flowers/bunch = 43 (c.v. = 55.1 %)
- – Number of bunches/year = 11 (c.v. = 30.5 %)
- – Number of nuts/bunch = 8 (c.v. = 34.5 %)

The high coefficients of variation (c.v.) suggested possibilities for improving both the number of nuts and the copra content. The latter trait in particular is highly heritable [6] and the cost of extracting fresh meat, a labour-intensive operation that is difficult to mechanize, can be reduced by increasing the copra content of the nut.Consequently, in 1963, surveys were launched in two coconut estates near the research station, Surunda Plantation and Leroux Plantation ((*figure 1*)) and led to the selection of the two Vanuatu Tall populations that were to become the basis for future genetic improvement: Vanuatu Tall Surunda (VTT1) and Vanuatu Tall Leroux (VTT2). Based on this nascent collection, the breeding programme at the Saraoutou station proceeded along two parallel and complementary lines. Firstly, improvement of the Vanuatu Tall continued with several mass selection cycles and crosses within and between populations, and secondly the hybridization pathway was explored by testing numerous combinations between local and introduced cultivars.After forty years of work and data gathering at the Saraoutou station, it seems now appropriate to describe here the breeding methods applied and the main results obtained. The first part of this article focuses on the improvement of Vanuatu Tall production potential by mass selection.

The mass selection improvement programme of the Vanuatu Tall

Initial selection work in the estates (initial generation G0) led to the creation of populations VTT1 and VTT2 (generation G1) by mass selection with open pollination.

We have data available making it possible to evaluate the gain obtained with population VTT2, which descended directly from palms selected in the Leroux estate. Selection focused first of all on copra weight per nut, which had to be over 160 g, and on overall yields, which had to be over 10 kg of copra per palm. Twenty-five palms were chosen and the nuts collected then underwent strict culling in the nursery. For instance, nuts that germinated late and the least vigorous seedlings were eliminated in appliance with protocols drawn up by IRHO [7, 8]. The Leroux estate, and the collection plot in which population VTT2 was planted, were very close to each other and were both located on coral soil.

Table 1(*Table 1*) shows that the production components of population VTT2 were largely improved when compared to the original population. Nut copra content (C/N) was improved by 26%, the number of nuts (NN) by 37% and total yields by 71%. The coefficients of variation for these parameters decreased. For lack of a "non-selected" control to compare with VTT2 in the same collection plot, it was not possible to determine the share attributable to the environment, management methods, palm age or the effect of culling (in the field and at the nursery stage) in the improvement of these components. However, the production potential of the Vanuatu Tall had already been revealed, along with the possibility of substantially increasing copra weight per nut.

However, several authors [6, 9, 10] showed that mass selection with open pollination, when compared to hybridization, was not particularly efficient in terms of genetic progress and also entailed major risks:

- Given the high negative correlation existing between the "number of nuts" and "copra weight per nut" traits, selection limited to a search for larger nuts could work against an increase in copra yields.
- During strong periods of growth in the hot season, the bunch emission rate accelerates, and high-yielding mother palms could adopt an autogamous reproduction system. As coconut palms have a heterozygous genome, their progenies would display a depressive inbreeding effect, which would be reflected in their lower average performance when compared to the parental population.

Thus, right from the second generation, mass selection was used with intercrossing. After a period of yield observations, the best palms in a population were crossed with each other. This required the hand pollination technique, which is much more labour-intensive than selection with open pollination, but more efficient in terms of the expected genetic progress. At Saraoutou, the risk of inbreeding was reduced by taking parents from two distinct populations, VTT1 and VTT2, though they are genetically close. The progenies obtained were tested in two comparative trials (GC2 and GC9), and formed generation G2.

A new selection cycle was undertaken, leading to the creation of the Elite A seed garden using seednuts from palms in trial GC9. Initially, culling was based on the germination rate and seedling vigour in the nursery. Then, at the adult stage, the least productive palms in the seed garden were eliminated to promote more favourable combinations. The seednuts produced in Elite A seed garden (generation G4) are currently distributed to growers in Vanuatu.

More recently, index-based pre-selection [11] was carried out, in order to more effectively assess the genetic value of individual palms. All the coconut palms in trial GC9 were classed according to an index based on the estimated copra yield per palm. Trial GC9 compared 24 half-sib families. The best 60 palms chosen from the best 5 families were intercrossed by hand pollination, avoiding within-family combinations. The progenies were planted in seed gardens in 1997 to supply future Elite B seednuts (generation G4).

A diagrammatic representation of the programme for VTT improvement by mass selection is given in (*figure 2*).

Table 1 Annual production means for palms in the Leroux plantation and its progeny.

	Leroux Plantation			**VTT2**				
Generation G0				**Generation G1**				
205 palms observed during 3 years				**290 palms observed during 4 years**				
(1963-1965)				**(1973-1976)**				
NN	**C/N**	**C/A**	**C/ha**	**NN**	**C/N**	**C/A**	**C/ha**	
Means(Min-Max)	68.5	139.2 g (62-223)	9432 g	1.35 t	93.7	175.2 g (123-235)	16114 g	2.3 t
Standard deviation	31.2	25.8	3962		36.2	22.8	5874	
C.V. (%)	45.6	18.5	42.0		38.6	13.0	36.5	

On-station trials: methods and results

Trial site

The Saraoutou station (longitude 167°12′E, latitude 15°27′S) is located 11 kilometres north of Luganville on the east coast of the island of Santo. Its current domain extends over around 500 ha, on a low terrace along the coast, comprising shallow humus-bearing coral soils, and a limestone plateau enriched with volcanic ash, with deep, fertile soils rich in clay and organic matter [12, 13]. (*Figure 3*) shows that it benefits from abundant rainfall with 2,815 mm on average between 1984 and 2002, and temperatures between 21.4°C (mean of monthly minimums from 1986 to 2002) and 28.6°C (mean of monthly maximums). July and August are the coldest and driest months of the year.

The country is periodically subject to cyclones. For its part, the Saraoutou station was particularly affected by cyclones Wendy (1972), Gordon (1979), Nigel (1985) Dani and Ella (1999) and Paul and Sose (2001).

Experimental design

The performance of the different Vanuatu Tall populations was assessed at different periods, in several collection and trial plots at the research station. This involved 28 plots containing VTT1 and VTT2 progenies planted between 1964 and 2000. Table 2(*Table 2*) gives the main characteristics of the trials and collections, for which data will be examined in the following sections.

Under these conditions, and in the absence of a constant control, it needs to be borne in mind that numerous environmental factors introduced bias when assessing the genetic value of the different generations arising from the selection cycles, such as:

- **–** soil: some trials at the station are conducted on coral soil, others on plateau soil. It may involve planting after forest clearance, or a replanting;
- **–** trial management: this embraces such diverse aspects as the development and age of the seedlings on leaving the nursery, the planting period, the care taken of seedlings and the fertilization applied, which are rarely identical for all trials;
- **–** adverse conditions: the effect of cyclones is considerable and can seriously reduce the performance of a palm [14]. A prolonged period of drought (rare event on Santo) can also disrupt growth and yields. Lastly, insect attacks or diseases may also play a role.

Table 2 Simplified description of the trials and collections observed.

Generation (Accession)	Type	Field number	Origin	Planting date	Experimental design	Sol
G1 (VTT1)	Collection	P02	Surunda Plant.	1964	–	Coral
G1 (VTT1)	Collection	P00	Surunda Plant.	1967	–	Coral
G1 (VTT2)	Collection	P00	Leroux Plant.	1967	–	Coral
G1 (VTT2)	Trial GC1	P43	Leroux Plant.	1969	Rows	Plateau
G2	Trial GC2	P51	VTT1 (P02) x VTT2 (P00)	1969	2 blocks	Plateau
G2	Trial GC9	P44/54	VTT1 (P02) x VTT2 (P00)	1969	Lattice 5x5, 6 replications	Plateau
G3	Trial GC14	P63	Trial GC2	1982	5 blocks	Plateau
G3	Elite A seed garden	P106/116/117	Trial GC9	1987	–	Plateau
G3	Elite B seed	P84	Trial GC9	1997	–	Plateau

	garden					
G4	Trial GC29	P50	Elite A seed garden	1998	5 blocks	Plateau

Observation methods

The main characteristics of the populations were recorded using methods developed by IRHO and standardized by IPGRI [15]. Harvesting was carried out by hand with hooked knives, taking bunches with partially dry nuts. The nuts were placed in the shade in a dry place for between 10 and 15 days to ensure a uniform degree of ripeness. After sorting to eliminate abnormal nuts, they were notched and placed in a seedbed with supplementary watering. New germinations were recorded each week. After cumulation, a germination-versus-time curve was plotted.

Once the first flower appeared in a plot, an inspection round was organized to record newly flowered palms every two months. A cumulated flowering curve gave the percentage of palms bearing flowers in relation to time.

At Saraoutou, the yields of the Tall populations were estimated by recording the number of bunches and the number of ripe nuts, palm by palm, at a rate of 6 harvesting rounds per year. Meat weight was then determined either by individual weighing in the case of collections, or by sampling the elementary plots in the case of trials, in order to make up a sample of 20 to 30 nuts per treatment. Nut copra content was calculated from the fresh meat weight and the moisture content of the meat obtained after drying in an oven at 105°C. By definition, copra weight was equivalent to that of meat with 6% moisture. The copra yield per palm was thus equal to the number of nuts multiplied by the weight of copra per nut. Lastly, the theoretical yield of a plantation was determined on the basis of 143 palms per hectare corresponding to a planting design in 9 meters equilateral triangles.

Results

Germination rate

The Vanuatu Tall is a Tall ecotype displaying very rapid germination [16], beating the Rennell Tall for this trait, which is itself reputed to be rapid. The germination curves were plotted for a few of the generations obtained ((*figure 4*)). Under good nursery conditions, with supplementary watering, the first germinations were obtained between 30 or 50 days after sowing, depending on the generation. The maximum rate was achieved more quickly for the last generation, G4, probably due to lower variability in that population. In this last case, 50% of germinated nuts were obtained after 60 days and the maximum germination rate was achieved around the 90th days and exceeded 90%.

Flowering precocity

The Vanuatu Tall is also reputed for its very early flowering [16, 17]. Flowering palms were recorded for the different Vanuatu Tall generations ((*figure 5*)). Generation G1 (VTT1 and VTT2) planted on coral soil (plot P00) had 50% of flowering palms after 54 months as opposed to only 44 months for the same type of material planted on plateau soil (P43). For generations G2, G3 and G4, which were all planted on plateau soil, the first flowers appeared after 29 to 33 months, which is remarkable for a Tall. For generation G2, 50% of the palms had flowered after 50 months, as opposed to 44 months for generation G3 and 36 months for G4. The performance of generation G4 (Elite VTT) was quite exceptional, with a much less staggered start to the flowering period than for the earlier generations, which may have been due to a less variable planting material from a genetic viewpoint, but also to planting with material displaying more uniform development on leaving the nursery. The seedlings of this generation also benefited from favourable climatic conditions in 1999 and 2000, which were warmer and wetter years than average.

Precocity therefore seems to depend on the environment, as already reported by de Nucé [16], who indicated that the VTT[1] flowered 12 to 18 months earlier in Vanuatu than at the Marc Delorme station in Ivory Coast, where the soil and climate are less suitable for its development. This trait is also improved through culling in the nursery.

The Vanuatu Tall has confirmed its very precocious Tall trait. The Elite T seeds currently distributed give an improved population which, under good nursery and field growth conditions, starts to flower after 30 to 36 months, with 50% of flowering palms between 40 and 45 months after planting. The first harvest can therefore take place 4 years after planting out.

Description of the palm

The VTT has along and thin stem, and a rather large bole (*(figure 6)*). The fruits are of medium size with various shapes but most of them are oblong and green, greenish brown, or reddish brown in colour (*(figure 7)*).

Yield characteristics

Improvement of copra content

The Vanuatu Tall populations on which the breeding programme is based had an average copra/nut weight (C/N) of under 150 g. At each stage of selection, an attempt was made to eliminate parents with a C/N of less than 160 g.

In addition, to obtain the palms in trial GC9, use was made of VTT1 parents from plot P02 whose individual C/N was equal to or greater than 189 g on average over 5 seasons (overall mean of the C/N for all these palms = 210 g), and VTT2 parents from plot P00 with an individual C/N equal to or greater than 183 g over 3 seasons (overall mean of the C/N for all these palms = 201 g).

The results obtained ((*figure 8*)) shows this selection to be efficient, as reflected in a 46% increase in C/N between G0 and G4[2], and even reaching 50% in the case of GC9 palms with almost 210 g of copra per nut (minimum 200g – maximum 226 g).

The environmental effect seems to be not decisive. No notable difference was found between palms of the same origin depending on soil type (coral or plateau). Moreover, de Nucé [16] did not report any significant difference for this character between the VTT population at Saraoutou and the one at Marc Delorme in Ivory Coast.

Number of nuts per palm and copra per palm

In the long term, these two parameters were closely dependent upon the environment (soil, growing conditions), but were also highly sensitive over shorter periods to cyclone effects in the case of mature palms. The yield curves ((*figure 9*)) clearly illustrate the fluctuating nature of production and its susceptibility to cyclones.

Table 3(*Table 3*) gives a recap of average annual yields calculated from 5 to 10 years after planting. This made it possible to integrate the precocity factor in yield expression.
Table 3 Yield characteristics for 3 VTT generations. Annual averages calculated from 5 to 10 years after planting.

	G1 (VTT2)	**G1(VTT2)**	**G2 (GC2)**	**G2 (GC9)**	**G3 (GC14)**
Field number	P00	P43	P51	P44-54	P63
Soil	Coral (a)	Plateau (b)	Plateau (c)	Plateau (d)	Plateau
Number of nuts/palm/year	71.6	81.4	74.5	75.1	83.1
Copra/nut (g)	172.7	173.9	194.7	209.8	197.0
Production copra/palm/year (kg)	12.4	14.1	14.5	15.8	16.4
Production copra/ha/year (tonnes)	1.77	2.02	2.07	2.25	2.34
Cumulated number of nuts 9 years after planting	342	414	372	352	448

[a]Effect of cyclone Wendy in year 5 and year 6.

[b]Effect of cyclone Wendy in year 4, of cyclone Gordon in year 9 and year 10, drought in year 11.

[c]Drought in year 4.

[d]Effect of cyclone Nigel in year 5 et year 6.

Discussion

In the absence of a constant control, and given the growing conditions, climatic adversities and planting dates, which differ depending on the trials, comparing the performance of the different generations is tricky. Nonetheless, these data provide some information:

- Yields per palm are mainly determined by the environment (soil type, growing conditions), which affects both flowering precocity and the number of nuts.

- There is no increase in the number of nuts per palm over the different generations, but rather a slight decrease. The progenies of GC9, whose parents were subject to severe selection for C/N, had a mediocre number of nuts. It should be noted that the control in GC9 was obtained by mass selection of VTT2 (plot P00) with open pollination (based on unknown selection criteria, though it was doubtless copra/nut). This control also produced very large nuts (C/N of 224 g) and came second out of 25 for this trait. For the number of nuts, it was within the trial mean. This shows that C/N is highly heritable and that the intensity of mass selection with open pollination is decisive. Consequently, in this precise case, controlled intercrossing was no more effective than mass selection with open pollination, since it was based too exclusively on the copra per nut criterion and involved two populations that are genetically very close.

- Selection is highly effective in increasing copra content, a trait which participates significantly, though in a limited way, in increasing the production potential of coconut palms.

- The gain, expressed as copra per ha, obtained between generation G1 (VTT2-P43) and G3 is modest (+15.8%), especially when bearing in mind that generation G1 was subjected to numerous climatic adversities (cyclone, drought).

- The performance of the latest generation G4 has yet to be completely assessed at the station[3] However, the production potential of the Elite seednuts (mean of years 5 to 10) can be estimated from that of generations G2 and G3 when established in good soil conditions:

    - Number of nuts = 75 to 85;

    - Copra per nut = 195 g to 205 g;

    - Copra per palm = 15 to 17 kg;

    - Copra per hectare = 2.1 to 2.4 tonnes (at a density of 143 palms per ha).

Seednut supplies to growers, and recorded performances

Dissemination of improved planting material primarily took place during the Coconut development project (Kokonas Devlopmen Projek or KDP) funded by the European development fund between October 1982 and March 1993. Over that period, around 2800 hectares were planted with improved planting materials produced by the research station, a majority of which were Vanuatu Tall palms. The origin of the seednuts varied over time. From 1982 to 1985, they were produced in a seed garden located at Matevulu (planted after 2 mass selection cycles with open pollination based on the Leroux population), then open pollinated seednuts from trial GC9 were distributed from 1985 to 1991 and, lastly, for the final phase of the project, seednuts from the Elite A seed garden were used [18].

Several demonstration plots were set up in Vanuatu [18, 19]. Some of them were observed during the KDP project, then from 1995 to 1997 in connection with a project of the International coconut genetic resources network (COGENT). By 3 1/2 years, 36% of the palms had flowered, and 93% by 4

1/2 years. The average copra weight recorded was 200.2 g, the number of nuts produced was 68.7 and annual production was estimated at 1.9 tonnes per hectare [20].

Achievements and limitations of VTT improvement by mass selection

The main purpose of the first genetic improvement work carried out on the Vanuatu Tall was to increase its production potential in a monoculture context, where it was often combined with cattle grazing, and exclusively geared towards copra production.

Mass selection with open pollination proved to be effective in improving nut copra content, right from the first generation. It led to populations that are more uniform, a trait that is also promoted by culling in the nursery. However, it revealed its limitations for increasing production potential. Flowering precocity, the number of nuts, and consequently copra production per plot remain highly dependent upon growing conditions and the care taken with seedlings in the nursery.

The breeding programme was based on using two Vanuatu Tall populations VTT1 and VTT2, which are probably very close in genetic terms, as they were surveyed in two estates next to the Saraoutou station. Mass selection with intercrossing thereby lost efficiency and the adaptation of progenies to ecological conditions different from those at Saraoutou – such as those found on soils developed on volcanic ash, or in a dryer or colder climate – could not be guaranteed. The demonstration plots set up during the KDP project were intended to assess such adaptation but, for lack of human and financial resources once the project ended, observations could not be satisfactorily completed. However, in order to widen the genetic base of the Vanuatu Tall, two surveys were carried out of local coconut populations between 1983 and 1986, then more recently between 1998 and 2000 on several islands in Vanuatu [21]. Samples of populations were collected and have been conserved ex situ at the Saraoutou station. These populations have been partially described and have yet to be used in a selection programme.

Compared to other types of higher-yielding planting material, such as hybrids, the Vanuatu Tall offers two major assets: total tolerance of Coconut Foliar Decay (CFD), a viral disease endemic in Vanuatu, and the possibility of being reproduced very cheaply by growers from seednuts harvested from under their palms.

Conclusion and prospects

In order to compensate for low efficiency in mass selection of the Vanuatu Tall, hybridization of distinct cultivars was launched at the beginning of the 1970s, for which the main constraint was the search for CFD tolerance. However, such a programme meant setting up and maintaining living collections of exotic cultivars (all of them susceptible to CFD), setting up seed gardens and implementing costly hybridization techniques.

Apart from its cost, the centralized production of improved planting material (hybrids or Elite VTT seednuts) in a scattered structure like the Vanuatu archipelago, was a major hindrance to widescale dissemination of this planting material [22]. In order to derive maximum benefit from the results obtained at the station, decentralized Vanuatu Tall seed gardens could be created on islands with a similar ecology to that at Saraoutou, using seednuts harvested from the Elite seed gardens. This would lead to a reduction in seednut costs and rapid access for growers to already improved material.

In the longer term, the efficiency of the first mass selection cycle demonstrated at the station in terms of copra content means that a similar selection scheme could be considered for setting up seed gardens based on smallholdings on the different islands in the archipelago. There are numerous advantages expected from such seed gardens, in different ways: better adaptation to the ecology of each island, maintenance of biodiversity, upgrading of the role played by growers, and stimulation of exchange networks.

Selection could be based on criteria specific to the growers, subject to their being highly heritable. The prerequisite for implementing such a production system is an in−depth study of current coconut seednut exchange and conservation systems in village communities. It also relies on growers having good knowledge of the individual traits of the mother palms that will supply seednuts for setting up the seed garden. Such research on the in situ management of local genetic resources is under way [23].

Research and development organizations will have a major role to play in helping growers to define selection methods and in providing training in nursery techniques and plantation management which, as we have seen, are decisive if the genetically improved Vanuatu Tall is to express its production potential.

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1 The origin of the VTT population at the Marc Delorme station is not formally known but, in view of the introduction date (1969), it can be imagined that it involves a selection from the Leroux estate (VTT2, generation G1). All the VTT populations worldwide (Tanzania, Ghana, Jamaica, Philippines, Brazil) are derived from this African collection.**2** C/N for generation G4 was calculated from the data collected during one year in GC29 trial.**3** In trial GC29, the first harvest took place 4 years after planting. In this trial, the yield of Elite VTT reached 2.0 tons for the fifth year after planting.

Illustrations

Figure 1 Surunda estate in 2003. Collection site for VTT1 in 1963. Photo J.P. Labouisse.

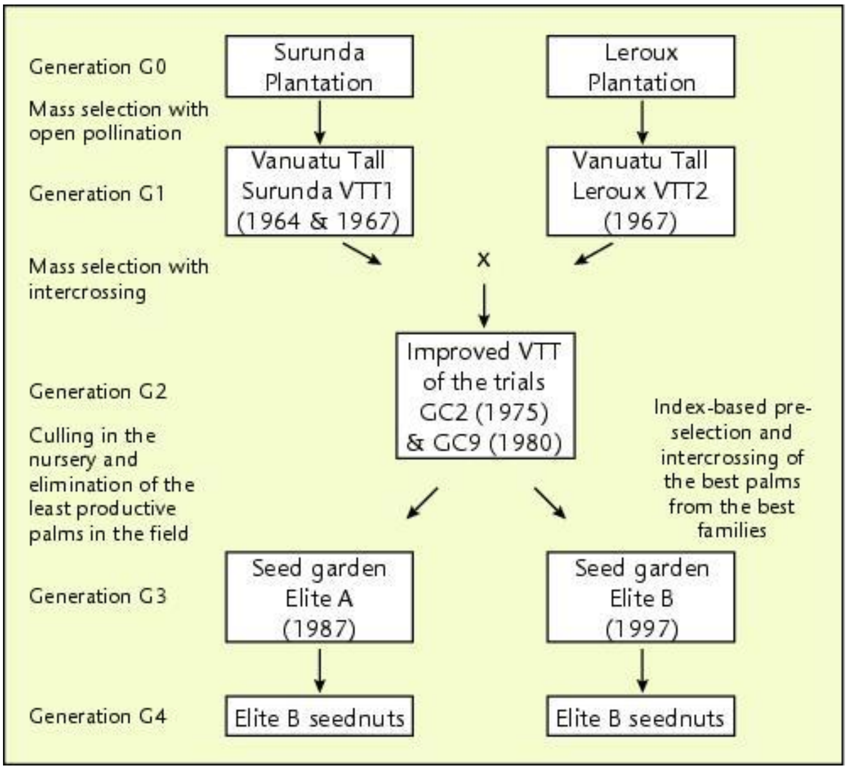

Figure 2 Diagrammatic representation of the programme for VTT improvement by mass selection (planting dates in brackets).

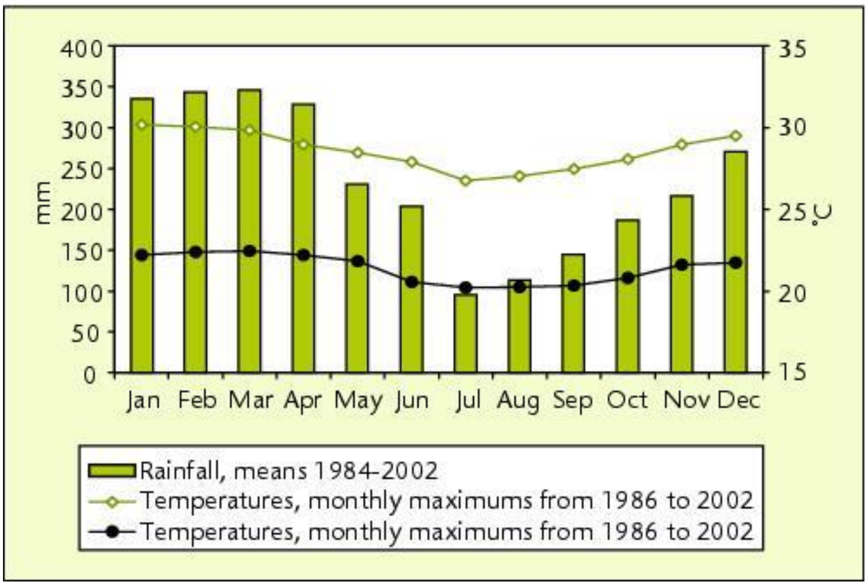

Figure 3 Average rainfall and temperatures at Saraoutou, Santo Island.

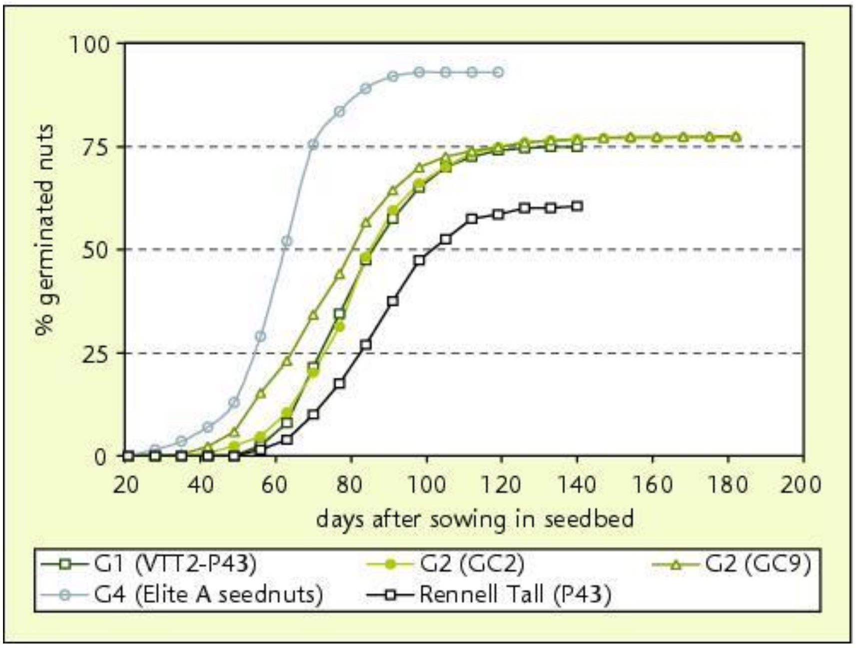

Figure 4 VTT germination in the nursery for different generations Rennell Tall as control.

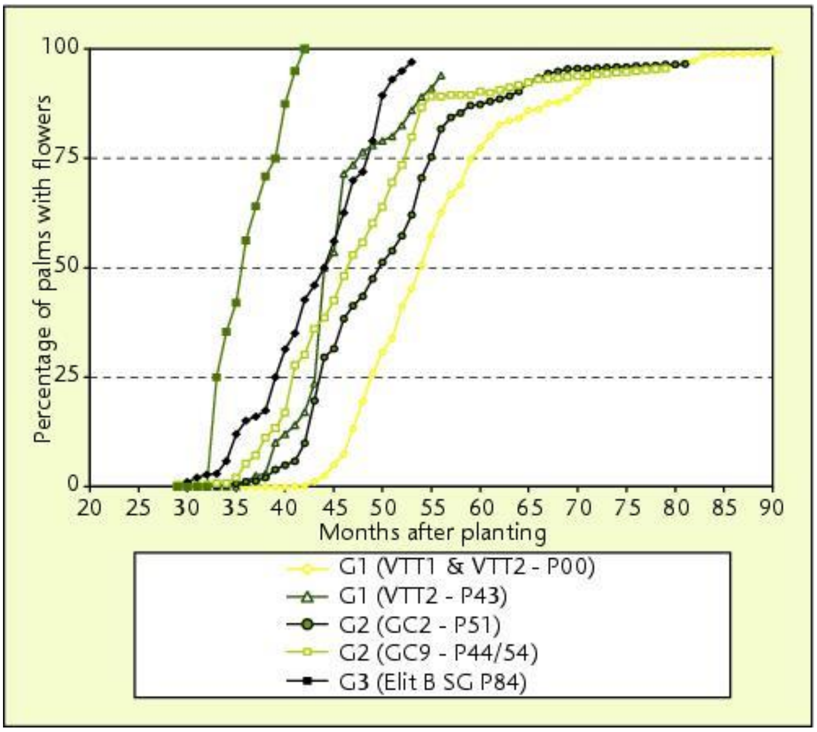

Figure 5 Vanuatu Tall flowering for different generations.

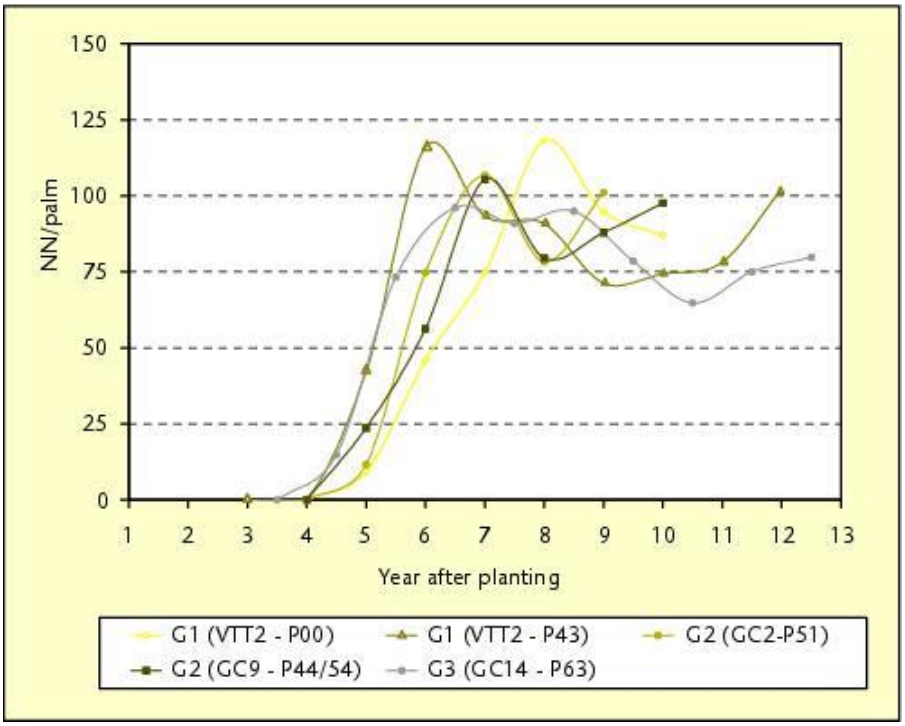

Figure 6 Young 5-year-old VTT in the trial GC29 (Generation G4). Photo J.P. Labouisse.

Figure 7 Bunch of VTT. Phto J.P. Labouisse

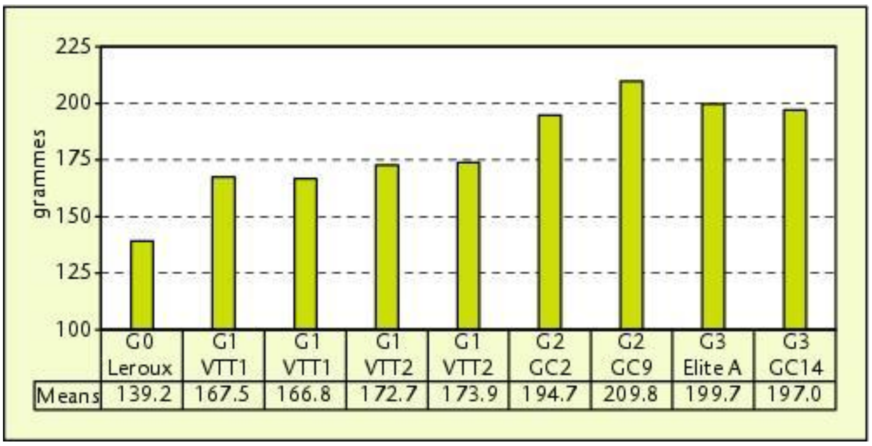

Figure 8 Copra content of the nuts (C/N) for different Vanuatu Tall generations.

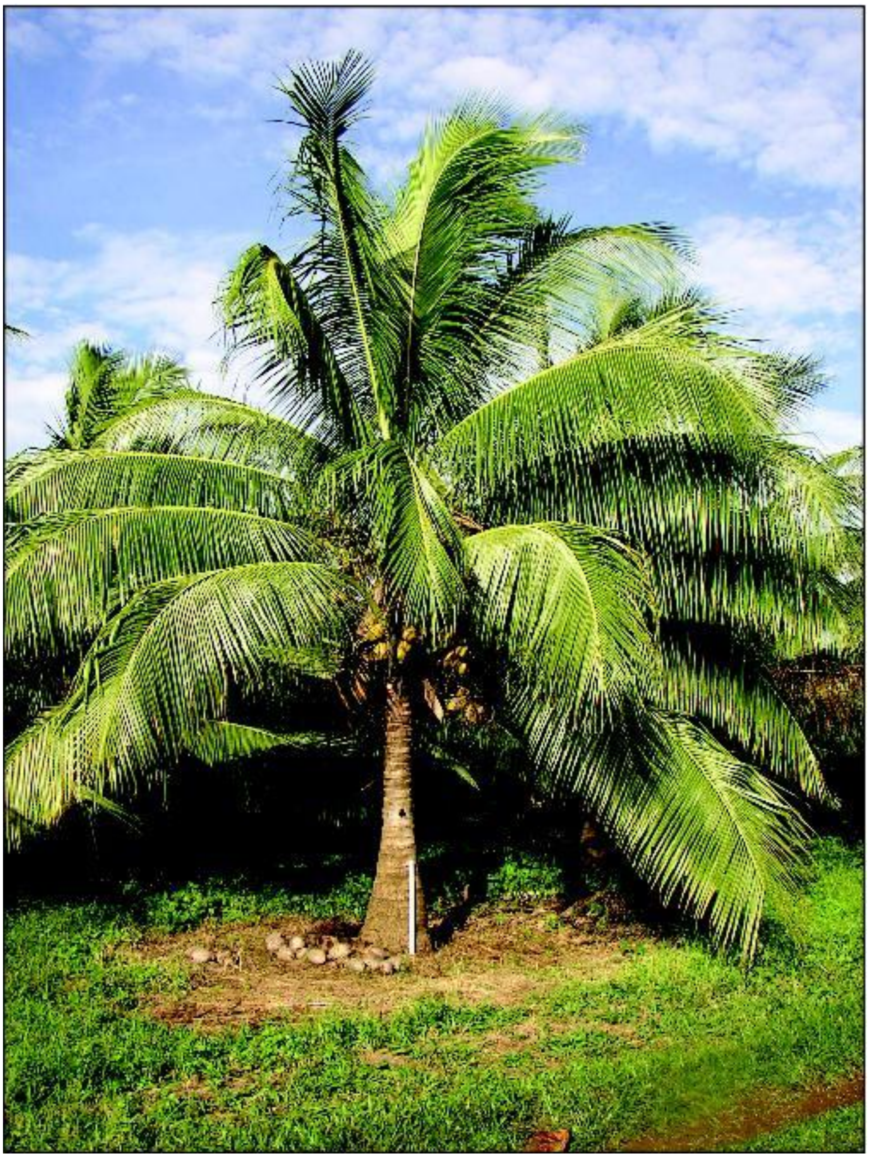

Figure 9 Nut yields per palm for the different VTT generations over time.