

Replanting/underplanting strategy for old coconut plantations in Papua New Guinea

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Auteur(s) : Jean OLLIVIER, W. AKUS, L. BEAUDOIN-OLLIVIER, X. BONNEAU, T. KAKUL, Cirad-CP, avenue Agropolis, TA 80/01, 34398 Montpellier Cedex 5, France.

Abstract: In most producing countries, the population of coconut palms is growing old, and ways of replacing them are rarely implemented to ensure that production is maintained and the future of the industry and its profitability are safeguarded. Rehabilitating/replanting coconut plantations and adopting appropriate intercropping systems is one of the main challenges to be taken up for the future of coconut in the Asia-Pacific region. The example of Papua New Guinea (PNG) reveals one of the lowest yields per hectare among the countries in the Asia-Pacific zone. Almost 106,000 ha were planted between 1910 and 1940, amounting to around 40% of the current coconut plantings, hence 80 to 100,000 ha can be expected to disappear in the next twenty years.

Faced with this forecast, the PNG Cocoa and Coconut Research Institute (PNG CCRI) launched several operations, beginning with the creation of a coconut research centre on the PNG mainland: examination of a replanting strategy for old coconut plantings, based on hybrid planting material, distribution of improved planting material through the creation of a seed garden, and development of a system for controlling pest populations in high-risk zones. The experiments set up at the station are designed to optimize the felling date for old coconut palms, by measuring the effects of competition with the underplanted hybrids, and to determine from an economic point of view the best strategy to be applied for implementing rehabilitation and/or replanting programmes in old coconut plantings.

This paper describes the results of these operations.

Key words: coconut, replanting, underplanting, pest control, rhinoceros, beetle.

Background data

Papua New Guinea (PNG) covers an area of 460,000 km² and has a population of almost 4 million inhabitants, 85% of whom are dependent upon agriculture. The coconut plantings are distributed along the coastal regions of the mainland and the islands. The main producing regions are located on the north coast of the mainland, extending from the western province of Sepik (near the Indonesian border) to Milne Bay province in the Southeast of the country, along with the provinces of the islands of Bougainville, New Ireland, New Britain and Manus.

Coconut is a very important crop for the coastal and island regions of PNG, given the income derived from the copra trade, but also through its use in the human and animal diet, construction materials or handicrafts. The main products exported are copra, coconut oil, presscake and fresh nuts. Smallholdings account for two thirds of the country's copra and coconut oil exports. In some regions of PNG, coconut is widely used as a shade tree for cocoa.

In recent years (1996-1999) production has fluctuated between 124,000 and 151,000 tons of copra, bringing in between US\$ 27 and 43 million, placing copra and coconut oil 4th in the league table of agricultural export products, after coffee, palm oil and cocoa.

Recent history of the coconut commodity chain in PNG

At the end of the 19th century, numerous plantations were launched in PNG and the copra industry developed and played a major role in the country's economic boom, accounting for up to 90% of the country's export earnings in 1920 [1].

In 1909, the area planted was estimated at 16,000 ha. Planting intensified between the two World Wars, bringing the total to 105,000 ha at the outbreak of World War II, for more than 80,000 tons of copra exports. After the war, coconut planting extended to smallholdings, bringing the current area to 260,000 ha.

One of the main characteristics of the coconut plantations is that they largely consist of unselected and

unimproved planting material, apart from a few estates. The development and success of hybrids on the islands, from 1973 onwards, remained highly relative, faced with substantial pressure from pests causing up to 100% mortality in young plantings [2]. Redevelopment of the coconut plantations therefore came to a standstill, pending the discovery of an effective control method able to keep down insect populations below an economically acceptable threshold.

The agronomy research and farming system programme, and a crop protection project funded by the European Union, based at CCRI, are examining possible ways of improving and diversifying income per unit area. At the same time as these field and laboratory studies, the distribution of improved planting material is being organized throughout the country.

Material and methods

Creation and dissemination of improved planting material

At the Omuru site, in the Madang province on the PNG mainland, the development of a seed garden led to the production of improved hybrid planting material, in an environment free from the pressure of the main pests. Fourteen hectares of Malayan yellow and red dwarfs are pollinated with Rennell Tall pollen.

Depending on orders, the seednuts produced are either dispatched throughout the country, or placed in nursery seed beds and transferred into polybags for marketing in seedling form.

Although seed transport is organized by the CCRI, freight costs, by land or sea, remain the responsibility of the purchaser. The distribution of planting material throughout the country from 1997, when hybrid production began, up to the end of 2000 is described.

Rehabilitation/replanting trial at the Stewart Research Station

Trial PNG-CCRI 804, set up in 1997 at the institute's research station, 40 km north of Madang, is located in a plot that was previously planted with cocoa trees (*Theobroma cacao*) in the 50s and 60s under the shade of old local tall type coconut palms planted in 1935, and *Leuceana*. Over the last ten years, the cocoa trees have disappeared through lack of upkeep, leaving a mixture of forest regrowth, *Leuceana*, bamboo and creepers growing up the coconut palms.

Land preparation consisted in manual felling of the regrowth in 1997. The plant debris was burnt on site, then the interrows were cleared of old coconut stems and other residues, which were placed in windrows down the old coconut rows. A *Pueraria phaseloides* cover crop was used to cover the surface of the trial. Lining for hybrid coconut planting (in treatments involving replanting) was carried out down the middle of the interrow of the old coconut palms, which were originally planted at 115 palms/ha. The hybrid seedlings were planted 7 m apart, to obtain a density of around 165 palms/ha. The same crop management sequences were applied in each treatment (cover crop, circle upkeep and localized chemical weeding).

*** Planting material**

The coconut hybrids, planted in December 1997, are Malayan Red Dwarf x Rennell Tall crosses produced by assisted pollination in the Omuru seed garden.

*** Soils and climatic conditions**

The trial was set up in the coastal plain, on a low alluvial terrace, near the bed of the current Rempi river. The soils are well drained, shallow (~ 50 cm) to moderately deep (50-90 cm) silty clay, overlaying a sandy clay horizon on sand and river gravel. The soil is classified as Typic Troporthent (USDA soil taxonomy) [3].

Climatic conditions at the Stewart station are highly favourable, with a mean annual rainfall of 3,533 mm [4]. The mean annual temperature is 26.5°C and can vary from an average 23.1°C for minimum temperatures to an average 30.0°C for maximum temperatures.

Rainfall recorded at the station since the trial was planted has been 3,021 mm per year (1997-2000 mean).

Experimental design

The experimental design considers three main treatments for old palm felling, compared to a control without replanting, with a fertilization or no fertilization subdivision for each treatment and the control.

The felling treatments are as follows:

P0: total felling of old palms at the time of hybrid replanting ;

P3: old palm felling deferred for 3 years after replanting ;

P6: old palm felling deferred for 6 years after replanting ;

C: control with neither replanting nor old palm felling.

The trial comprises five replicates chosen along a gradient established at the outset of the trial and based on the residual density of the old palms: replicate 1 has a low old palm residual density, and replicate 5 has a high old palm residual density.

Main treatments - Old palm felling

Felling in treatment P0 took place in December 1997. The palms were first poisoned by injecting 50 ml of a neat monosodium methylarsonate (MSMA) solution into the stem of each palm. Once the crown had disappeared, the stems remained upright and gradually rotted.

Felling in treatment P3 was carried out from July to November 2000, by sawing and chopping the lower section of the stem into 9 meter lengths for use as coconut wood.

Treatment P6 is scheduled for 2003

Fertilizer treatments

The young coconut palms receive (subdivision F1) or do not receive (subdivision F0) mineral fertilizers. The choice of fertilizers and rates applied is based on the initial results obtained in a reference fertilizer trial. Although applications in 1998 involved nitrogen (N), phosphorus (P), potassium (K), and chlorine (Cl), only N and Cl were used in subsequent years. The fertilizers were applied to the foot of the underplanted hybrids in treatments P0, P3, and P6, and in the middle of the interrow for C, the control.

Observations carried out

Leaf analysis

A leaf analysis was carried out in 1996 on a representative sample of the old palms (before the trial was set up), then in 2000 on the palms felled in plots P3. The underplanted hybrids were sampled in 1999 and 2000.

Observations of vegetative growth and production

Vegetative growth and flowering was monitored while the hybrids were young. Three variables were observed every six months: girth 20 cm from the ground (G), the number of fronds emitted in the six months between two inspections (NFE) and the length of frond rank 4, 9 or 14 (FL). Flowering was observed every 3 months, from the start of flowering.

On the old palms, the number of nuts produced has been recorded palm by palm every month from the start of the trial. The nuts are grouped by sub-plot, husked and the weight of split husked nuts is recorded.

Copra weight after drying is recorded at regular harvesting intervals, so that the ratio of copra weight to husked nut weight, without water, can be calculated.

Econometric measurements

Working time, hired labour costs and input costs were recorded between 1997 and 2000, covering trial set-up, the immature phase of the hybrids, but also production costs for the copra harvested from the old palms, thereby enabling an initial economic approach to the different strategies envisaged.

Daily working time was measured for all activities, and expressed as the number of days' work (man-days corresponding to 5 to 6 hours of effective work). Only work specific to dehusking in the field is paid according to output and based on split husked nut weight. The data expressed in Kinas (local currency) were converted into dollars taking a mean annual Kina-US\$ exchange rate.

Identification of a new technology for coconut pest control

Although the experiment described above is being carried out in a region where *Scapanes australis* damage is negligible, it should be remembered that some of the disseminated planting material will be subjected to severe pest pressure.

S. australis and *Oryctes rhinoceros* cause serious damage in the first ten years after coconut palms are planted out. Adults mine a gallery in which they feed, damaging the terminal bud and thereby adversely affecting the development of young coconut palms. This damage leads to the death of the palm, but it is exacerbated through attacks by *Rhynchophorus bilineatus* which are attracted by the smell of fermenting tissues, develop and speed up the death of the coconut palm.

These pests were responsible for the failure of several coconut development projects in the 80s [2]. They do

not always have disastrous consequences throughout their natural range. All three of them are a veritable threat in the island region (New Britain, New Ireland), where cocoa plantings under coconut have been extensively developed. On the mainland, where only *S. australis* and *R. bilineatus* are found, attacks remain slight and isolated.

The aggregation pheromone of *R. bilineatus*, 4-methyl-5-nonanol, is being tested in the field to trap weevil populations in New Britain [5]. The pheromone of *O. rhinoceros* has been identified [6, 7] and is being used in the field.

The launch of a European project in 1997 led to further knowledge of the biology and behaviour of *S. australis* in terms of its control using attractants. Isolation and identification techniques have made it possible to propose a control method for use at the time of coconut replanting and for the early years after planting, at the stage when coconut palms are highly susceptible to attacks by the insect. Biological tests, such as electroantennography and olfactometry, along with trapping in the field, have been used to assess the efficacy and appropriate doses of the molecules identified for insect trapping. These tools are being tested in the field to assess their effectiveness in pest trapping.

Results

Dissemination of improved planting material

As early as 1997, the first seednuts produced were dispatched to the provinces of West New Britain, Milne Bay, to the capital Port Moresby, and throughout the Madang province in which the seednuts were produced. In 1998 and 1999, requests for seednuts were received from five and three new destinations respectively. From 1998 to 1999, seednuts were sent out on average to eight clearly distinct provinces or regions.

The geographical distribution of the seednuts over the last three years is shown in [Figure 1](#). The figures indicate the will to develop coconut not only in zones at risk, in terms of pest pressure, but also in zones where these insect populations are virtually nonexistent.

The greatest demand comes mostly from the provinces of West New Britain, Morobe, the mining region of OK Tedi and Sepik province (22, 23, 13, and 19% of total seednut distribution, respectively). With an increasing production from 1998 onwards, the demand for, and distribution of, seednuts increased from 5,613 in 1997 to 53,934 in 1998, 65,974 in 1999 and 63,667 in 2000. Seedlings that have developed in the nursery are mostly sent out to Madang province, more exceptionally to Morobe, and very rarely to other destinations ([Figure 1](#)).

Replanting trial

*** Old coconut mortality**

The residual density of the old coconut palms at the beginning of the trial throughout the five replicates was 76.6 palms/ha, *i.e.* two thirds of the original density ([Table 1](#)). In view of the protocol adopted, this residual density varies from one replicate to the next, at around 60 to 86 palms per hectare for replicates 1 and 5, respectively. Depending on the zones, the old coconut palm density was therefore only half in the worst case (rep1) and three quarters in the best situation (rep5). Observations carried out between 1997 and 2000 revealed an average loss of 9 palms/ha throughout the trial, bringing the mean annual residual density in 2000 to 67.6 old palms/ha, *i.e.* under 60% of the original density. The loss of these old palms is obviously due to age; they are more susceptible to strong winds or storms, as the subsidence frequently encountered in old coconut plantings weakens their anchorage.

*** Young coconut mortality**

Treatment P3 caused the accidental death of three palms when old palms fell on them during felling; this amounted to a loss of under 1%. Another six hybrids also died while young, amounting to 0.5%.

*** Old coconut yields**

Old palm production amounted to 50 nuts/palm in 1998, 75 nuts/palm in 1999 and 55 nuts/palm in 2000, on average, throughout the trial ([Table 2](#)). The average weight per split husked nut was stable over the years: 569 g in 1998, 586 g in 1999 and 570 g in 2000. Taking a mean observed ratio for the trial of 28%, the weight of copra/palm/year was 8 kg in 1998, 12.2 kg in 1999 and 8.8 kg in 2000. The production recorded per ha was 601 kg of copra/ha in 1998, 878 kg/ha in 1999 and 600 kg in 2000. The number of nuts required per ton of copra is high and relatively stable from one year to the next, at around 6,100 to 6,300 nuts. No noticeable effect has been found between underplanted treatments P3/P6 and the control without

underplanting. Neither did the yield observations on the old palms reveal any effect of the fertilizers applied in the interrow and to the young palms.

* *Soil analysis*

The chemical analysis of these alluvial soils shows that they are rich in exchangeable bases, especially calcium and magnesium [8]. The soil analyses in 1999, when compared to those in 1993, reveal a drop in CEC but a better base saturation rate. There was a clear improvement in organic matter contents and in total nitrogen, the carbon contents on the surface horizon rose from 3 to 6% and total nitrogen increased from 0.3 to 0.5%. There was also a clear improvement in K contents, which rose from 0.88 to 2.88 meq/100 g, which could be explained by substantial returns to the soil when debris was burnt during the land preparation phase.

* *Leaf analysis*

Old palms

A comparison of the leaf analyses in 1996 and 2000 shows a clear increase in nitrogen contents from 1.71 to 1.91%, which confirms the soil analyses. Chlorine contents were satisfactory, suggesting that the root systems of old coconut palms located on a low terrace near the sea are sufficiently developed to reach the saline water table, as there is no atmospheric contribution.

Young palms

The main result is a spectacular increase in the chlorine (Cl) levels, revealing very good uptake of this element by young palms. The differences in Cl contents are significant: 0.051% (F0) to 0.242% (F1) in 1999 and 0.082% (F0) to 0.317% (F1) in 2000. The nitrogen levels in 1999 were slightly better with the urea applications: 1.96% (F0) to 2.05% (F1), but this difference was no longer significant in 2000.

However, the 2000 results confirmed the effect of the main treatments on N contents, with an advantage for P0 (1.93%) over P3 (1.79%) and P6 (1.76%).

* *Growth and flowering of young palms*

The variables observed during the immature phase of the coconut palms improved with the mineral fertilizer applications over the first three years ([Table 3](#)). The number of fronds emitted over the first three years amounted to 39.2 for F0 as opposed to 41.4 for F1. In 2000, a slight significant effect between main treatments was found for frond length: 506 cm for P0 as opposed to 491 cm and 492 cm for P3 and P6, respectively. The number of fronds emitted in the first three years revealed a slight decline in the treatments in which the old coconut palms were present: 39.3 fronds for P3 and 39.8 for P6, as opposed to 41.8 fronds in treatment P0.

The precocity of the underplanted hybrids was improved by the fertilizer applications ([Figure 2](#)). While F1 was seen to have an advantage over F0 26 months after planting, albeit not significant, it became highly significant at 29 and 32 months, and remained significant at 35 months.

At 35 months, the great majority of palms were flowering, but the main treatments were found to have an effect: P0 (98.9%) was significantly different from P6 (92.7%) and it will therefore be interesting to see whether this is confirmed by young palm yields, in which case treatment P3 could be judged to be more favourable than P6 from an agronomic point of view. This point will need to be validated from an economic point of view.

* *Economic results - Rehabilitation costs*

The cost of rehabilitation/replanting per hectare over the first three years (1997-1999) amounted to US\$ 746 if the old palms were kept and to US\$ 795 if the palms were poisoned, as opposed to only US\$ 422 for rehabilitation alone. The fertilization applied (two years of application) cost US\$ 120/ha [9].

The income recorded from copra sales over the three years considered varied, depending on the plots, from US\$ 134 to 695. The lowest income was recorded for P0 plots (\$ 134 to 238), where palm poisoning in the second year resulted in no income in the following two years. In plots where the old palms were kept throughout the period, large disparities were recorded in plots where the residual densities were lowest, and the highest income was recorded where the residual densities were highest.

The substantial variability in the size of the nuts harvested from the old palms, which was linked to genetic determinism, and doubtless to the physiological age of the palms, explained the high number of nuts used per ton of copra, at around 6,200 over the last two years. This factor is very important in terms of work load and of the cost of nut processing. A comparison with the results observed for young D x T hybrids, for

which only 4,500 nuts are required per ton of copra, further vindicates the replacement of old palms by hybrids with 30% higher copra per nut (Ollivier, unpublished).

The cost of nut collection and processing is very high in this trial, amounting to US\$ 170 per ton of copra on average. This cost is largely linked to collection costs, which are all the higher in that harvesting is carried out monthly and the area covered to collect the number of nuts required for one ton of copra is large. On average, it is around 14.1 ha for a residual density of 68.5 palms per ha. Depending on residual density, collection costs per ton of copra vary from \$ 60 to 143. The large number of nuts required for a ton of copra (6,200 nuts) has consequences for the cost of drying, turning the split nuts in the dryer, shelling and bagging.

Taking salaried work into consideration, the profits made over the 3-year period varied between +\$ 174 (in the best case) to -\$ 142 (in the worst case). The best situations were found with high residual densities and no fertilizer applications. The worst situations were due to old coconut poisoning and fertilizer applications, whose cost remained prohibitive under the conditions in PNG.

If work costs are not taken into account, the turn-over minus transport costs would lead in most cases to a profit that covers the cost of seedling, cover crop seed and herbicide purchases needed for replanting. However, a cash-flow advance may possibly be necessary.

* *Existence of a pest control tool*

Attacks by *Scapanes*, *Oryctes* and *Rhynchophorus* pests are a real threat in the island region in young replantings. [Figure 1](#) shows the zones at risk where the pest(s) is (are) present, but where attacks remain isolated or only slight. In *Scapanes*, it has been seen that the male has a signalling behaviour at nightfall. During this typical signalling activity, the insect emits a substance attractive to members of both sexes. This substance is a mixture of 2-butanol, acetone (3-hydroxy-2-butanone) and 2,3-butanediol, but only the first two compounds are required in a ratio of 90:5 to produce an aggregation pheromone.

A trap has been developed by CCRI for capturing *Scapanes* males and females. Mass trapping results are encouraging in terms of the number of insects caught from April 1998 to January 2000 ([Figure 3](#)).

In order to optimize the trapping of the three pests, an original type of trap is undergoing field tests; it consists of a PVC tube (dia. = 16 cm, H = 2 m) containing dispensers with *Oryctes*, *Scapanes* and *Rhynchophorus* pheromones, along with plant matter acting as a synergist. Given its depth, the trap effectively retains the three insect species who cannot escape ([Figure 4](#)).

Discussion

In the first three years, competition between young and old coconut palms is not significant and suggests that the two populations can exist side by side without any apparent damage to either young coconut growth or old coconut yields. However, it remains to be shown how long this situation lasts. In Tanzania, under very different conditions (low rainfall, sandy soils) [10] the competitive action of adult Tall palms (age not specified) was demonstrated with respect to young underplanted palms, which was likely to substantially reduce the performance of the young palms. It is obvious that each situation is specific and responses will depend on the conditions encountered.

From an economic point of view, in the trial described in this paper, it is clear that treatment P0 is the least successful model, since it rules out any income for three years. Although it slightly improves the growth and precocity of young palms, it is not very likely that the effect will be strong and sustainable enough to compensate for the income losses over the first three years. However, things could be different if there were a lucrative market for coconut wood, or in the case of high insect pest pressure on the coconut palms, making poisoning difficult to apply due to a considerable threat to the new plantings.

Yields from the old palms in P3 and P6 were no different from those of the control, suggesting that local agricultural and ecological conditions temporarily allowed a high palm density per hectare (at least during the 3-year observation period), which varied depending on the replicates from 222 to 249 palms/ha.

Short-term action seems essential for optimizing the use of land occupied by the old coconut palms, especially when the land offers suitable conditions in terms of infrastructures and market access.

In some zones, such as the islands, land occupation pressure is high and the possibility of extending cultivation is limited if not nil. In this case, replanting strategies and techniques become relevant. Moreover, replanting is a very effective way of protecting the environment and natural resources, by using existing infrastructures and limiting plantation extensions on newly cleared forest. On the other hand, total replanting is out of the question for smallholdings, where farmers are often against felling coconut palms so long as they are still yielding, and where only lightning or senility may possibly lead to felling [11]. Deciding on the

right time to replant greatly depends on various factors: variety, residual density, productivity and condition of the palms. As the tendency is to replace old Tall palms with more precocious and higher yielding D x T hybrid varieties, the density should often be higher than in the original design. This leads to a conflict in the planting layout, but it can be solved, as shown in our trial, or as described as "strip replanting" in the Philippines [12].

Whilst the poisoning solution offers numerous advantages, it cannot be applied everywhere. In some regions, rotting coconut wood left standing can provide larva sites for the dynastid beetle (*Oryctes* spp.), resulting in outbreaks that cause substantial damage in young plantings, but also in the neighbouring adult palms [13]. However, the discovery and testing of new tools, such as trapping, and the enthusiasm reflected in the growing demand for improved planting material since 1997 show that the constraint associated with pests no longer seems to be a limiting factor for the redevelopment of coconut cultivation.

Using part of the stem from old coconut palms for conversion into coconut timber is feasible and the experiment (conducted in July 2000 in treatment P3 of the trial) showed that felling old coconut palms does not cause any major damage to young underplanted palms (Ollivier, unpublished).

Conclusion

Although coconut replanting is not an urgent problem for smallholdings, it will become so in the medium term, and it is already so for the old colonial estates set up before World War II, which are tending to be redistributed to smallholders.

The main purpose of the trial described in this paper is to serve as a guide for a rehabilitation and replanting strategy in the old coconut plantations of PNG. Under the trial conditions, resumption of upkeep and restoration of nitrogen fertility by planting a legume cover crop made it possible to maintain good yields in the old coconut palms. Underplanting with high-yielding hybrid coconut palms is an attractive way of rehabilitating old plantations. The growth of young underplanted palms does not seem to be affected by competition from the old palms, especially in the first two years of growth. This enables producers to continue harvesting copra and to maintain their income, whilst safeguarding the future by setting up a young coconut planting which should generate more income.

The distribution of planting material throughout the different provinces in the country reveals that growers have regained their confidence. The creation of the Cocoa Coconut Extension Agency in 1998 made it possible to widely publicize the actions undertaken, so as to encourage coconut rehabilitation in PNG.

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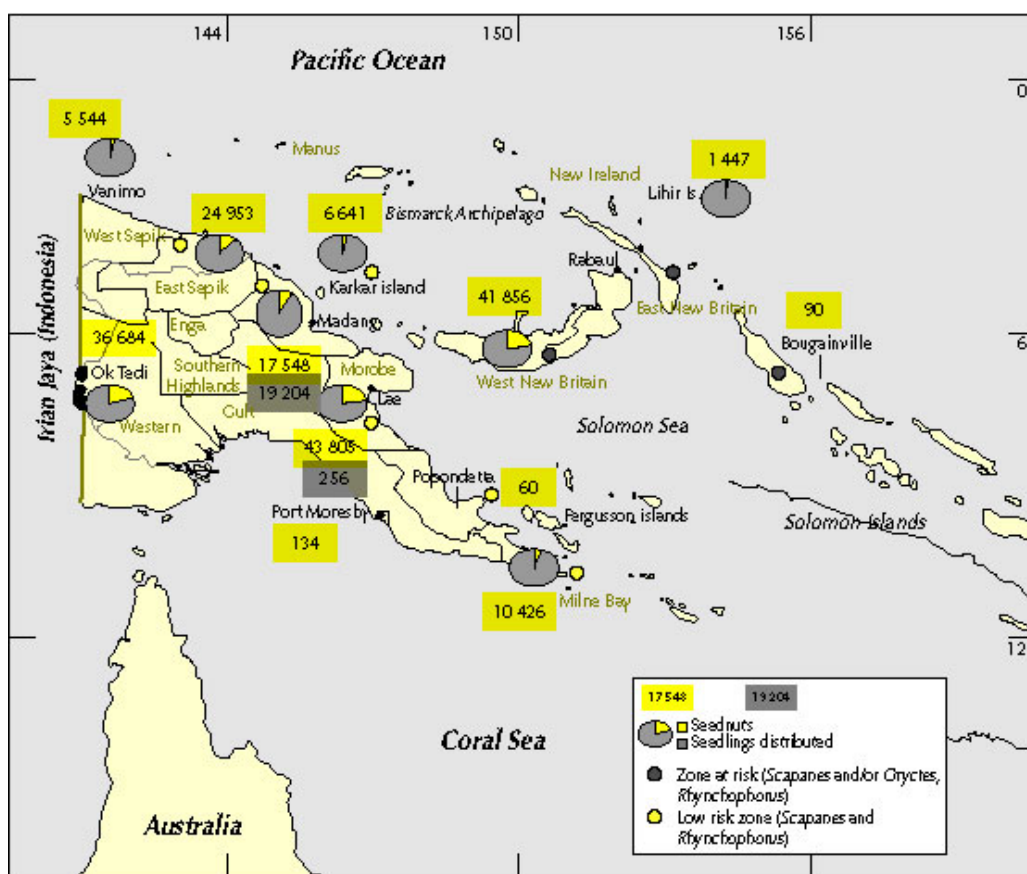


Figure 1. Dissemination of improved planting material from 1997 to 2000.

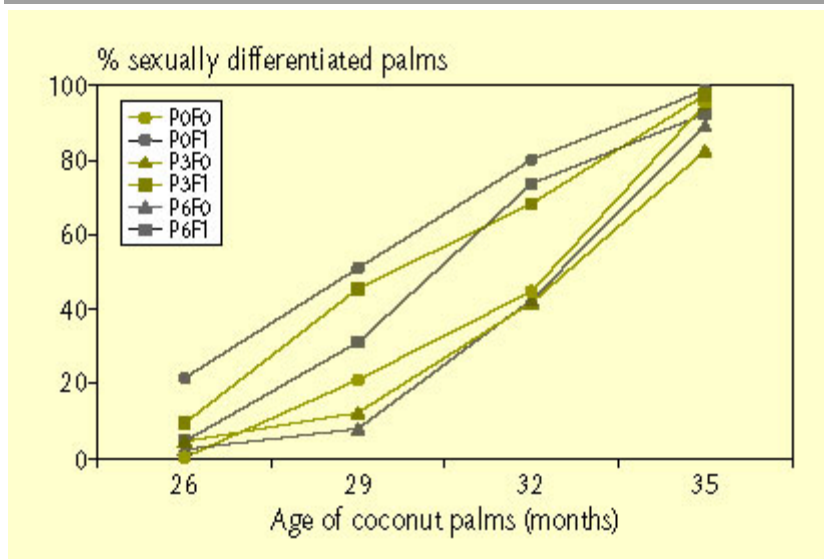


Figure 2. Trial PN CCRI 804 - Sex differentiation.

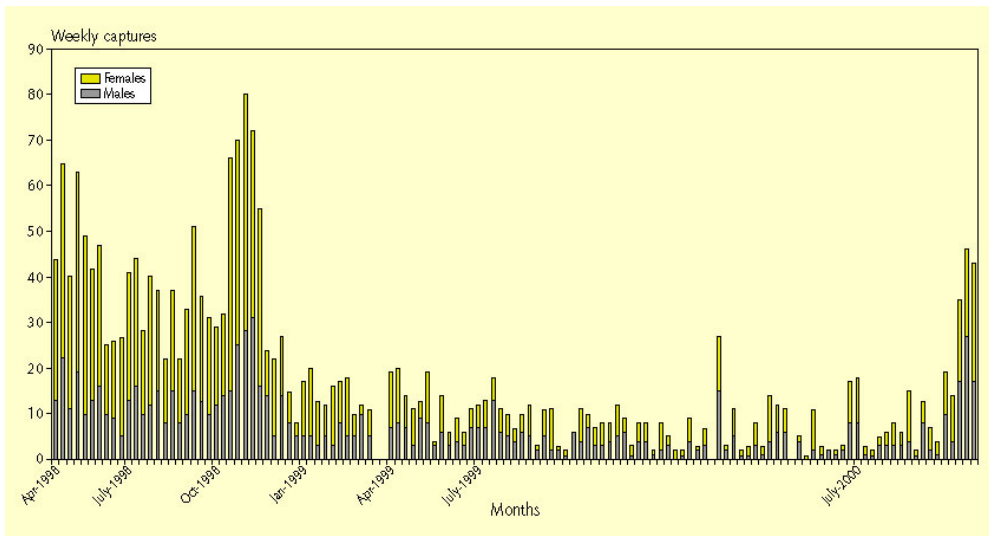


Figure 3. *Scapanes australis* captures at the Tavilo estate ENBP, PNG-CCRI, from April 1998 to October 2000.

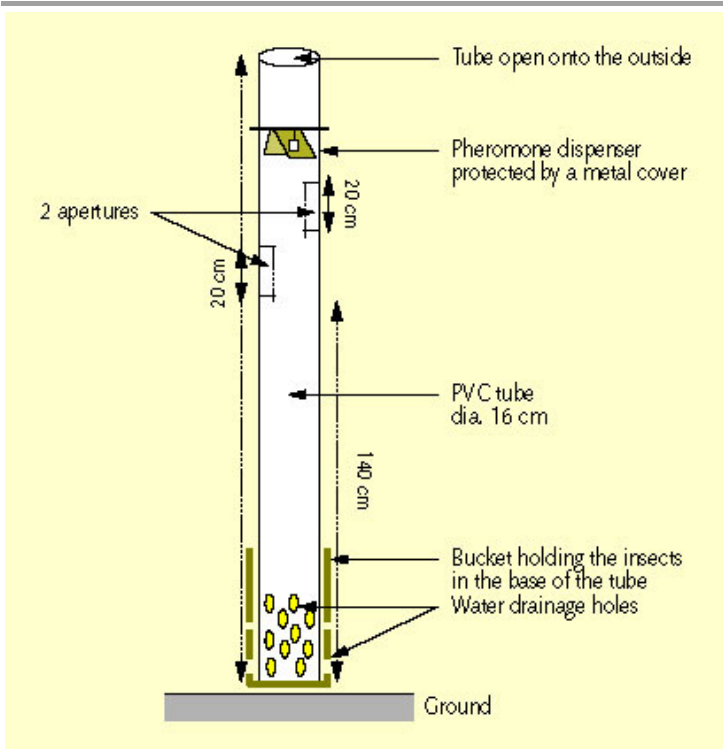


Figure 4. Prototype trap developed by CCRI for *Oryctes rhinoceros*, *Scapanes australis* and *Rhynchophorus bilineatus* capture.



Photo. Aerial view of a replanting trial at the Stewart Research Station. July 2000 (Acknowledgement : J. Ollivier).

Table 1. Residual density observed in December 1997 then in February 2000 expressed as the number of palms/ha (residual: origin ratio).

| Replicate | 1 | | 2 | | 3 | | 4 | | 5 | | 1-5 | |
|---------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | 1997 | 2000 | 1997 | 2000 | 1997 | 2000 | 1997 | 2000 | 1997 | 2000 | 1997 | 2000 |
| Maximum resid.: origin ratio | 70.7 61.5 | 66.8 58.1 | 86.4 75.1 | 82.5 71.7 | 90.3 78.5 | 32.5 71.7 | 94.3 82.0 | 86.4 75.1 | 94.3 82.0 | 90.3 78.5 | | |
| Minimum resid.: origin ratio | 39.3 34.2 | 35.3 30.7 | 66.8 58.1 | 53.9 51.2 | 74.6 64.8 | 58.9 51.2 | 66.8 58.1 | 55.0 47.8 | 74.6 64.8 | 70.7 61.5 | | |
| Mean resid.: origin ratio | 60.2 52.3 | 49.8 43.3 | 75.3 65.5 | 63.1 59.2 | 80.5 70.0 | 39.7 30.6 | 83.8 72.9 | 75.3 65.4 | 85.8 74.6 | 79.9 69.5 | 76.6 66.6 | 68.5 59.3 |

Original density: 115 coconut palms/ha.

Table 2. Production of old coconut palms in kg copra/ha depending on replicate – 1997 to 2000.

| Replicate | 1 | | | | 2 | | | | 3 | | | | 4 | | | | 5 | | | | 1-5 | | | |
|------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|
| | 1997 | 1998 | 1999 | 2000 | 1997 | 1998 | 1999 | 2000 | 1997 | 1998 | 1999 | 2000 | 1997 | 1998 | 1999 | 2000 | 1997 | 1998 | 1999 | 2000 | 1997 | 1998 | 1999 | 2000 |
| Number nuts/palm | 49.0 | 73.0 | 56.2 | | 46.6 | 76.3 | 54.9 | | 52.1 | 79.9 | 47.1 | | 53.8 | 72.6 | 62.7 | | 49.2 | 72.0 | 54.7 | 56.3 | 50.1 | 74.7 | 55.1 | |
| Copra/ nut (g) | 168 | 178 | 162 | | 154 | 158 | 159 | | 160 | 168 | 163 | | 153 | 154 | 160 | | 161 | 160 | 153 | 161 | 159 | 164 | 159 | |
| Copra/ palm (kg) | 9.1 | 8.2 | 13.0 | 9.1 | 8.6 | 7.2 | 12.0 | 8.7 | 9.5 | 8.3 | 13.4 | 7.7 | 9.0 | 8.2 | 11.2 | 10.0 | 8.8 | 7.9 | 11.5 | 8.4 | 9.06 | 7.97 | 12.25 | 8.76 |
| Density/ha* | 60.2 | 57.9 | 53.4 | 49.8 | 75.3 | 74.6 | 71 | 68.1 | 80.5 | 77.2 | 73.6 | 69.7 | 83.8 | 82.5 | 79.5 | 75.3 | 85.8 | 84.8 | 81.2 | 79.9 | 76.6 | 75.4 | 71.7 | 68.5 |
| Copra/ ha | 549 | 477 | 694 | 453 | 648 | 535 | 856 | 592 | 762 | 643 | 988 | 537 | 756 | 679 | 922 | 753 | 759 | 676 | 935 | 671 | 694 | 601 | 878 | 600 |
| Nuts/ton copra | | | | | | | | | | | | | | | | | | | | | 6,211 | 6,289 | 6,097 | 6,289 |

* Mean residual density observed over the year.

Table 3. Growth results for young palms (fertilization subdivision).

| Date | Age (months) | G F0 | G F1 | NFE F0 | NFE F1 | LF4 or LF9 (> 12/99) F0 | LF4 or LF9 (> 12/99) F1 |
|-------|-----------------|---------|---------|-----------|-----------|----------------------------------|----------------------------------|
| 12/97 | 0 | 22.2 | 21.8 | (6.7) | (6.7) | | |
| 06/98 | 6 | 30.9 | 38.5** | 3.7 | 4.6** | 263 | 259 |
| 12/98 | 12 | 49.2 | 65.4** | 4.7 | 5.0** | 270 | 316** |
| 06/99 | 18 | 102.0 | 114.0** | 6.7 | 7.1* | 391 | 416** |
| 12/99 | 24 | 128.8 | 139.5 | 7.3 | 7.7** | 476 | 499** |
| 05/00 | 29 | n.m. | n.m. | 8.7 | 8.9** | n.m. | n.m. |
| 12/00 | 34 | 128.8 | 139.5 | 8.1 | 8.1 | 492 | 501* |

G: girth; NFE: number of fronds emitted; LF4/9: length of frond rank 4/9; n.m.: not measured.

* Significant at 5% limit. ** Significant at 1% limit.