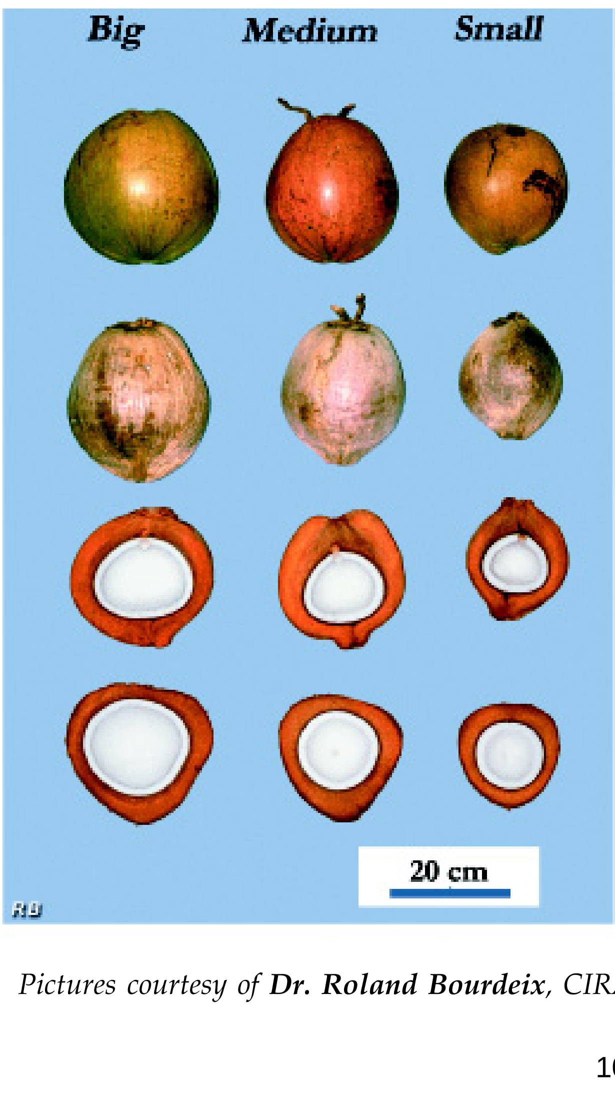
Thailand Tall (THT)









Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

Chapter 2
Other experiences related to coconut hybrid development

- Results of hybrid production by CIRAD and its partner institutions
- Results of coconut hybrid trials by United Plantation Sdn Bhd, Malaysia
- Performance of coconut hybrids in selected countries of Asia, the Pacific, Africa, and Latin America: Their potential for increasing farm productivity

Coconut hybrids developed by CIRAD and its partner institutions

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Introduction

The French Agricultural Research Centre for International Development (CIRAD) has been strongly involved in coconut breeding research activities for more than 50 years. During this period, CIRAD had collaborated with the major coconut growing countries and organizations, which include:

- National Agronomic Research Centre, Marc Delorme Coconut Station, Côte d'Ivoire
- Vanuatu Coconut Research and Training Center, Santo, Vanuatu
- Philippine Coconut Authority, Philippines
- Brazilian Agricultural Research Corporation, Brazil
- Cocoa and Coconut Research Institute, Papua New Guinea
- Chumphon Horticultural Research Centre, Thailand
- Research Institute for Coconut and Palmae, Indonesia
- National Coconut Development Programme, Tanzania
- Dong Go Experimental Station, Oil Plant Institute of Vietnam, Vietnam
- Taveuni Coconut Centre, Fiji
- Wenchang Coconut Research Institute, China
- Oil Palm Research Institute, Coconut Research Programme, Ghana

With these institutions, coconut breeding programmes and genetic field experiments have been conceived and implemented in partnership with CIRAD. Collaboration between CIRAD and these organizations span from five to more than 50 years.

Major hybrids developed

Although CIRAD has developed many coconut hybrids, nine of the more popular hybrids were selected and described here based on their adaptation performance and the extent of their dissemination and use in different countries of the world. The nine hybrids featured here include: PB121 or Mawa (MYD x WAT) and its improved variant PB121+; PB113 or Camren (CRD x RIT); PCA 15-2 or Matag (MRD x TAG); Maypan (MYD/MRD x PNT); CRIC 65 (SLT x PGD); PB133+ or Maren+ (improved variant; MRD x RIT); PB213+ or Waren+ (improved variant; WAT x RIT); PB214+ (improved variant; WAT x VTT); and PB332 (MYD x MRD). Table 1 summarizes the yield and fruit characteristics of these nine hybrids, all of which were evaluated in Côte d'Ivoire at the Marc Delorme Coconut Station over a period of more than 30 years. It should be noted that the yield estimates of these hybrids were obtained under medium to good agronomic conditions prevalent in the coastal region of Côte d'Ivoire and incorporating good field management practices like planting of a cover crop (usually a leguminous plant), application of 1 kg of fertilizer per palm per year on average, and weeding twice a year.

Five of the nine hybrids have been improved by individual combining ability progeny test. These second-generation improved hybrids are usually 15% - 30% more productive than the original, first generation hybrid. In Table 1, PB121 is used as the reference or base hybrid for comparison as it was the very first hybrid developed by CIRAD and widely distributed and planted in many coconut producing countries. Presently, CIRAD in Côte d'Ivoire produces only second generation improved hybrids which yield 15% - 20% more than the original PB121.

Each of the hybrids featured herein are individually described as to their parentage, morphology, yield and other characteristics, along with catalogue pictures that illustrate their morphology. The text and pictures of these hybrids were extracted from an upcoming book entitled "Handbook of coconut cultivars" by R. Bourdeix, J.L. Konan and Y.P. N'Cho. Most of the pictures were taken at the Marc Delorme Research Centre in Côte d'Ivoire, while others were taken in Jamaica, Sri Lanka and Vanuatu.

Table 1. Estimated yield and fruit characteristics of the nine hybrids produced by CIRAD in Côte d'Ivoire

	PB 121 or Mawa (MYD x WAT)	PB 121+ or Mawa+ (improved) (MYD x WAT)	PB 113+ or Camren+ (improved) (CRD x RIT)	PCA 15-2 or MATAG (MRD x TAGT)	Maypan (MYD or MRD x PNT)	CRIC 65 (SLT x PGD)	PB133+ or Maren+ (improved) (MRD x RIT)	PB 213+ or Waren+ (improved) (WAT x RIT)	PB 214+ (improved) WAT x VTT	PB 332 (MYD x MRD)
Recommended planting density (palm per ha)	160	160	160	160	160	160	160	143	143	210
First flowering (years)	3	3	3	3	3	3	3	4	3-4	2-3
First nut harvest	4	4	4	4	4	4	4	5	4-5	3-4
Nut size	Medium	Medium	Medium	Big	Big	Medium	Big	Big	Medium	Small
Nut colour	Green to brown	Green to brown	Brown	Brown to green	Green to brown	Green to brown	Brown	Brown	Green to brown	Yellow-red
Nuts per palm	130	150	120	95	100	110	110	120	150	125
Yield (nuts per hectare/year)	19 760	22 800	18 240	14 440	15 200	16 720	16 720	16 302	20 378	24 938
Copra per nut (g)	200	210	250	280	250	230	280	270	200	185
Copra per palm (kg)	26	32	30	27	25	25	31	32	30	23
Copra per hectare/year (tons)	4.0	4.8	4.6	4.0	3.8	3.8	4.7	4.4	4.1	4.6
Weight of whole fruit (g)	1000	1000	1250	1500	1300	1100	1420	1400	900	1000
Weight of whole nut (g)	650	700	900	1150	1000	730	1050	1000	600	700
Weight of husk (g)	350	300	350	350	350	370	370	400	300	300
Weight of shell (g)	150	150	170	180	170	170	210	220	150	150
Weight of meat (g)	350	380	440	550	460	390	490	450	340	360
Fruit quality (%)	24	25	26	26	26	25	26	25	25	23

Note: *Fruit Quality = Weight of copra ÷ (Weight of husk + Weight of shell + Weight of fresh albumen) * 100*

PB 121 or Mawa (MYD x WAT)

Coconut hybrid PB 121 is a cross between the Malayan Yellow Dwarf (MYD), used as the female parent, and the West African Tall (WAT) as the male parent. The name Mawa is derived from the contractions of its parent varieties: "Ma", which stands for Malayan, and "wa", for West African. This hybrid was created in Côte d'Ivoire in 1962 and has become the most widely used improved variety in the world. By 1985, it was already being grown in more than 40 countries.

The fruits, usually medium in size, weigh from 900 to 1200 grams (990 grams on average). The inner nut weighs from 600 to 750 grams and contains oil-rich meat varying in weight from 320 to 380 grams. In estates, it is rare for copra weight (dried kernel) to exceed 200 grams per fruit. In research stations, copra weight varies from 190 grams to 240 grams. The copra has a high oil content of around 65%.

PB 121 serves as the reference hybrid in most coconut hybrid trials. Under suitable growing conditions, it usually starts bearing four years after planting and produces 80 to 220 fruits before the end of the 6th year. Mature palms produce from 3.5 to 4.5 tonnes of copra per hectare (or 130 to 170 nuts per palm) at a density of 160 palms per hectare. In Côte d'Ivoire, estates belonging to the former Palm Industrie Company made it possible to compare the production of 4000 hectares of WAT palms with 12 500 hectares of hybrids (with 90% PB 121) spread throughout the country on highly variable soils. From 1985 to 1990, the hybrids produced an average of 2.4 tonnes of copra per hectare, compared to only about 1.5 tonnes per hectare for the WATs.

PB 121 adapts well to a wide spectrum of farm conditions and is relatively tolerant to water stress. Yet the introduction of PB 121 in some regions of Indonesia and the Philippines failed because of two reasons: (1) a substantial number of the hybrid succumbed to a fungus of the genus *Phytophthora*, especially in the plantations; and (2) farmers considered the nuts too small to have significant economic value. In Indonesia and the Comoro Islands, PB 121 remains greatly appreciated for the production of toddy, a fermented drink made from coconut palm sap obtained by binding and tapping the inflorescence.

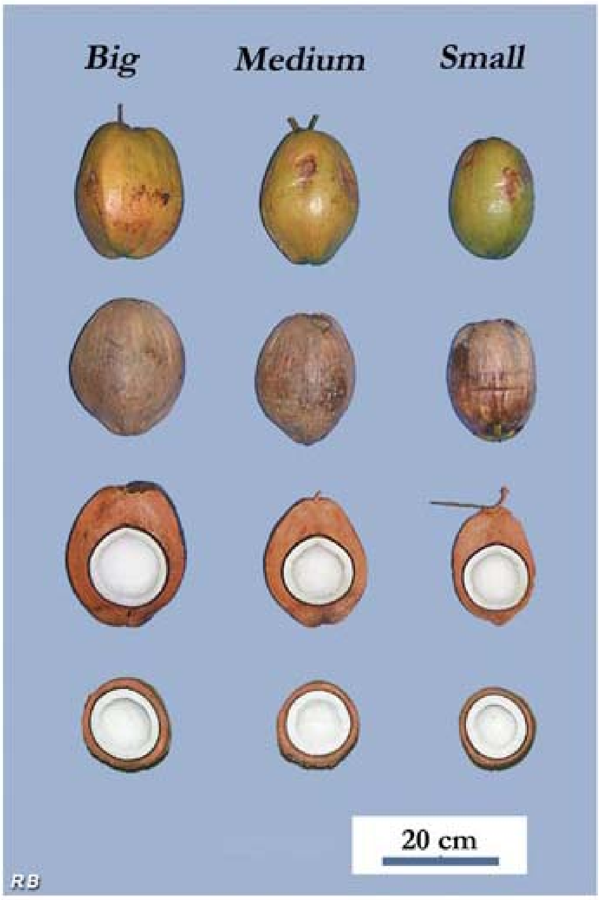
Up until 1995, PB 121 distributed from Côte d'Ivoire was derived from two populations: around a hundred WAT male parents were used in a mixture to pollinate several thousand MYD female parents. It was therefore impossible to precisely determine the "father" of each hybrid, since an entire population had been used as the male parent. However, not all the palms in a population are genetically similar and their progeny does not have the same value. Half-sib families, each made up of a single WAT male and several MYD females, were compared with a view to improving PB 121. The results of those experiments were highly encouraging, with the best half-sib families producing well over average yields. In addition, some males transmitted tolerance of certain diseases to their progenies, such as nut-fall caused by *Phytophthora*.

The Marc Delorme Research Station currently distributes an "improved" PB 121 (PB 121+) which is 15% to 20% more productive. Yields exceeding 5.5 tonnes of copra per hectare have been achieved at research stations, although only an average of 3.5 tonnes of copra per hectare have been recorded in Côte d'Ivoire farmers' fields.

Morphological Description

The slender stem, which has a discreet bole, displays rapid vertical growth similar to that of its Tall parent (WAT). Its very dense, circular crown contains a large number of fronds. Immature fruits are mostly yellowish green, but there are also various shades of brown. This hybrid produces a large number of oblong fruits, without marked ridges and containing an almost round nut with thick meat.

PB 121 Hybrid



Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

Hybrid PB 113 or Camren (CRD x RIT)

Coconut hybrid PB 113 was developed in Côte d'Ivoire in 1971 by crossing the Cameroon Red Dwarf (CRD) with the Rennell Island Tall (RIT). The name "Camren" comes from the contraction of the hybrid's two parent varieties - "Cam" for Cameroon and "Ren" for Rennell.

Seednuts harvested from the CRD female parent quickly dry out as they receive little protection from their thin husk and shell and therefore precautions have to be taken to prevent this. Their germination is also slow.

Under suitable planting conditions, PB 113 starts bearing four years after planting. It can produce more than 200 fruits before the 7th year. Yields, which are sometimes erratic on immature palms, subsequently achieve a high level. Irregular annual production have also been observed; for instance in just one plot, 134 fruits have been harvested per palm at 9 years, 87 fruits at 10 years, 119 at 11 years and 88 at 12 years.

The hybrid's fruits weigh from 1.1 to 1.3 kg on average depending on the plots. Its nuts weigh from 800 to 1000 grams and contain 400 to 480 grams of meat, which produce 230 to 260 grams of moderately oil-rich copra.

An improved variant of this hybrid was launched in Côte d'Ivoire in 1981. Over the 9- to 11–year period, the best progenies identified produced 4.8 tonnes of copra per hectare per year, or 12% more than the average yield of reference hybrid PB 121 which only produced 4.1 tonnes. These record figures should not be extrapolated to field-growing conditions, which are often less suitable, but the relative differences between the different crosses tested are expected. Yields of three to five tonnes of copra per hectare can be expected (i.e., 80 to 130 fruits per palm per year) for improved hybrids grown appropriately on suitable soils.

For harvesting, some producers merely wait for the coconuts to fall while others climb to pick them by hand. A more common way to harvest them without climbing is to use a long pole (usually bamboo) with a sharp metal hooked knife attached to one of its ends. The bunch stalk is cut and the bunch falls to and breaks up on the ground. PB 113 is one of the easiest hybrids to harvest as its vertical growth is generally slow and, in particular, its long bunch stalks can easily be reached and cut with the hooked knife.

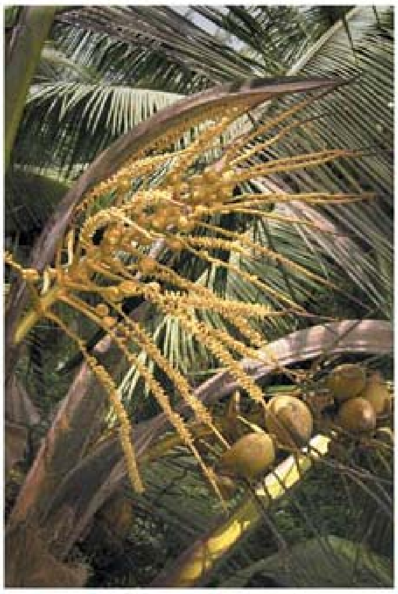
Husking is often done manually using a pointed metal or hardwood stake embedded in the ground, with the sharp tip pointing upwards. For PB 113, husking is quite tricky as the husk is so thin that the husking spike sometimes pierces the shell and damages the nut.

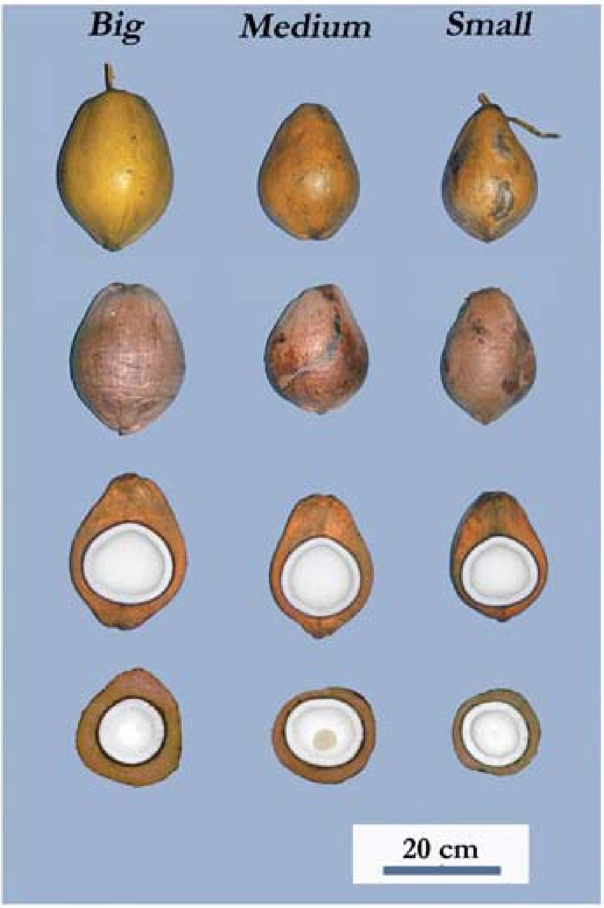
Like other CRD hybrids, PB 113 demands high levels of magnesium. Its nuts are fairly susceptible to bug attacks and rodents could easily pierce the thin-husked nuts. On the other hand, its RIT parent transmits good tolerance to nut-fall caused by fungi of the genus *Phytophthora*, but also transmits a degree of susceptibility to drought.

Morphological Description

Its long-stalked bunches and highly rectilinear leaflets, inherited from its Dwarf parent, render it certain elegance. The stem is slender with a slightly broader bole than PB 121. Its predominantly reddish-brown, pear-shaped fruits are not much larger than those of PB 121 on average, but their composition is much better. They sometimes bear the typical nipple of RIT fruits at their tip. The inner nut is round and is generally larger than that of PB 121, although with slightly thinner meat.

PB 113 Hybrid





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PCA 15-2 or Matag (MRD x TAGT)

PCA 15-2, or Matag, is a cross between the Malayan Red Dwarf (MRD) and the Tagnanan Tall (TAGT). The hybrid was developed by the Philippine Coconut Authority, therefore the PCA in the hybrid's name. The term "Matag" comes from the contraction of the names of its parent varieties: "Ma" for Malayan and "tag" for Tagnanan. Presently, in some countries like Malaysia, the Malayan Yellow Dwarf (MYD) is used as the female parent, chosen because of its availability in that particular country and the colour of the fruits produced by the crossing. This hybrid was first planted in 1979 in the Philippines and in Côte d'Ivoire.

Matag starts bearing five years after planting. Yields remain slightly lower than those of PB 121 up to around 10 years, after which it starts bearing more than the reference hybrid PB 121. In terms of cumulative yields, PCA 15-2 only overtakes PB 121 around the 13th year after planting. However, it should be noted that this comparison is based on the first generation PB 121, which has since been improved in Côte d'Ivoire.

The fruits weigh from 1300 to 1700 grams. The inner nut is round and usually weighs over a kilogram and gives 500 to 600 grams of moderately oil-rich meat. The copra weight per fruit fluctuates between 260 and 320 grams.

In Côte d'Ivoire, production peaks of 6.1 tonnes of copra per hectare (around 150 fruits per palm) have been recorded at 10 years at a planting density of 160 palms per hectare. In Malaysia, yields of more than seven tonnes have been reported— a world record of some sort. However, these figures should not be extrapolated to true growing conditions, which are often less suitable. Yields of around 3 to 4 tonnes of copra per hectare per year can be expected (or 70 to 90 fruits per palm).

Several fungi of the genus *Phytophthora* cause either bud rot, which kills the coconut palm, or nut-fall, which reduces yields without killing the palm. Only the second symptom occurs at the Marc Delorme Research Station in Côte d'Ivoire. PCA 15-2 displays little susceptibility to nut-fall with only 1% fruit losses at 10 years, as opposed to 14% for hybrid PB 121. However, in the Philippines, where coconut palms are killed by *Phytophthora*, PCA 15-2 seems to be more susceptible with mortality rates of up to 14% being recorded.

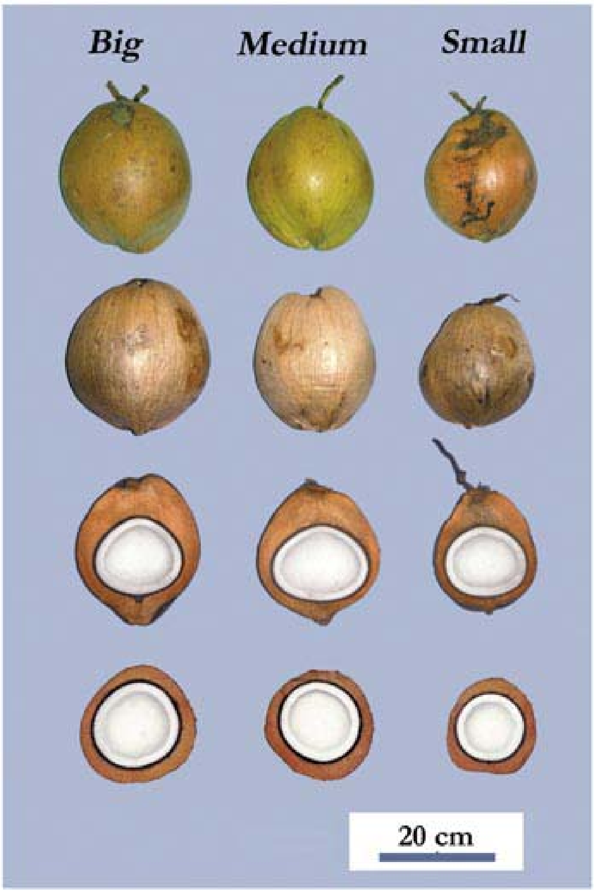
Tagnanan Talls produce green or brown fruits depending on the palms. In the Philippines, the first hybrid seednuts were produced using only Tall parents with green nuts. Later on, Talls with brown nuts were also used. In Côte d'Ivoire, PCA 15-2 was produced using the MRD as female parent and both green and brown Tagnanan as male parents. Seednuts with a brown germ were considered as true PCA 15-2 hybrids while seednuts with red germ were regarded as illegitimate plants due to accidental selfing of the female parent.

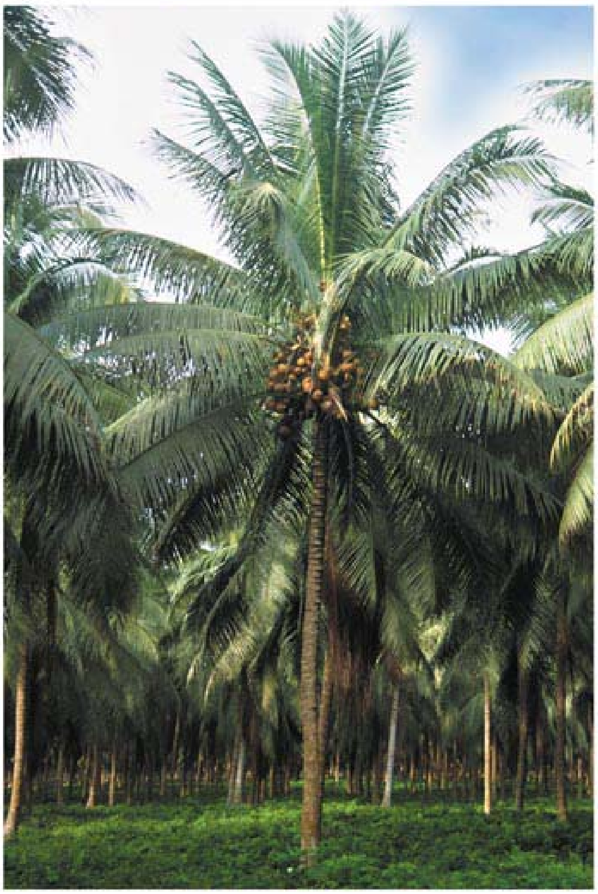
Between 1990 and 1999 under a rehabilitation project funded by the World Bank, around 16 000 hectares were planted to the hybrid in the Philippines. Additionally, in an international experiment initiated in 2002, PCA 15-2 was exported from Côte d'Ivoire to six other countries: Benin, Brazil, Jamaica, Mexico, Mozambique and Tanzania to compare its performance and suitability against the improved variant of PB 121 (PB 121+) and PB 113 as well as with local Tall coconut varieties.

Morphological Description

Matag palms have thick stems, broad bole and long fronds with narrow leaflets. The fruits are usually reddish-brown to brown, never green, round and large, and rich in water and copra. Its vertical growth, which is strong for a Dwarf x Tall type hybrid, is similar to that of PB 121. At 14 years, the stem reaches a height of 8.5 metres (measured from the ground to the base of the first green frond).

PCA 15-2 Hybrid





Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

Maypan (MYD x PNT)

The Maypan hybrid was developed in Jamaica in the 1960s by crossing Malayan Yellow Dwarf (MYD) or Malayan Red Dwarf (MRD) - the female parent - with Panama Tall (PNT) which was imported to the island at the beginning of the 20th century. The name Maypan is derived from the contractions of its parent varieties: "May" for Malayan and "pan" for Panama Tall.

As Lethal Yellowing Disease (LYD) is widespread in Jamaica, it is prudent not to import planting material from that country. Molecular biology studies have confirmed the close similarity between the Panama Talls present in Jamaica and those in the towns of Aguadulce and Monagre in Panama. The closest kinship exists between the Monagre and Jamaica origins. In Côte d'Ivoire, only MYD is used as female parent for the Maypan hybrid, with Panama Talls of Aguadulce and Monagre origins as the male parent.

The Maypan hybrid starts bearing five years after planting and can produce 200 fruits before the 7th year. It remains slightly less productive than PB 121 in Côte d'Ivoire, particularly before maturity. For cumulative yields over a 5- to 8-year period, the difference amounts to 2.6 tonnes of copra per hectare, or 100 fruits per palm.

Once the palm reaches maturity, yields increase and its yield difference with PB 121 diminishes. Over the 9- to 13-year period, the Maypan and PB 121 hybrids produce an average of 4.6 and 4.8 tonnes of copra per hectare per year, respectively (i.e., 122 and 143 fruits per palm per year). The Maypan produces fewer but larger fruits, averaging from 1200 to 1400 grams. The nut weighs around 1000 grams and contains 450 to 470 grams of meat on average. Copra weight per fruit varies from 240 to 260 grams depending on the age of the palm and planting conditions. The yields indicated above, which are quite high, were obtained under research station conditions. They should be extrapolated with caution to true growing conditions, which are often less suitable.

Until recently, the Maypan was considered to be tolerant of LYD in Jamaica. Since 1972, up to 100 000 seednuts have been produced per year in that country. In 1969 the so-called "Jamaica Tall" local variety accounted for 90% of the 3 million coconut palms in Jamaica. However, 26 years later, stands of the variety have almost been completely decimated by LYD as well as by cyclones. Presently, the "Jamaica Tall" accounts for no more than 1% of the entire coconut plantings in the country, with the remainder consisting of Panama Talls (also 1%), Malayan Dwarfs (49%) and Maypan hybrids (49%).

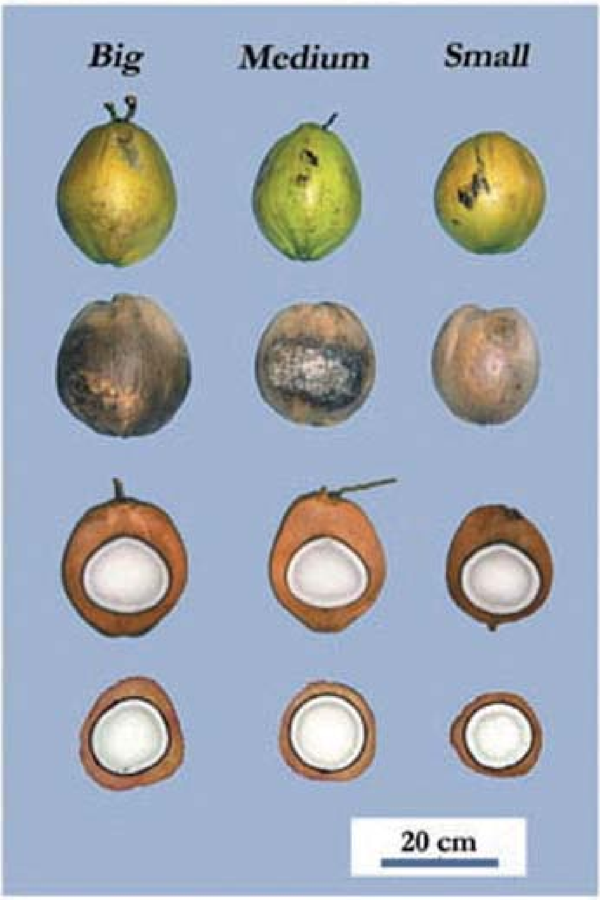
Despite this initial brilliant success, the hybrids started dying in the thousands in the mid-1990s. Experts are examining various hypotheses to understand and attempt to control this susceptibility of Maypan hybrids due to the resurgence of LYD.

With Maypan, various fungi of the genus *Phytophthora* cause either bud rot, which kills the palm, or nut-fall, which reduces yields without killing the palm. In Côte d'Ivoire, only nut-fall has been observed with this hybrid at the Marc Delorme Research Station. Overall, the Maypan hybrid displays little susceptibility to nut-fall, with only 1% fruit losses, compared to 9% with reference hybrid PB 121. However, in Jamaica, where coconut palms are killed by *Phytophthora*, up to 14% mortality has been recorded.

Morphological Description

The Maypan stem is no thicker than that of PB 121. In Côte d'Ivoire, its vertical growth is slightly slower. Its shorter fronds bear shorter and narrower leaflets. The fruits are almost round though slightly more oval and richer in husk than those of its Panama Tall parent. Nevertheless, their composition is generally good, with a large quantity of meat and water, and relatively little husk. Its fruit colour varies from yellowish-green to reddish–brown. Fresh fruits often have slight corrugations in the epidermis which meet at the tip. The inner nut is not totally round as its upper half retains a slightly conical shape that is characteristic of its Tall parent.

Maypan Hybrid



Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

CRIC 65 (SLT 02 x PGD)

CRIC 65 is a cross between the Sri Lanka Green Dwarf (PGD), the female parent, and the Sri Lanka Tall (SLT 02) coconut palm from the Ambakelle seed garden in Sri Lanka. CRIC in the hybrid's name stands for the Coconut Research Institute of Sri Lanka, which developed the hybrid. In Côte d'Ivoire, this hybrid was reproduced using the Dwarf (PGD) as the male parent; studies carried out in Sri Lanka showed that the cross direction did not affect yields.

When planted under suitable conditions, CRIC 65 starts flowering three and a half years after planting, and then starts bearing after four years. Whilst its precocity is similar to PB 121, its yields remain lower up to maturity. CRIC 65 produces 90 fruits per year per palm over the 4- to 8-year period, or about eight fruits fewer than hybrid PB 121. On average, CRIC 65's fruits weigh 1100 grams and the nuts 700 to 750 grams. Copra weight per fruit varies from 220 to 260 grams depending on the age of the tree.

On reaching maturity, fruit production increases. In Côte d'Ivoire, CRIC 65 gives 113 fruits per palm per year, equivalent to 4.1 tonnes of copra per hectare over the 9- to 12-year period, or about 21 fruits or 600 kilograms of copra less than hybrid PB 121.

In Sri Lanka, two varieties are distributed to farmers: CRIC 60, derived from a cross of selected Sri Lanka Talls; and CRIC 65. Debate on which one is better has been ongoing for some time in the country. Several farmers, who have only grown Tall coconut palms for centuries did not take too well to the new hybrid, saying that its husk did not have the same characteristics as their traditional Talls, the wood was of poorer quality and the meat did not taste so good.

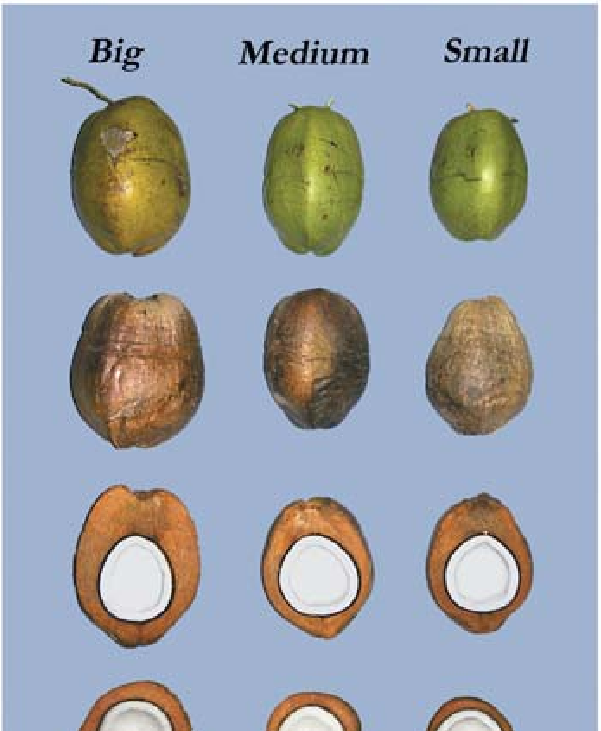
Results of a series of large-scale trials launched in Sri Lanka starting in 1982 confirmed the superiority of CRIC 65 over the improved Tall CRIC 60 in terms of the number of nuts or meat weight. This superiority is particularly expressed in the first 12 years after planting, after which it wanes then disappears. But the first 12 years of any variety are, of course, the most decisive in terms of its profitability and economic value, especially in plantations. On average, over the first four harvesting years, CRIC 65 produces 39% to 116% more fruits depending on existing conditions of the area in which they are planted.

The Ambakelle seed garden is planted with alternating rows of PGDs and SLTs and supplies both CRIC 60 seednuts and CRIC 65 hybrid seednuts. Production of improved seednuts remains inadequate to meet the country's requirements. For instance, from 1983 to 1990, Sri Lanka produced around 11 million seednuts, of which 79% were of unselected Talls, 18% CRIC 60 improved Talls and only 3% CRIC 65 hybrids.

Morphological Description

CRIC 65 only slightly differs in appearance from the reference hybrid PB 121. Its vertical growth is slightly slower. At seven years the stem, measured from the ground to the base of the first green frond, does not exceed 1.9 metres as compared to 2.5 metres in PB 121 for the same period. Although their frond lengths are similar, the leaflets of CRIC 65 are more numerous, and are longer and narrower. The husk thickness on its oblong, predominantly greenish-brown fruits varies but is usually substantial. The fruits are larger and their shapes are more varied than those of PB 121. They contain a sturdy, thick-shelled nut which is ovoid to almost round in shape, but is always longer than it is wide.

CRIC 65 Hybrid



Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

Maren (MRD x RIT)

The Maren hybrid was created in the 1960s at the Yandina research station in the Solomon Islands. It is a cross between the Malayan Red Dwarf (MRD), used as the female parent, and the Rennell Island Tall (RIT). It was reproduced in various countries but subsequently improved in Côte d'Ivoire.

Climate and crop management sequences determine coconut palm yields. Maren and PB 121 hybrids were compared in two similar experimental plots at the Marc Delorme Research Station. In a plot planted in 1971, the Maren flowered after four years, or three months after hybrid PB 121. However, in a plot planted in 1979, the Maren hybrid flowered after only three years, or two months before hybrid PB 121! On farms, the difference in flowering is even more pronounced.

Depending on the plots, the palms start bearing four to five years after planting. On immature palms, yields fluctuate between 39 and 94 fruits per palm per year. On mature palms that are 9 to 15 years old, annual production does not exceed 78 fruits per palm on average, as compared to 109 for PB 121. However, as the fruits of the Maren are much larger, copra yields are not much different from PB 121 at 3.4 tonnes of copra per hectare, or only 260 kilograms less than hybrid PB 121.

The fruits weigh 1.7 kilograms on average and contain a nut weighing from 1200 to 1300 grams. Copra weight per fruit varies from 279 to 310 grams depending on the plot conditions.

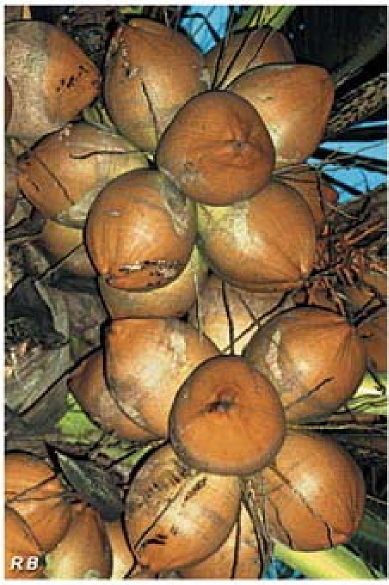
The results obtained to date are for the first generation Maren. Experiments in Côte d'Ivoire designed to create the second generation improved Maren have just been concluded. The progeny of the best RIT parent produced 5.3 tonnes of copra per hectare per year, or 128 nuts per palm, over the 9- to 13-year period. This shows an improvement of 31% more than the first generation Maren hybrid. These production data should not be extrapolated to field-growing conditions, which are often less suitable. However, the relative differences between the first and second generation hybrids should be more or less consistent.

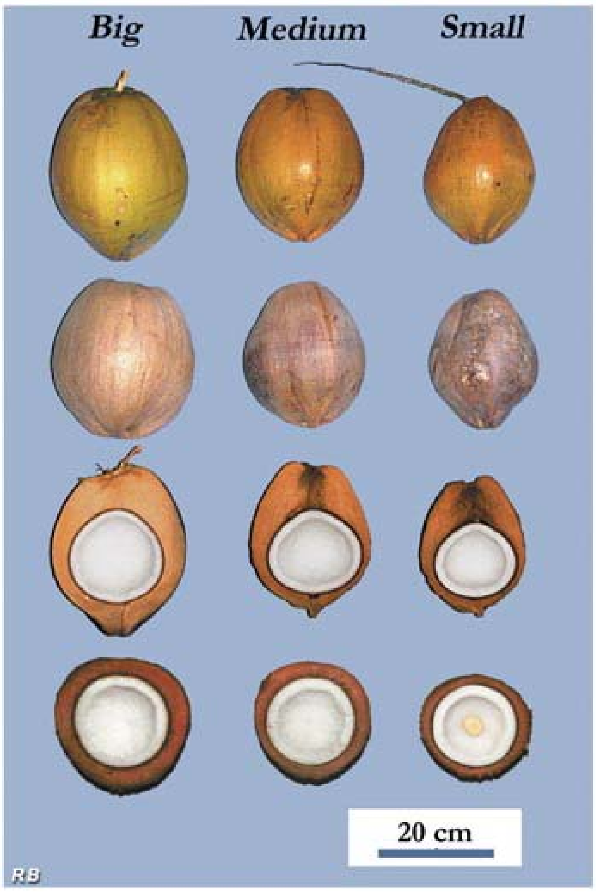
The Maren hybrid displays excellent tolerance to fruit rot caused by fungi of the genus *Phytophthora*, although it is susceptible to attacks by large leaf-eating beetles that are notably rife in the Papuan islands. The Maren hybrid was produced on Taveuni in the Fiji Islands prior to being replaced by the cross between the Malayan Yellow Dwarf and the Rotuma Tall. In the 1990s, the Maren was also produced under the name VIC 10 at Hacienda Victoria in Costa Rica, before being replaced by the Maypan, which showed more promise against LYD. In Côte d'Ivoire, PB 113 (CRT x RIT) is preferred to the Maren. Small-scale Maren hybrid production is still ongoing on the island of Upolu, in the Western Samoas. This cross is recommended for volcanic soil with good rainfall, except in Vanuatu where the foliar decay virus is widespread.

Morphological Description

The stem of the Maren hybrid begins with a marked bole, but rapidly narrows. At 17 years old, the stem, measured from the ground to the base of the first green frond, reaches 7.4 metres, or about 60 cm shorter than that of reference hybrid PB 121 in the same plot. Its large fruits are much rounder and heavier than those of PB 121, and are rich in meat and free water. Their colour varies from yellowish brown to reddish brown. They are oblong to pear-shaped, midway between the shapes of the fruits of its two parents. The inner nut is slightly round with a slightly conical-shaped upper section.

Maren Hybrid





Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

PB 213 (WAT x RIT)

PB 213 is a cross between the West African Tall (WAT), as the female parent, and the Rennell Island Tall (RIT). It was developed in 1969 at the Marc Delorme Research Station in Côte d'Ivoire and was subsequently improved in that country following good results in initial trials.

Depending on the plots and periods, its fruits weigh from 1250 to 1600 grams on average. The inner nut weighs from 900 to 1100 grams and contains 450 to 525 grams of thick meat.

The vertical growth of this hybrid is faster than that of the WAT and of reference hybrid PB 121. At 14 years old, the stem, measured from the ground to the base of the first green frond, reaches 10.75 metres, almost a metre more than that of its WAT parent in the same plot. The frond length calls for a low planting density so that the palms do not hamper each other's growth. In Côte d'Ivoire, Tall varieties and Tall x Tall hybrids are usually planted at 143 palms per hectare. In comparison, Dwarf x Tall hybrids are planted at 160 palms per hectare.

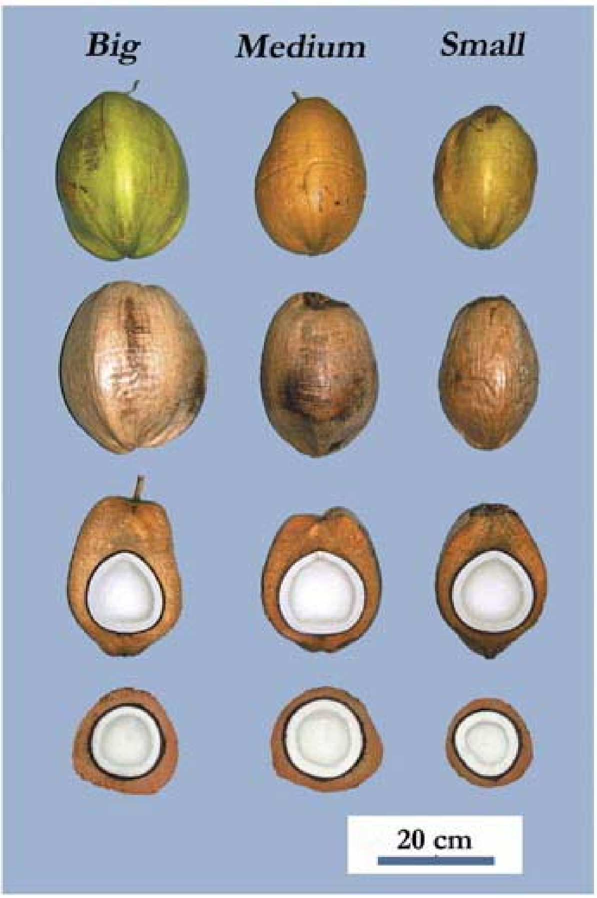
Flowering begins between four and five years after planting, usually around six months before the West African Tall parent, but six months after reference hybrid PB 121. In Côte d'Ivoire, improvement of PB 213 was undertaken in 1980. The progenies of the best RIT parents achieved 4.7 tonnes of copra per hectare per year, or 122 nuts per palm, over the 9- to 13-year period. This is equivalent to about 11% more for immature palms and 14% more for mature palms than the first generation PB 213. These yield data should not be extrapolated to actual growing conditions, which are often less suitable. However, the relative differences between the first and second generation hybrids should be more or less consistent.

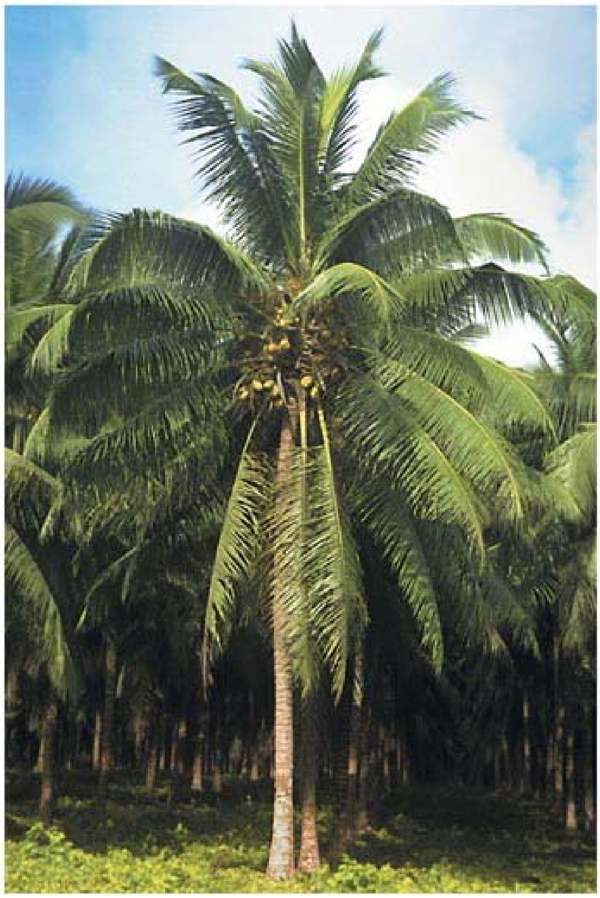
Although recommended by the Marc Delorme Research Station, this hybrid, which has already been tested in more than a dozen countries, has yet to be distributed on a large scale. Tall x Tall hybrid seednuts are more difficult and more expensive to produce. And like most RIT hybrids, PB 213 has a certain degree of susceptibility to drought. It is also susceptible to nursery diseases, for which effective treatments have been developed. PB 213 is a hybrid with vigorous growth under which intercrops like cacao or pepper could be grown. It can also fit into a regional planning scheme for tropical coastal zones. In this case, it is preferable to plant it outside urban zones in which damage could be caused if nuts, fronds or even the entire palm fell.

Morphological Description

Compared to Dwarf x Tall hybrids, Tall x Tall hybrids have a reputation of being bulkier, more heterogeneous and later bearers, but they are also hardier and highly productive once they have matured. The fruits of PB 213 have a different shape from those of its two parents. They are oblong, clearly more rounded, and they have better meat content than the fruits of the WAT parent. However, they do not have the pear shape and distal nipple of its RIT parent.

PB 213 Hybrid





Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

PB 214 (WAT x VTT)

PB 214 was created in Côte d'Ivoire in 1972. It is a cross between the West African Tall (WAT), used as the female parent, and the Vanuatu Tall (VTT).

On average, the fruits weigh slightly less than one kilogram and contain a nut weighing 350 to 400 grams. After drying to 6% moisture content, its meat weighs around 340 grams and gives approximately 210 grams of copra.

Flowering begins 3.5 to 5 years after planting. In studies conducted in Côte d'Ivoire, PB 213 emerged as the top performer, ahead of five other experimental Tall x Tall type hybrids. Over the 9- to 14-year period, it produced an average of 3.1 tonnes of copra per hectare per year, or around 110 fruits per palm. This performance, which was achieved in a less-than-fertile plot, remains very average in absolute values. However, in relative values, the yields of this hybrid amount to almost 230% of WAT reference yields, in which case the difference is considerable.

Although it flowers early and produces good yields, this hybrid has not been widely disseminated in Côte d'Ivoire due to difficulties in producing seednuts on fast growing varieties and the substantial cost it entails. However, improvement of hybrid PB 213 was launched in 1988. The best progenies identified flowered, on average, 41 months after planting, or only six months after reference hybrid PB 121. Such a small difference in precocity had never been seen before between a Tall x Tall hybrid and hybrid PB 121, which is known for its rapid flowering. At six years old, these progenies produced almost 130 fruits per palm. This experiment is still continuing and is constantly being monitored.

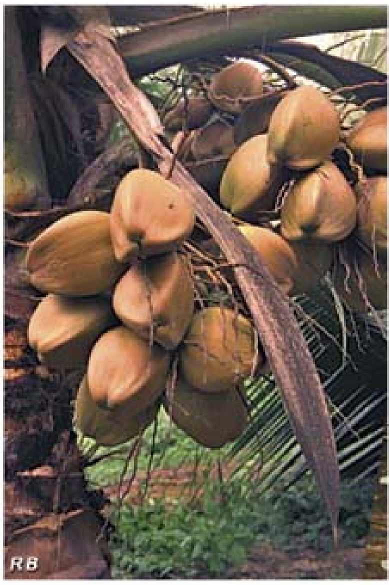
Hybrid PB 213 is susceptible to foliar decay in Vanuatu despite the resistance of the VTT parent. Moreover, in that country, its performance is inexplicably quite mediocre.

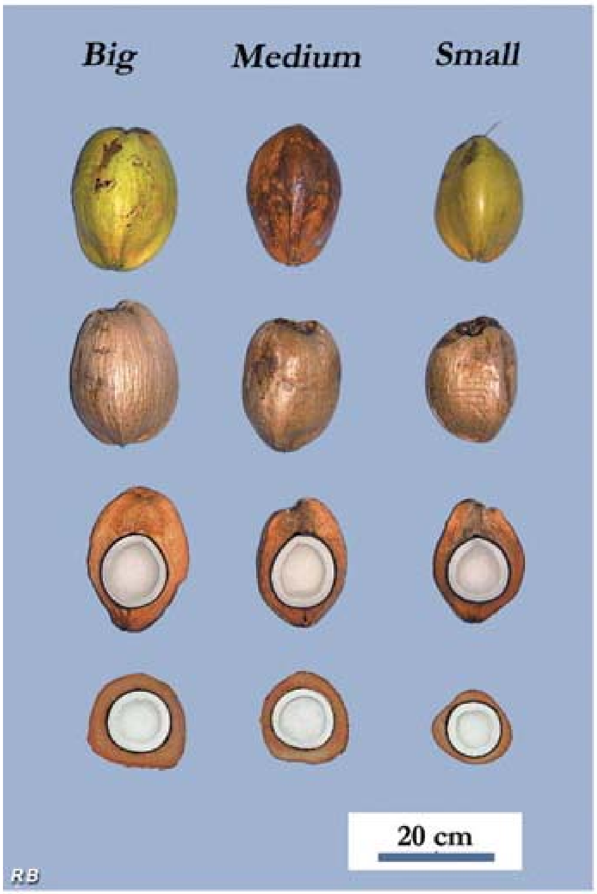
The only drawback with this early-flowering, high-yielding hybrid lies in its low copra/fruit weight. This characteristic only leads to extra labour costs when the harvest is processed. If nuts are sold separately per unit, their average size can be advantageous. Large nuts, which are often fragile, are usually not appreciated for export.

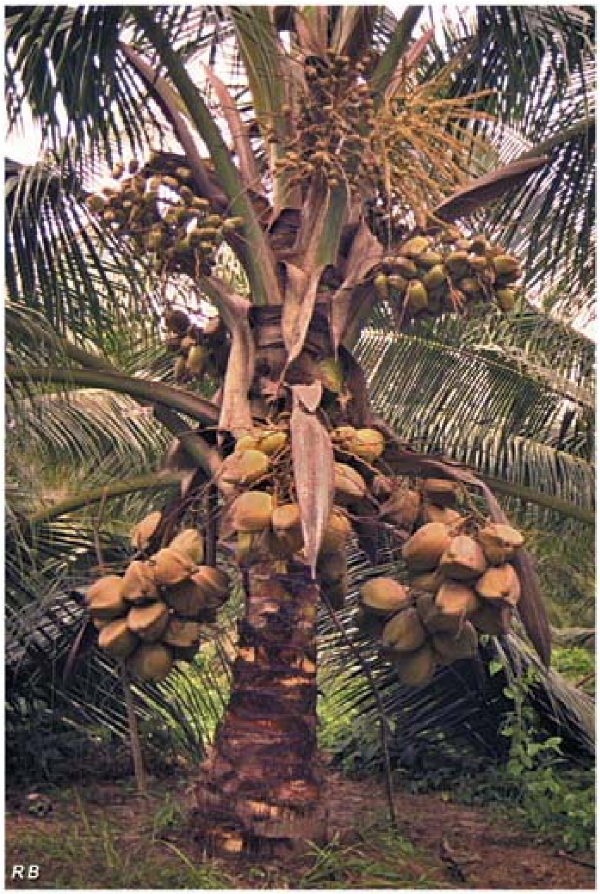
Morphological Description

This is a large, fast growing palm. The fairly thick stem has a powerful base. The fronds, which are quite short for a Tall x Tall type hybrid, bear shorter and narrower leaflets than those of its African parent. The fruits, which are primarily green, are small but have a good composition, with thick meat and a thin but irregular husk. The fruits often have three ridges at their tip, which quickly smooth out towards the central section; the cross–section of the fruit is triangular in shape with very rounded corners. The inner nut is oval with a thick resistant shell and is clearly longer than it is wider.

PB 214 Hybrid







Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

PB 332 (MYD x MRD)

In 1926 in the Fiji Islands, a botanist named Marechal produced the first coconut hybrid by crossing the Niu Leka and Malayan Red Dwarfs. The idea of crossing Dwarfs therefore goes way back, but did not catch on. Of the different types of hybrid coconut palms, those of the Dwarf x Dwarf type remain the least studied worldwide. Crossing two Dwarf coconut palms has always given a Dwarf type palm.

Hybrid PB 332 is a cross between Malayan Yellow Dwarf (MYD) and the Malayan Red Dwarf (MRD). It was created in 1971 at the Marc Delorme Research Station in Côte d'Ivoire.

It usually starts bearing four years after planting. Yields appear to be very uniform from one palm to another. However, they vary considerably over time on immature palms. For instance, in a plot without irrigation, an average of 32 fruits per palm was recorded in the fourth year, 141 in the fifth year, 41 in the sixth year and 192 in the seventh year.

The average-sized fruits weigh a little over 1000 grams or 200 grams more than those of the MYD parent. The inner nut weighs around 700 grams and contains 350 to 400 grams of meat.

Once the palm reaches maturity, yields stabilize and reach a good level. At the Marc Delorme Station, this hybrid has produced an average of 3.8 tonnes of copra per hectare per year over the 8- to 15-year period, equivalent to about 126 nuts per palm per year. Under the same conditions, MYD and MRD produce around a tonne of copra per hectare per year less. These yield data should not be extrapolated to true growing conditions, which are often less suitable. However, the relative differences between the crosses tested are expected.

In 2003, no Dwarf x Dwarf type hybrid had yet been widely distributed to farmers. This material suffers from the poor reputation of Dwarf coconut palms, which are judged to be susceptible to adverse climatic conditions, to diseases and to attacks by certain pests. However, although Dwarfs are mostly used as garden ornamentals, they are sometimes planted in estates, notably in Brazil, Jamaica and Thailand. Most of these estates are mainly dedicated to the production of drinking nuts, are well irrigated and fertilized, and are extremely profitable.

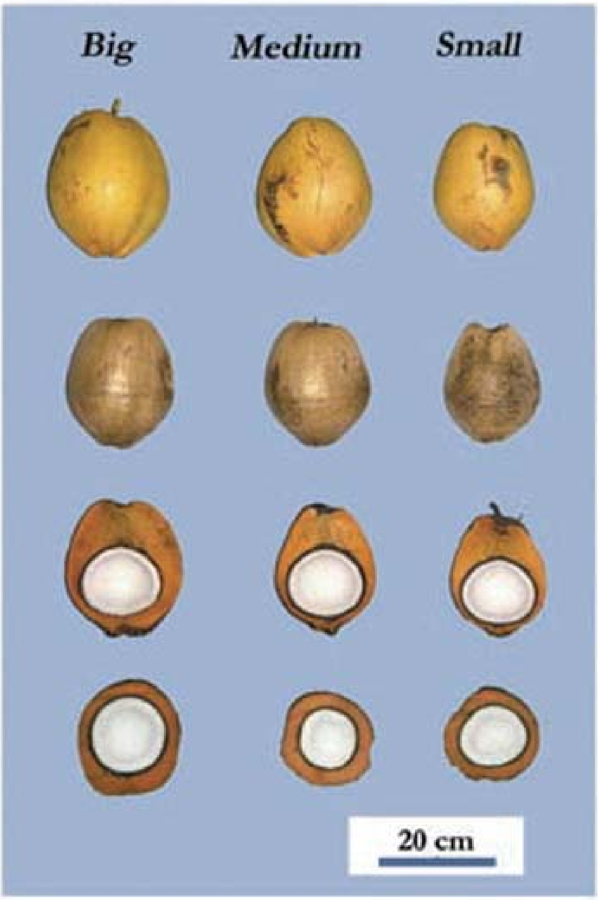
In Jamaica, MYD and MRD have long been considered to be a single variety with two colours. However, hybrid PB 332 proved to be much more productive than either of its parents. This vigour showed that the two parents in question are genetically different and indeed formed two distinct varieties. Further DNA analysis has confirmed this finding.

In Côte d'Ivoire, nuts are often harvested using a long pole with a sharp, metal hooked knife attached to one end. Given the hybrid's slow vertical growth, the leaf crown of the PB 332 is compact. The bunch stalks are very short and embedded between the fronds thereby making it difficult to reach with the hooked knife and considerably slows down harvesting. Experience has shown that it takes longer to harvest a 9-metre tall PB 332 than a 14-metre tall PB 213 (West African Tall x Vanuatu Tall). Other Dwarf hybrids are currently being tested in Côte d'Ivoire to address this problem. So far, some of the Dwarfs chosen as parents produce easily accessible long-stalked bunches.

Morphological Description

Although hybrid PB 332 remains a Dwarf coconut palm, its dimensions are slightly greater than those of its parents. Compared to MYD, its stem is about 3 cm thicker. At 16 years, it is 44 centimetres taller on average; its fronds are longer and bear more numerous, longer leaflets. Its inflorescences are also larger. The fruits have an orange-yellow colour, midway between those of MYD and MRD. They are also larger and have slightly narrower oblong shape.

PB 332 Hybrid



Pictures courtesy of ***Dr. Roland Bourdeix****, CIRAD*

Results of coconut hybrid trials by United Plantations Sdn Bhd, Malaysia

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Introduction

United Plantations Berhad's (UPB) involvement in the cultivation of coconut as a plantation monocrop dates as far back as 1912. The variety of choice then was largely the Malayan Tall (MLT) and, to a lesser extent, the Malayan Yellow, Red and Green Dwarfs (MYD, MRD and MGD). Subsequently, the diminishing economic returns from coconut production led to a general shift of emphasis to oil palm cultivation.

The revival of interest in the crop took place during the late 1960s when cocoa was successfully used as an intercrop beneath the tall coconut canopy. However, the focus thereafter shifted to cocoa as a main crop, whilst the humble coconut was relegated to a secondary status as a shade tree. With the introduction of MAWA hybrid (PB121) in the early 1970s, there was a renewed interest in the systematic rehabilitation of the old MLT stands. In most cases, the method of choice then was poisoning and underplanting with MAWA hybrids (since there was already cacao underplanted in the field). Clearing and replanting were carried out in the early 1980s when budded clonal cacao became available. The MAWA planting densities adopted ranged from 78 to 102 palms per hectare.

The long drawn low cacao commodity prices that followed in the l980s and rising cost of production coupled with tight labour situation on plantations finally led to a demise of the cacao-coconut cropping system in favour of oil palm. Demand for copra for coconut-based lauric oils was also increasingly being replaced by the increased production of oil palm kernel oil. Thus coconut cultivation as an industrial crop for oil extraction was not a very attractive proposition leading to a free fall in coconut area in the country.

Parallel to the above mentioned scenario, the downstream sector for coconut products started expanding for both the local and export market. The decline in domestic nut supplies triggered an increased demand with resulting improvement in prices. The key drivers for this demand were the desiccated coconut, spray dried coconut milk, nata de coco and tender nut market.

Currently, there are 3519 hectares of coconuts at UPB the bulk of which is planted with MAWA and MATAG hybrids. In 2003, UPB produced more than 76 million nuts from its coconut plantation.

The company has a long term commitment to coconut cultivation and as such is committed to continue its R&D efforts towards improving the agronomic management of growing coconut and exploit new hybrids with improved yield and returns. Currently, there are 19 field trials focusing on these areas of research at UPB.

This paper will however be confined in its focus on some of the evaluation results obtained for the coconut germplasm collection, as well as the performance of the various hybrid combinations, at UPB.

Over the years, the germplasm collection at UPB has gradually increased to six Tall and seven Dwarf cultivars (Table 1). Among the materials evaluated, only the Tahiti Tall (THT) and Cameroon Red Dwarf (CRD) have not been systematically studied owing to a more frequent shifting of sites and the small population size.

Table 1. Sources of the coconut germplasm in United Plantations Berhad

No.	Coconut cultivar	Abbreviation	Year introduced	Source
Talls				
1	Malayan Tall	MLT	1912	Indigenous
2	West African Tall	WAT	1972	IRHO, Port Bouet, Ivory Coast
3	Rennel Island Tall	RLT	1974	-do-
4	Tahiti Tall	THT	1976	-do-
5	Tagnanan Tall	TGT	1979	Tagnanan Estate, Davao, Philippines
6	Laguna Tall	LGT	1980	Philippine Coconut Authority, Davao, Philippines
Dwarfs				
1	Malayan Red Dwarf	MRD	1931	Indigenous
2	Malayan Yellow Dwarf	MYD	1931	- do -
3	Malayan Green Dwarf	MGD	1931	- do -
4	Catigan Dwarf	CAD	1980	Philippine Coconut Authority,
5	Tacunan Dwarf	TAD	1980	Davao
6	Cameroon Red Dwarf	CRD	1980	IRHO, Port Bouet, Ivory Coast
7	Aromatic Green Dwarf or 'Pandan'	AGD	1991- 2000	DOA & Commercial Nurseries, Malaysia

The performance of these germplasm in the current new trials will be presented together with the hybrids since they were planted together. Dwarf x Tall and Tall x Tall hybrids were usually planted together with the next cycle of selections of the Tall cultivars. Similarly, the Dwarf x Dwarf hybrids were planted with Dwarf cultivars. This was unavoidable because of the different density requirements of the materials as well as practical field constraints.

Early breeding and selection work involving the Malayan Tall

The allogamous Malayan Tall population exhibits very high variability for nut production. Jack (1929) reported that over an 8-year period of production, the Malayan Tall population had a 34% coefficient of variation in terms of nut production, with a mean range of 5 to 115 nuts per palm per year.

In UPB, breeding and selection work for improvement of the Malayan Tall population was carried out systematically soon after World War II using mass selection in which high yielding individuals were selected from commercial plantings and these open-pollinated materials were used for commercial plantings.

In 1950, 118 individual palms were selected based on nut yield and copra content for seed production. However, this approach was abandoned shortly thereafter in favour of block selection in commercial fields to meet the high demand for coconut planting materials at that time. At this point, 5782 palms were selected based on high yielding commercial blocks (Chan 1982). A comparison of the yields of the progenies derived from selected individuals and block selection did not show appreciable differences.

A serious flaw in the approach was that seednuts were obtained via open-pollination in a coconut estate. This initiated a renewed selection programme aimed at improving the Malayan Tall. Selections were carried out involving 2782 palms from an 11-year old (1965) planting. Based on the three years of yield recording and nut analysis, superior palms were identified and used to produce a new generation of Malayan Talls. They were used as pollen sources to produce Dwarf x Tall hybrids with Malayan Yellow and Red Dwarfs as mother palms using the controlled pollination technique.

Ibrahim *et al* (1988) reported some success in selections within the Malayan Tall population for high nut yield and copra content via crossings of selected palms. They also opined that the initial generation of selection would result in segregation that releases variability and this will only be fixed in subsequent generations leading to a more homozygous population. This will be useful as parents in hybrid seednut production.

A comparative performance of the relatively improved MLT will be discussed under Tall x Tall Hybrid Trial 1 later in this paper. All the coconut trials reported in this paper are situated at Sungai Bernam Estate which is derived from marine alluvial deposits. The soils are characterized by their high clay content and are inherently fertile but require intensive draining. Being on the coastal plain along the west coast of Peninsular Malaysia, the plantation has an average annual rainfall of 1788mm (from 1983-2003) with a short dry spell for 2-3 months where the moisture deficit can vary between 50-100mm.

Tall x Tall hybrids in Trial 1

Table 2 shows the four hybrid combinations planted at Sungai Bernam in 1982 using a 4x4 Latin Square layout with 20 palms per plot. The planting pattern adopted was rectangular (10.7m x 12.2m) giving close to 77 palms/hectare. The lower planting density adopted was due to the scheduled intercropping with cocoa (cocoa was removed in the 1990s).

Table 2. Status of the four T x T hybrid combinations planted at Sungai Bernam

Type of crosses	Name of hybrid	Yield data on the17th year of harvest (per palm)			Vegetative data on the17th year of harvest (per palm)		
		No. of nuts	No. of bunches	Dry albumen (kg)	Rachis length (Frond 14)	No. of fronds produced	Height of stem (m)*
WAT x RLT	WATREN	186	18.8	52.4	4.05	17.4	11.75
WAT x MLT	WATMAT	186	18.5	43.0	4.21	17.4	12.47
MLT x MLT	Malayan Tall (MATMAT)	153	18.7	44.3	4.38	17.4	13.46
MRD x WAT (Control)	MAWA (R)	211	18.7	42.7	4.11	17.4	11.38
LSD (p=0.05)		**4.14**	**0.23**	**-**	**ns**	**ns**	**0.58**
LSD (p=0.01)		**5.95**	**0.33**	**-**	**ns**	**ns**	**0.82**

**Note: Stem height is measured from the base of frond No.25 to ground level*

The results obtained in Table 2 during the 17th year of harvest showed that whilst the MAWA Control in this trial produced significantly higher number of nuts, it had lower dry albumen yield when compared with WATREN hybrid. It was interesting to note that the difference in dry albumen yield among MAWA, MATMAT and WATMAT was very small.

The MATMAT was significantly taller than the rest of the hybrids in this trial and the hybrids derived from the use of Malayan Tall as a parent were taller than those derived from Rennel Island Tall. The hybrids were comparable in terms of frond production and rachis length.

Table 3. Mean yield data of the four hybrids over a 17-year period

Type of crosses	Name of hybrid	Mean yield data over a 17-year period (per palm)		
		No. of nuts	No. of bunches	Dry albumen (kg)
WAT x RLT	WATREN	135	16.2	38.0
WAT x MLT	WATMAT	150	16.3	34.7
MLT x MLT	Malayan Tall (MATMAT)	126	15.8	36.5
MRD x WAT	MAWA (R)	182	16.7	36.8
LSD (p=0.05)		**4.18**	**0.22**	**-**
LSD (p=0.01)		**6.01**	**0.32**	**-**

From Table 3, the MAWA (control) produced the highest number of nuts per palm per year in the trial over the 17 years of production. However, WATREN was marginally higher yielding in terms of dry albumen production. It was interesting to note that the difference in dry albumen production was low between MAWA and MATMAT. Although the planting density adopted in this trial was low, it is opined that this would not have changed the outcome very much (among the test hybrids) if the optimum planting density had been employed.

Dwarf x Tall hybrids in Trial 2

Four hybrid combinations were planted on Bernam series marine alluvial soil in 1982, using RCBD with 20 palms per plot. The planting pattern adopted was rectangular (9.14m x 10.7m) giving 102 palms/hectare. The lower planting density adopted here was due to intercropping with cocoa (cacao was removed in the 1990s). The performance of these four Dwarf x Tall Hybrids is presented below (Table 4).

Table 4. Performance of four Dwarf x Tall hybrids

Type of crosses	Name of hybrid	Yield data on the 18th year of harvest (per palm)		
		No. of nuts	No. of bunches	Dry albumen (kg)
MRD x WAT	MAWA - R	248	17.5	53.8
MYD x WAT	MAWA - Y	251	17.6	51.8
Mean for MAWA		**250**	**17.6**	**52.8**
MRD x RLT	MAREN – R	135	17.7	39.2
MYD x RLT	MAREN - Y	134	17.9	34.2
Mean for MAREN		**135**	**17.8**	**36.7**
MRD x MLT	MAMAT – R	148	17.7	35.5
MYD x MLT	MAMAT - Y	137	17.9	30.0
Mean for MAMAT		**143**	**17.8**	**32.8**
MRD x TGT	**MATAG**	**212**	**17.5**	**54.2**
LSD (p=0.05)		**16.5**	**0.26**	**-**
LSD (p=0.01)		**23.2**	**0.36**	**-**

The results in Table 4, which were obtained during the 18th year of harvest, showed that the MAWA Control produced the highest number of nuts/palm. But MAWA was marginally lower yielding when compared with MATAG hybrid in terms of dry albumen production. What is more interesting is the narrowing gap between MAWA and MATAG for dry albumen yield in the last couple of years.

Based on the results in Table 5, the MAREN hybrids were significantly shorter in height than the rest of the hybrids under evaluation. The MAREN also tended to have shorter fronds when compared to MAWA and MATAG. All the hybrids were comparable in terms of frond production.

Table 5. Vegetative data of the four D x T hybrids after 21 years of planting

Type of crosses	Name of hybrid	Vegetative data on the 18th year of harvest or 21 years after planting		
		Rachis length (Frond 14)	No. of fronds Produced	Stem height (m)
MRD x WAT	MAWA – R	4.11	17.4	11.05
MYD x WAT	MAWA – Y	4.13	17.4	11.49
Mean for MAWA		**4.12**	**17.4**	**11.27**
MRD x RLT	MAREN – R	4.02	17.4	10.10
MYD x RLT	MAREN - Y	3.98	17.4	9.95
Mean for MAREN		**4.00**	**17.4**	**10.03**
MRD x MLT	MAMAT – R	4.07	17.4	11.22
MYD x MLT	MAMAT - Y	4.04	17.4	11.35
Mean for MAMAT		**4.06**	**17.4**	**11.29**
MRD x TGT	**MATAG**	**4.10**	**17.4**	**10.84**
LSD (p=0.05)		**0.11**	**ns**	**0.65**
LSD (p=0.01)		**0.16**	**ns**	**0.91**

Table 6 shows that over the 18 years of production, the MAWA produced the highest number of nuts per palm per year in the trial followed by MATAG. Despite the low planting density adopted, MAWA yielded an average of almost 19 000 nuts/ha/year. However, MATAG was slightly higher yielding in terms of dry albumen production.

Table 6. Mean yield data of the four D x T hybrids after 18 years of production

Type of crosses	Name of hybrid	Mean yield over an 18-year harvest period (per palm)		
		No. of nuts	No. of bunches	Dry albumen (kg)
MRD x WAT	MAWA – R	183	16.6	39.8
MYD x WAT	MAWA - Y	188	16.8	38.8
Mean for MAWA		**186**	**16.7**	**39.3**
MRD x RLT	MAREN – R	131	15.9	38.0
MYD x RLT	MAREN - Y	135	16.4	34.6
Mean for MAREN		**133**	**16.2**	**36.3**
MRD x MLT	MAMAT – R	147	16.2	35.3
MYD x MLT	MAMAT - Y	136	16.6	29.8
Mean for MAMAT		**142**	**16.4**	**32.6**
MRD x TGT	**MATAG**	**164**	**16.1**	**42.0**
LSD (p=0.05)		**13.3**	**0.35**	**-**
LSD (p=0.01)		**18.7**	**0.49**	**-**

A point of caution which cannot be overemphasized is the tendency to use short-term yield data to extrapolate the yield potential of the hybrids. This is shown by the example below from the Dwarf x Tall Trial 2 (Figs 1 and 2).

Fig.1. Average nut yield per palm of the four D x T hybrids

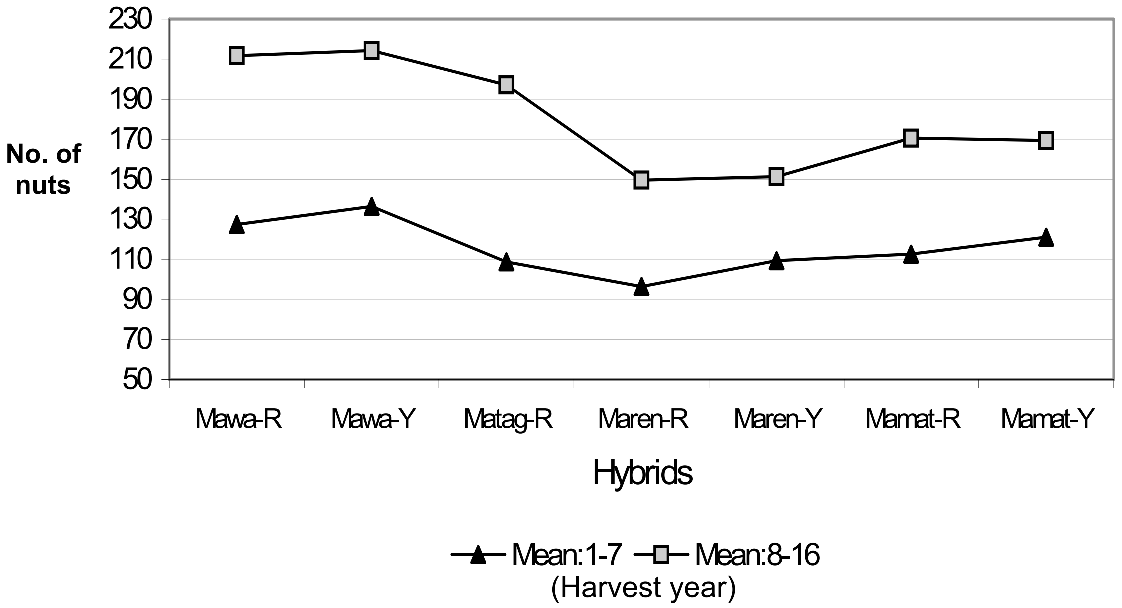
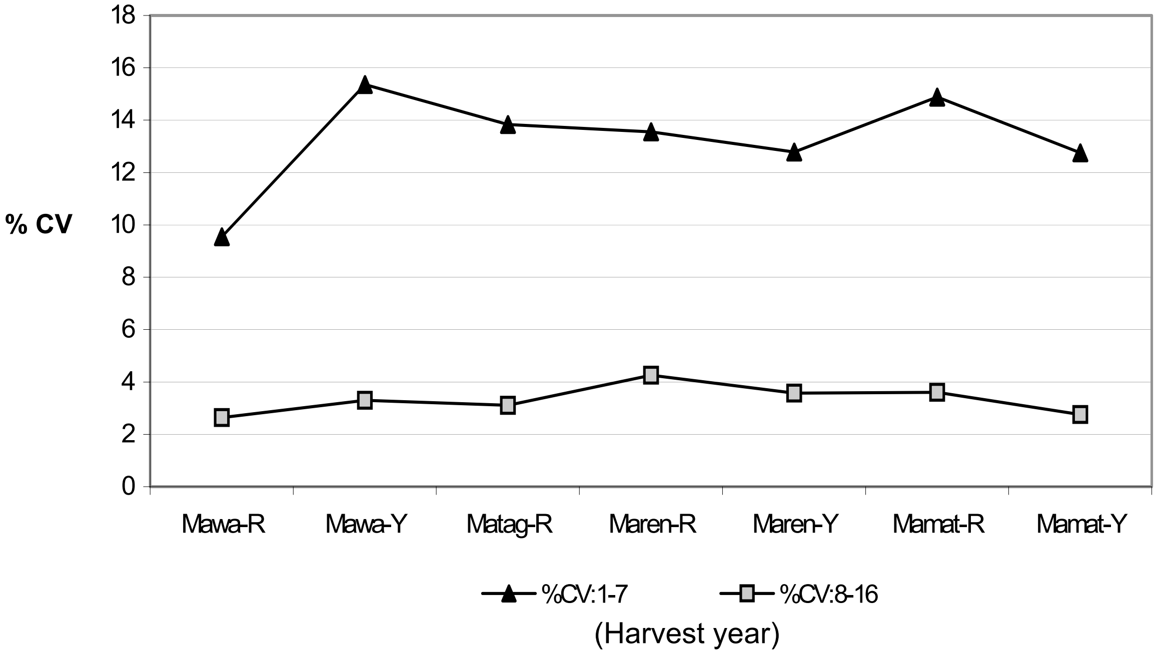


Fig 2. Coefficient of variation (CV%) for nut yield per palm of the four D x T hybrids



The two graphs illustrate the yield stability comes after 8 years of production in this trial and therefore coconut breeding trials will need long term evaluation (in this case from year 8 to 16 from commencement of production).

Which should be the choice material for planting? Dwarf x Tall or Tall x Tall hybrids?

There has been much written on this subject in the past. Dwarfs have been implied to impart a lower tolerance to drought/moisture stress in Dwarf x Tall hybrids. They are also known to exhibit alternate bearing characteristics (a peak crop followed by a trough in the following year).

However, Dwarfs have the advantage of imparting early bearing and yield precocity traits in the hybrids and produce more uniform progeny due to their higher homozygosity attributed to their autogamous nature. These characters make them useful as parents in hybrid breeding programmes.

A comparison was carried out to compare nut yield variation within the progenies over 16 years of harvest between the Tall x Tall Hybrids in Trial 1 and Dwarf x Tall Hybrids in Trial 2, under favourable agroecological conditions and good management inputs at UPB.

Results presented in Figs 3 and 4 show that although the Tall x Tall hybrids lagged behind in coming to maturity and had higher CV values during the early years of production, they became stable thereafter, with the %CV for nut yield dipping below 10% for hybrids in both the groups after nine years of harvest. This suggests that Tall x Tall hybrids are a viable option provided their cumulative yields can match the Dwarf x Tall hybrids in the medium to long term.

Fig 3. CV percentage for nut yield per palm for Tall x Tall hybrids (1982 Planting) in Trial 1

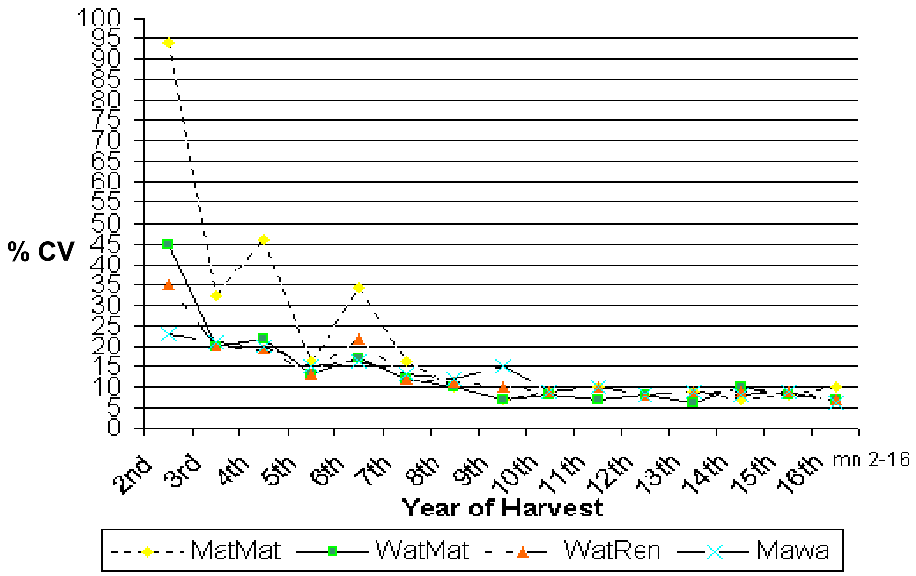


Fig 4. CV percentage for nut yield/palm for Dwarf X Tall hybrids (1982 Planting) in Trial 2

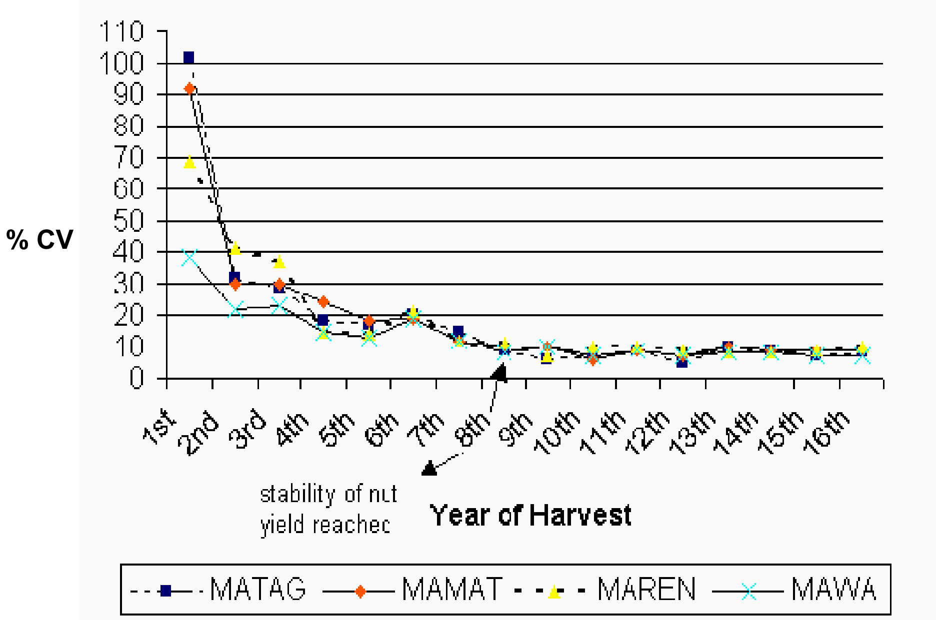


Fig 5. Nut yield profile (per palm basis) over 16 years of harvest for Tall x Tall hybrids in Trial 1

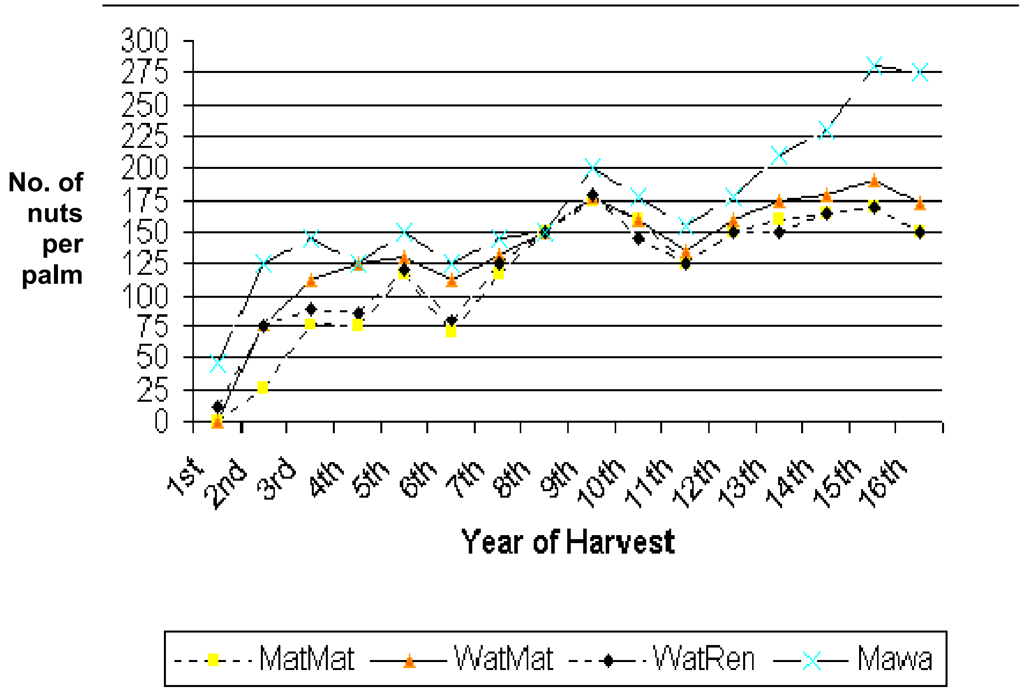
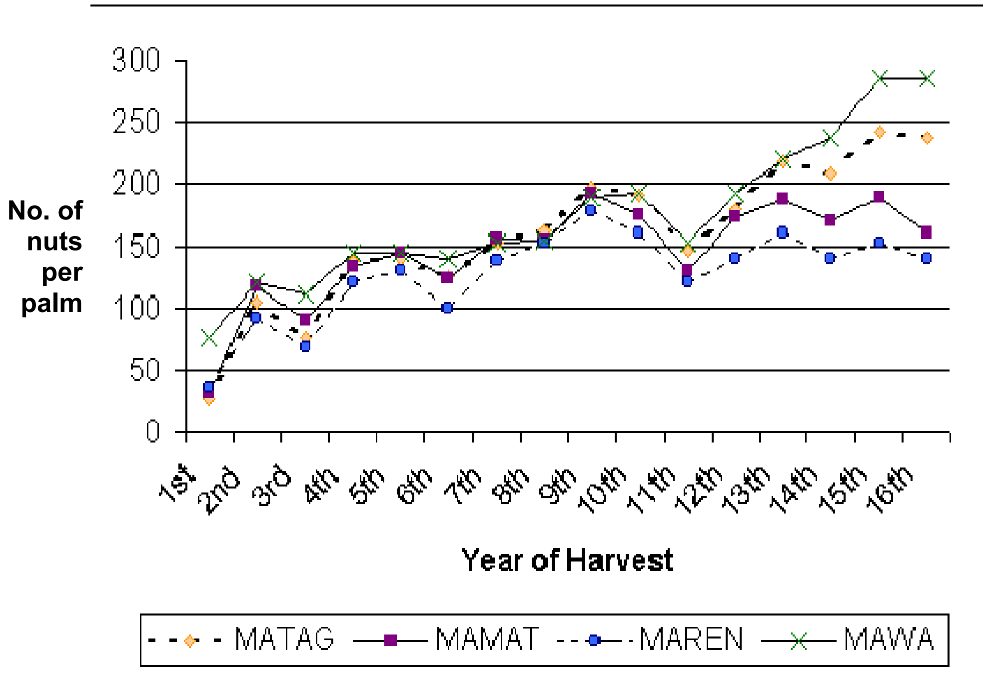


Fig 6. Nut yield profile (per palm basis) over 16 years of harvest for Dwarf x Tall hybrids in Trial 1



Figures 5 and 6 show that the Tall x Tall Hybrids can match the Dwarf x Tall Hybrids in the longer term since the profile of the MAWA (control) was comparable in both the trials. Some of the Tall x Tall combinations (e.g. WATREN) were high yielding both in terms of the number of nuts produced and dry albumen. Alternate bearing was not so evident in Dwarf x Tall under the good growing conditions prevailing in both the trials.

However, it must be cautioned here that despite the near optimal growing conditions in this plantation, the Dwarf x Tall hybrids early precocity may not have been fully exploited because of the level of management expertise at that time. Since then, significant strides of improvement have been made with respect to agronomy, improved drainage and *Orycetes rhinoceros* beetle damage control.

This has led to a significant shortening of the period of immaturity in the commercial hybrid plantings and significantly higher initial yields (Table 7). For this reason, there are plans to monitor the Dwarf x Tall hybrids in comparison with the Tall x Tall hybrids in the newer trials established during the 1990s over the longer term to see if our conclusions made earlier remain valid.

Table 7. Nut yield per hectare of the hybrids in the 1980s and 1990s

Period of planting	Age to maturity (months)	Nut yield per hectare at planting density of 178 palm			
		Year 1	Year 2	Year 3	Cumulative yield
1980's	48	9765	17734	17491	44990
1990's	33	18518	24820	27914	71252

Mixed Hybrids in Trial 3

In this trial, MAWA (and its reciprocal cross – WAT x MYD), MATAG, CAMWA and WATREN were compared in a block planting layout. The results obtained are presented in Table 8.

During the 17th year of production, both the MAWA and its reciprocal cross were the top performers in terms of nut production, outyielding MATAG by 12% and 11%, respectively. WATREN had the lowest nut production in the trial, yielding 31% lower than the MAWA. On per hectare basis, MATAG yielded 28 689 nuts against 33 810 and 33 672 by MAWA and its reciprocal cross, respectively.

Over the 17 years of production, MAWA outyielded the MATAG by only around 5% for nut yield but owing to its superior conversion, MATAG outyielded the MAWA by 16% for dry albumen yield/palm/year. However, the gap between the two was narrowing with the MATAG just outyielding MAWA by less than 10% for dry albumen yield in the 17th year of harvest.

Table 8. Vegetative measurements of the five mixed hybrids

No. of Palms/Ha	131	138			
Layout	Block Planting				
Spacing (m)	9.1 x 8.2	9.1 x 7.9			
Year Planted	April 1982				
Planting Material	MRD x TGT (MATAG)	WAT x RNT (WATREN)	CRD x WAT (CAMWA)	MYD x WAT (MAWA)	WAT x MYD (MAWA Reciprocal)
Yield Data: 2003					
No. of nuts/palm	219	169	214	245	244
No. of bunches/palm	17.5	17.6	18.6	18.4	17.4
Weight of dry albumen/palm (kg)	57.2	47.6	42.5	52.2	49.6
Yield Data: 17-Year Mean					
No. of nuts/palm/year	182	129	165	192	193
No. of bunches/palm/year	17.0	15.8	16.3	16.9	16.9
Weight of dry albumen/palm/year (kg)	47.5	36.4	32.8	40.9	39.2
Vegetative Data: 2003*					
Rachis length (frond 14)	4.13	-	3.91	4.12	-
No. of fronds produced/year	17.3	-	17.3	17.4	-
Total Height (ground to frond 25)	11.66	-	8.68	11.14	-

**Vegetative measurements were carried out only for MATAG, CAMWA and MAWA*

The use of WAT as either male or female parent in the production of MAWA and its reciprocal cross did not show any appreciable difference in yield. This is contrary to the findings of Patel (1937), as reported by Menon and Pandalai (1960), but is in agreement with the findings of Tammes (1955) and Liyanage (1956).

Within the over 500 palms in the MATAG block, there were also around 180 MAWA palms randomly distributed.

A comparison between the yield components of MAWA and MATAG palms within this block (same density of planting) was made over 17 years of production. This is shown in Figs 7 to 8 below.

From the charts presented above (Figs 7 to 9), nut yield gap has been maintained consistently between MAWA and MATAG with the former holding a lead. MAWA has been producing a slightly higher bunch number over the last two years.

There has been also been a trend whereby the gap in the difference in fruit set (expressed as the number of nuts/bunch/year) between MAWA and MATAG has narrowed. However, MAWA is still leading in this respect with about 13 nuts per bunch whilst the MATAG produced an average of 12 nuts per bunch during the 17th year of production.

Fig 7. Nut yield per palm for MAWA vs. MATAG over a 17-year production period

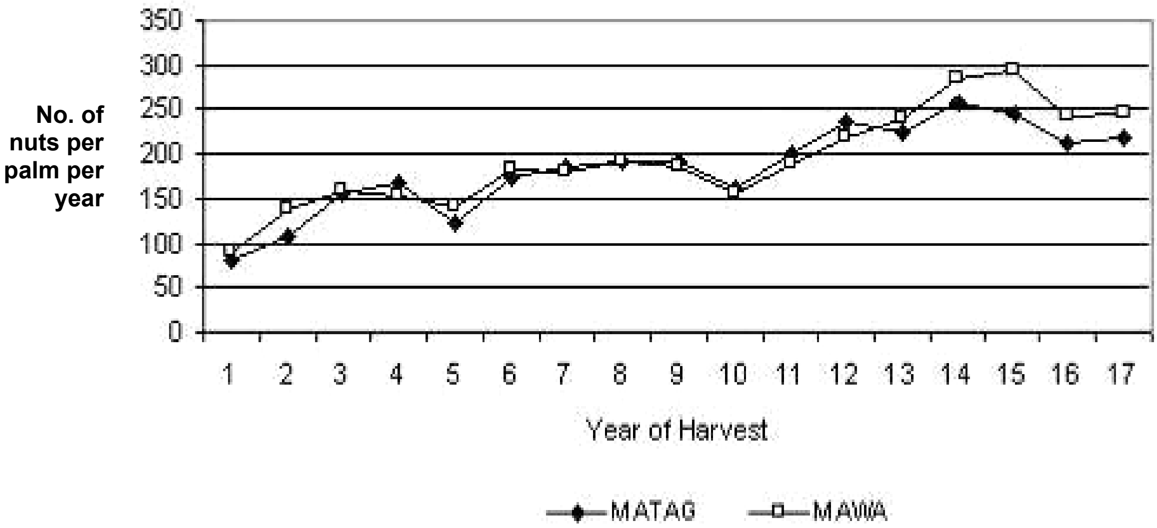


Fig 8. Number of bunches per palm for MAWA vs. MATAG over a 17-year production period

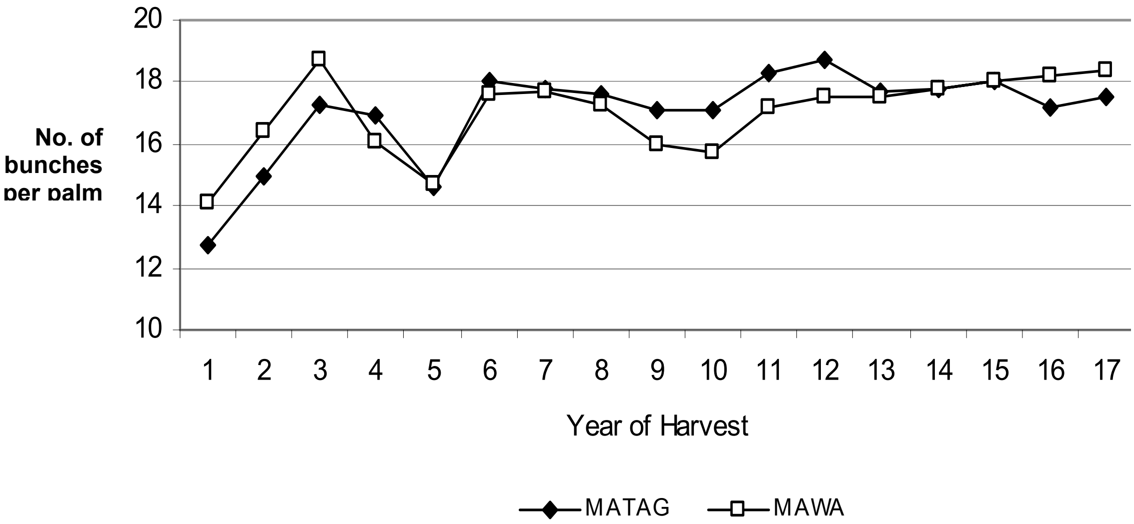


Fig 9. Number of nuts per bunch for MAWA vs. MATAG over a 17-year production period

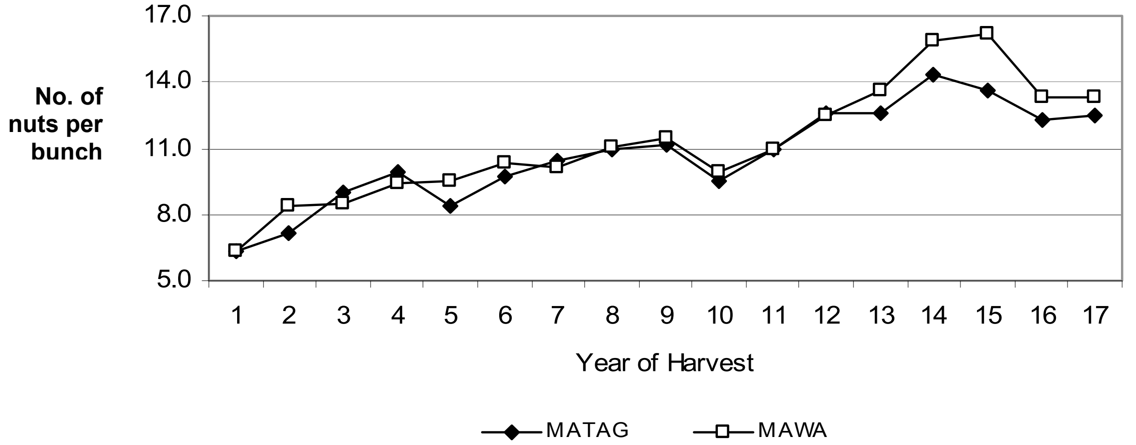
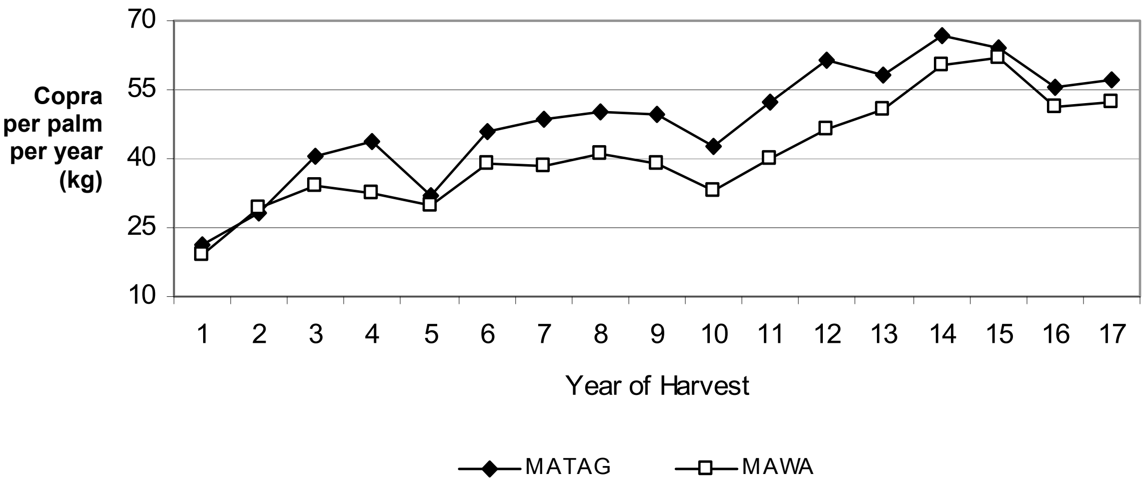


Fig 10. Dry albumen per palm for MAWA vs. MATAG over a 17-year production period



Although Figure 10 shows that the dry albumen yield has narrowed considerably between MAWA and MATAG in recent years, the MATAG holds the edge over MAWA because its larger nut size and better conversion adds more versatility in its use for downstream sector. Its higher water content and bigger endosperm makes it much sought for in the tender nut market. As such, it commands a better price premium over MAWA which tips the economic scale in favour of MATAG.

MAWA's attributes of slower germination allows longer harvesting intervals to be possible (45-day rounds) as compared to MATAG (30-day rounds). This is an advantage in the Malaysian scenario where labour constraints and logistics problems can make this a desirable feature in a cultivar.

However, both the hybrids are intermediate in height between the Dwarfs and Talls. This puts a limit to the period that Dwarf x Tall hybrids can be harvested for tender nuts since Tall palm climbers are no longer available in Malaysia (ladders are used in the local scene). In this respect, the Dwarfs have an advantage but the popularly consumed (as tender nuts) varieties of MRD and MYD have a smaller nut size and as such fetch a lower unit price as compared to MATAG.

This has prompted an attempt to try and get better varieties to add versatility of use for coconuts. New combinations are currently being evaluated and preliminary results from on-going trials are presented below together with results of the newer cycle of selections from the germplasm materials.

Tall and Dwarf germplasm in Trial 4

Laguna Tall, with an average production of 30 155 nuts/hectare, outyielded the Rennel Tall by 15 170 nuts/hectare while the Tacunan Dwarf yielded 18 392 nuts/hectare during the 8th year of harvest (Table 9).

Table 9. Comparison of yield data of Laguna Tall, Rennel Tall and Tacunan Dwarf

Details	Talls		Dwarfs
	Laguna	Rennel	Tacunan
Date Planted	Feb. 1992		Feb. 1992
Spacing	7.9 m eq.Δ		6.9 m eq.Δ
No. of Palms/ha	185		242
Layout	Block Planting		Block Planting
Yield Data – 8th Year of Harvest			
No. of nuts/palm	163	81	76
No. of bunches/palm	17.4	17.9	17.8
No. of empty bunches/palm	0.5	0.7	0.8
Dry albumen/palm (kg)	41.7	26.2	18.6
Yield Data - (8-Year Mean)			
No. of nuts/palm	142	79	78
No. of bunches/palm	16.6	16.6	17.3
No. of empty bunches/palm	0.9	1.2	1.5
Dry albumen/palm (kg)	36.4	25.6	19.1

Despite the lower bunch number of the Laguna Tall, it outyielded the Rennel Tall owing to its superior fruit set, producing an average of 9 nuts/bunch against 4 nuts/bunch by the Rennel Tall; while the Tacunan Dwarf produced 4 nuts/bunch in the 8th year of harvest.

In terms of dry albumen yield, Laguna Tall produced 7.71 t/ha against 4.85 t/ha by the Rennel Tall and 4.5 t/ha by Tacunan Dwarf during the 8th year of harvest.

Over the 8 – year period of production, the Laguna Tall yielded an average of 26 270 nuts/hectare and 6.73 t dry albumen per hectare.

Tall and Dwarf germplasm at Trial 5

Results in Table 10 showed that the Laguna Tall was the top yielder amongst the Tall varieties, producing 20 470 nuts/hectare during the 4th year of harvest. However, none of the Talls could match the MAWA which yielded 40 584 nuts/hectare. The main difference in yield was attributed to the higher fruit set in MAWA since the bunch production was similar amongst the three cultivars.

Table 10. Yield and vegetative data comparison of seven varieties in 1997

Details	Talls			Hybrid	Dwarfs		
	Laguna	Tagnanan	Rennel	MAWA*	Catigan	Tacunan	Malayan Yellow**
Date Planted	January 1997				January 1997		
Spacing (m)	8.5 x 7.5 6.5 x 7.5				8.5 x 6.5 6.5 x 6.5		
No. of Palms/Hectare	178				205		
Layout	Block Planting in Double- Hedge Rows						
No. of Sampled Palms	356	144	237	90	254	105	29
Mean Yield Data (2003)							
No. of Fruits/Palm	115	106	77	228	91	90	168
No. of Bunches/Palm	17.7	17.6	17.6	18.0	17.6	17.9	17.4
No. of Empty Bunches/Palm	0.7	0.7	0.6	0.3	0.5	1.0	0.5
Yield Data (4-Year Mean)							
No. of Fruits/Palm	90	49	77	182	92	88	118
No. of Bunches/Palm	13.3	8.8	17.8	15.4	18.0	18.2	15.6
No. of Empty Bunches/Palm	0.6	0.3	1.6	0.3	0.8	1.2	0.5
Vegetative Data (2003)							
Rachis Length of Fr.14(m)	4.16	4.70	4.07	4.22	3.61	3.65	3.49
Frond Production	17.6	17.8	17.6	17.6	18.0	17.9	17.9
Total Height (m)	4.23	5.27	3.95	3.89	2.69	2.60	2.97

* = *Control for Tall cultivars*
** = *Control for Dwarf cultivars*

Comparing the Dwarfs, both Catigan and Tacunan had comparable nut yields during the fourth year of harvest, i.e. each producing more than 18 500 nuts/hectare while the MYD Control yielded 34 944 nuts/hectare. Again, fruit set was the main factor supporting the high yields of MYD (9.7 fruits/bunch) when compared to Catigan (5.2 nuts/bunch) and Tacunan (5.0 nuts/bunch) during 2003.

Within the Talls and MAWA group, frond production was comparable while Tagnanan had significantly longer fronds and was taller than the rest of the group. Comparing the Dwarfs, both rachis length and frond production were similar while MYD was significantly taller than Catigan and Tacunan.

Tall x Tall Trial 6

During the second year of harvest, the West African Tall (WAT), WALA (WAT x LGT) and WATAG (WAT x TGT) outperformed the rest of the Talls in the trial, producing on average 26 166, 25 276 and 24 564 nuts per hectare, respectively (Table 11). The Tagnanan Tall produced significantly lower number of bunches as compared to the rest of the Talls.

In terms of dry albumen yield, the WATAG, WALA and LATAG (LGT x TGT) hybrids yielded 6.4, 6.1 and 5.2 t/ha during the first year of harvest.

The Tagnanan Tall had the longest fronds while all the Talls were comparable in terms of frond production. In terms of palm height to date, the Tagnanan and WATAG were significantly taller as compared to Laguna and Rennel Tall.

Table 11. Yield and vegetative data comparison of seven hybrids/ cultivars in 2003

Type of crosses	Name of hybrid/cultivar	Yield data - 2003 (per palm)		Vegetative Data – 2003		
		No. of Nuts	No. of Bunches	Length of Frond 14 (m)	Frond Prod'n	Total Height of Stem (m)
WAT x WAT	West African Tall	147	17.0	4.05	17.2	3.11
TGT x TGT	Tagnanan Tall	97	16.0	4.46	17.6	3.21
LGT x LGT	Laguna Tall	120	16.8	4.06	17.3	2.95
RNT x RNT	Rennel Tall	77	17.4	4.02	17.3	2.89
LGT x TGT	LATAG	128	17.6	4.32	17.2	3.11
WAT x TGT	WATAG	138	17.4	4.31	17.3	3.25
WAT x LGT	WALA	142	17.4	4.03	17.3	3.10
Mean		**121**	**17.1**	**4.18**	**17.3**	**3.09**
LSD (P=0.05)		**12.1**	**0.90**	**0.08**	**0.27**	**0.15**
(P=0.01)		**16.6**	**1.24**	**0.11**	**0.38**	**0.21**

Year Planted : August 1998
Spacing (m) : 8.5 x 7.5 and 6.5 x 7.5 (double hedge rows)
No. of Palms/hectare : 178
Plot size : 20 palms
No. of Replicates : 4
Layout : Randomized complete blocks

Mixed hybrids Trial 7

Based on the results of comparing three hybrids during their second year of production, CAWA was the top yielder, producing 21 894 nuts/hectare (Table 12). CATAG (CAD x TGT) which produced an average of 18 512 nuts/hectare was the lowest yielder in this trial. All the three hybrids were comparable in terms of bunch production but fruit set was highest in CAWA. However, in terms of dry albumen yield, the CATAG yielded 4.78 t/ha while CAWA and CALA yielded 4.75 and 4.34 t/ha, respectively.

Table 12. Yield and vegetative data comparison of three hybrids

Type of crosses	Name of hybrid	Yield data on the 2nd year of harvest (per palm)		Vegetative data (Per palm)		
		No. of Nuts	No. of Bunches	Length of Frond 14 (m)	Frond Prod'n	Total Height of Stem (m)
LGT x CAD	CALA@	119	16.9	4.12	17.3	2.84
CAD x TGT	CATAG	104	16.1	4.30	17.2	3.00
CAD x WAT	CAWA	123	16.6	4.01	17.2	2.69
Mean		**115**	**16.5**	**4.14**	**17.2**	**2.84**
LSD (P=0.05)		**12.23**	**1.09**	**0.12**	**0.13**	**0.21**
(P=0.01)		**18.52**	**1.65**	**0.18**	**0.19**	**0.32**

@ = Reciprocal cross where LGT was used as the female parent
Trial No : 3.018
Year Planted : September 1998
Spacing (m) : 8.5 x 7.5 and 6.5 x 7.5 (double hedge rows)
No. of palms/hectare : 178
Plot size : 20 palms
No. of Replicates : 4
Layout : Randomized complete blocks

Dwarf x Dwarf Trial 8

When compared in terms of copra production, MACA (MYD x CAD) was the top producer with 6.3 t/ha while Catigan was the lowest yielding with 5.2 t/ha in the third year of harvest (Table 13).

In terms of vegetative traits, all four Dwarfs were comparable in terms of both the frond length and production but when compared in terms of height, Tacunan was the shortest while the MACA was the tallest.

Mean nut production of the Dwarfs in this trial showed a significant decline - from 31 920 in the second year of harvest to 24 681 nuts in the third year (22% less). This reflects on the alternate bearing pattern of Dwarfs. MACA hybrid was marginally higher yielding as compared to the rest of the Dwarfs, yielding 26 220 nuts/hectare during the third year of harvest. The decline in this trial was both as a consequence of both lower fruit set and reduction in the number of bunches produced per palm.

Table 13. Yield and vegetative data comparison of four Dwarfs

Details	Tacunan	Catigan	MATA	MACA
Date Planted	1998			
Spacing (m)	8.5 x 5.5 and 6.5 x 5.5			
No. of Palms/Ha	228			
Plot Size	20 palms			
No. of Replicates	3			
Layout	Randomized complete blocks			
Yield Data (2003)				
No. of Nuts/Palm	100	108	110	115
No. of Bunches/Palm	17.0	17.5	17.4	17.2
No. of Empty Bunches/Palm	0.48	0.32	0.27	0.27
Dry Albumen/Palm (kg)	25.5	22.8	24.1	27.6
Yield Data (3-Year Mean)				
No. of Nuts/Palm	98	96	114	118
No. of Bunches/Palm	15.9	16.1	17.2	17.2
No. of Empty Bunches/Palm	0.49	0.38	0.33	0.45
Dry Albumen/Palm (kg)	28.0	20.3	25.0	28.4
Vegetative Data (2003)				
Rachis Length of Frond 14 (m)	3.64	3.60	3.58	3.57
Frond Production	17.5	17.4	17.4	17.4
Total Height (m)	1.84	2.05	2.08	2.35

Nut component analysis for the new hybrid combinations at UPB

Results Tables 14 and 15) of the nut components analysis shows some potentially good hybrid combinations for which early yields are promising. These are characterized by having an average fruit weight of more than 1.3kg, large nut size with mean dry albumen yield of above 200g/nut.

Table 14. Comparison of morphological data of nine cultivars

Cultivar	No. of nuts analyzed	Content per fruit (g)							
		Fruit	Nut	Husk	Water	Shell	Albumen	Dried Albumen	Oil
MACA	45	1076.4	796.2	280.2	258.4	164.4	373.3	200.8	124.3
MATA	65	1225.1	906.9	318.2	305.2	184.5	417.2	221.8	134.1
CATAG	148	1624.7	1138.0	486.7	402.1	239.5	496.4	258.6	155.1
CAWA	189	1341.1	819.2	522.0	235.1	194.2	389.8	216.9	138.5
CALA	360	1257.3	849.4	407.9	269.8	192.3	387.3	205.3	125.4
MALA	224	1348.9	974.6	374.3	351.4	184.7	438.5	234.6	144.7
WALA	15	1389.3	928.7	460.7	259.3	228.0	441.3	251.4	162.3
WATAG	288	1440.4	980.5	459.9	301.4	224.4	454.8	249.8	159.9
LATAG	87	1391.5	1003.7	387.8	326.4	209.5	467.7	227.5	140.2

Table 15. Comparison of morphological data of nine cultivars

Cultivar	Content per fruit (%)						
	Nut	Husk	Shell	Water	Albumen	Dried Albumen	Oil
MACA	74.00	26.00	15.30	24.01	34.69	18.68	11.56
MATA	74.05	25.95	15.11	24.75	34.19	18.22	11.02
CATAG	69.93	30.07	14.85	24.44	30.63	16.01	9.61
CAWA	61.26	38.74	14.61	17.34	29.30	16.31	10.44
CALA	67.41	32.59	15.38	21.00	31.04	16.45	10.04
MALA	72.32	27.68	13.79	25.84	32.69	17.49	10.80
WALA	67.65	32.35	16.80	18.35	32.50	18.61	12.06
WATAG	68.11	31.89	15.72	20.65	31.74	17.45	11.18
LATAG	71.86	28.14	15.18	23.03	33.65	16.17	10.00

Conclusion

There is scope for improving traditional Talls as shown in the data on improved yields in selected MLT x MLT crosses and some of the other combinations. However, a disadvantage of using Talls apart from WAT is the relatively faster rate of germination under the present management constraints in Malaysia. There is still an advantage of using WAT based crossings in other Tall x Tall and/or Dwarf x Tall combinations, provided that the nut yield and size of the resulting progenies are comparable to MATAG.

It is fortunate that UPB's policy of crop diversification has allowed work on coconut breeding and selection to continue despite the negative opinion prevailing on this crop since the 1980s. This resulted in the commercial release of the MATAG hybrid in 1993. Results presented have demonstrated the high yield potential of the MAWA and MATAG hybrids. New promising hybrids are also being evaluated for which there is scope in view of the new emerging downstream markets.

The focus of breeders when trying to breed and select for new or potential hybrids for commercialization has been driven primarily towards increasing copra yield. This approach was also adopted at UPB which led to commercialization of MAWA.

However, the MATAG is more versatile as a new hybrid cultivar. Its advantage over MAWA lies in its larger nut size and superior albumen conversion as well as higher copra yield.

However, diverse coconut-based products have placed a need for different breeding objectives based on the market needs. For example, high meat content is important for white meat yield/ recovery as well as milk yield and viscosity in the spray dried milk industry. The characteristic advantages can result in a premium price being offered for varieties that could produce such nuts. In this respect, WATAG, WALA, MALA and CATAG may be potentially good candidate hybrids to replace MAWA and MATAG in the future.

Other possibilities are to fulfill the demand for drinking in the tender nut market where the sweetness of the coconut water and aromatic flavour has caught on. In this respect, the MYD and AGD have a good potential to harness this market segment.

Similarly, Dwarf x Dwarf hybrids such as MACA and MATA have also a good potential as drinking nuts. Buyers are willing to pay a premium price over the MYD for these hybrids since the water is sweet and the fruit size is quite large. The advantage of these Dwarf hybrids is that they allow the adoption of a much higher planting density to boost nut yield per unit area. The longer period of harvesting of these nuts for the tender nut market (before height becomes a constraint) adds on to the long term economic benefit.

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Performance of coconut hybrids in selected countries of Asia, the Pacific, Africa and Latin America: Their potential for increasing farm productivity

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Introduction

Coconut (*Cocos nucifera* L.) varieties grown worldwide are popularly classified as Tall, Dwarf or Hybrid. The Talls (T) and the Dwarfs (D) are mostly selected races of economic importance among the local farmers. Most of them evolved from continuing natural or mass selection. The hybrids are mostly produced from intercrossing these selected races or traditional varieties (i.e., D x T, T x D, T x T) to develop the desired ideotypes, which for most breeders meant varieties with broad adaptability, pests and disease resistance, and high yield.

Promising hybrids

A few capable national coconut breeding programmes in coconut growing countries, either on their own or through foreign assisted projects, have been in the forefront of collecting, conserving, evaluating and breeding coconut germplasm since the early 80s. Each of these country programmes has produced their own set of recommended or promising hybrids. A survey of the performance of some these hybrids was conducted by the International Coconut Genetic Resources Network (COGENT) (Batugal 2004), and the result of this survey are summarized and analyzed below.

China

The Wenchang Coconut Research Institute's sole recommended hybrid is a cross between Malayan Yellow Dwarf (MYD) and the local Hainan Tall (HAT) variety. This MYD x HAT hybrid (WY78F1) exhibited early flowering (3-4 years) and 3-4 fold increase in terms of harvested nuts (80/palm/year) and copra (4 t/ha/year), compared to the Tall parent.

The Philippines

The Philippine Coconut Authority (PCA) recommended nine hybrids derived from single crosses involving the local cultivars, Catigan Green Dwarf (CAT), Tagnanan Tall (TAG), Baybay Tall (BAY), Laguna Tall (LAG), Bago-Oshiro Tall (BAO), and the introduced varieties, Malaysian Red Dwarf (MRD) and Polynesian Tall (PYT). Most of these recommended hybrids started flowering on the 3rd to 4th year. The average number of nuts per palm ranged from 117 to 155 and copra yield per hectare, from 4-6 tonnes. The local tall BAY was comparatively good producing 114 nuts/palm with a copra yield of 5t/ha. Among the nine hybrids, MRD x TAG (PCA 15-2) and MRD x BAY (PCA15-3) were outstanding giving the highest number of nuts (144-155/palm) and copra yield (6t/ha).

Thailand

The Chumphon Horticulture Research Centre (CHRC) of the Horticulture Research Institute of Thailand recommends three high-yielding hybrids: Sawi Hybrid No.1 (an introduced hybrid known as PB 121 or MAWA), and the locally developed hybrids Chumphon Hybrid

No.60 (Maphrao Yai or Thai Tall x West African Tall) and Chumphon Hybrid No. 2 (MYD x Thai Tall). A trial comparing the locally developed hybrids with the local Thai Tall (THT) in 1975 showed that THT yielded the least. The recommended hybrids exhibited nut and copra yields ranging from 80-126/palm and 3.4 4.2t/ha, respectively.

Vietnam

The Oil Plant Institute (OPI) of Vietnam recommends seven introduced high-yielding hybrids in the country which have significantly outyielded the local Tall (Ta). The introduced hybrids were PB111, PB121, PB 132, PB 141, JVA 1, JVA2 and CRIC 65 with nut production ranging 48-69/palm in 1996. The local variety Ta yielded 31-35 nuts on the same year. OPI is currently testing six local hybrids in Dong Go Experimental Center (Eo x Ta; Tam Quan x Ta; Tam Quan x BAOT); and in Binh Thanh Experimental Station (MYD x Renell Island Tall; MYD x Palu Tall; and MYD x Ta).

Bangladesh

The Agricultural Research Institute (BARI) has developed two high-yielding coconut varieties: BARI Narikel –1 and BARI Narikel-2. These varieties are broadly adapted and capable of producing 65-70 nuts/palm throughout Bangladesh. In addition, BARI is recommending two introduced varieties to the country's coconut growing communities, namely: Sri Lanka Tall (SLT) and Malaysian Yellow Dwarf (MYD).

India

The Central Plantation Crops Research Institute (CPCRI) has released the largest number (12) of single-cross hybrids among the surveyed countries, involving Chowgat Orange Dwarf (COD), West Coast Tall (WCT), Laccadive Ordinary (LCT), Gangabondam (GBGD), MYD, SS Apricot by KAU (SSAT) and East Coast Tall (ECT). All the hybrids performed better than the traditional cultivar WCT. The recommended hybrids have reported average nut yields of 98– 156/palm while the WCT has recorded only 80 nuts/palm of recorded yield. COD x WCT (Chandra Sankara), WCT x SSAT (Kera Sowbagya) and WCT x MYD (Kera Sree) produced the highest copra yields (i.e., more than 4 t /ha/year).

Sri Lanka

The Coconut Research Institute (CRI-SL) has developed two hybrids, [(Sri Lanka Green Dwarf (SLGD) x Sri Lanka Tall (SLT)] and SLT x SR, and a first generation inbred (SLT x SLT) for its national replanting programme. Their yields ranged from 80-125 nuts/palm and 3.6 – 4.0t copra/ha. Hybrids' nut yields are double that of the usual yield of the local cultivar, Sri Lanka Tall, but their copra content/yields are similar.

Vanuatu

The Vanuatu Research and Training Centre have produced hybrids involving the local cultivars Vanuatu Tall (VTT) and Vanuatu Red Dwarf (VRD), and the introduced varieties Renell Island Tall (RIT) and Brazilian Green Dwarf (BGD). The Malaysian Red Dwarf (MRD) was also used as a mother palm for crossing with RIT but the resulting hybrids only performed slightly better (in terms of copra yield) compared to the local VTT and were very susceptible to coconut foliar decay (CFD). The BGD crossed with either RIT or VTT produced the best copra yields of 4.4-5.2 t/ha but they were also found to be very susceptible to CFD. The VRD x VTT hybrids had lower copra yields (3.3-3.7t/ha) but were found to be more tolerant against CFD. Both the traditional and improved VTT types had the lowest reported copra yields of 2.6-2.8 t/ha, but comparable with the hybrid MRD x RIT.

Côte d'Ivoire
The CNRA Marc Delorme Research Station has initially identified seven outstanding hybrids: PB 213 (WAT x RIT), PB 214 (WAT x VTT), PB121 (MYD x WAT), PB 132 (MRD x TAT or Tahitian Tall), PB123 (MYD x RIT) and PB111 (CRD or Cameroon Red Dwarf x WAT).These hybrids flower very early (40-57 months after field planting) under Côte d'Ivoire conditions. Despite early flowering, they produced from 100 to 132 nuts/palm/year, which is 34% to 138% higher than the population control West African Tall (WAT). Further, their copra yields ranged from 3.15-4.8t/ha or 86-135% more compared with WAT.

Ghana
All coconut cultivars in Ghana are considered to be at risk from the Cape St. Paul Wilt disease (CSPWD), a lethal yellowing type of disease. Hence, the coconut breeding programme in the country is geared towards developing hybrids resistant or highly tolerant to CSPWD. There are six cultivars and 21 hybrids being tested in four locations: Cape Three Points, Discove, Agona Junction and Akwidae. These varietal resistance trials are still under observation although some of the test materials were already totally infected by the CSPWD.

Tanzania
The Mikocheni Agricultural Research Institute (MARI) is currently testing six hybrids with the local East African Tall (EAT) as sole pollinator. Mother palms included the Malayan Green Dwarf (MGD), CRD, Pemba Red Dwarf (PRD), MYD, MRD and improved EAT populations. In addition to determining their yield performance, the F_1 progenies are also being evaluated for their resistance to lethal disease and tolerance to drought stress.

Mexico
Coconut research at the Instituto Nacional de Investigacion Agropecuaria Y Forestal is focused on developing hybrids resistant to lethal yellowing disease (LYD). Initial hybrids were mainly derived from crosses between MYD and improved Pacific Tall populations. Intra population crosses of selected Pacific Tall were also done and these are currently being tested.

COGENT, through its CFC-funded multilocation trials, is in the process of determining the suitability of selected hybrids across its member countries (see related articles in Chapter I). The inclusion of all promising hybrids, however, is constraint by financial and material resources limiting the number of hybrid entries and location trials.

Conditions favouring coconut hybrid performance and use

Agroclimatic
In a comprehensive hybrid performance assessment study (Rethinam *et. al* 2004) initiated in 1998 in 10 countries, most of the participating countries reported that, with few exceptions, hybrids generally came into early bearing and exhibited better productivity in the wet zones than in intermediate and dry zones. The result of the study suggested that to maximize the potential of most hybrids, they should be planted under favourable soil and moisture conditions.

Farmers' preferences
As part of the APCC/COGENT study, farmer respondents in the surveyed countries were asked to indicate their varietal preference and their reasons for their selection. Of the total

381 responses, 55.6% were in favour of hybrids and 28% preferred planting the local and/or selected Talls (Table 1). However, individual countries showed diverse rates of preference for hybrids. In Samoa, all the farmers covered in the survey stated they would grow hybrids, given a second chance. In Thailand, 70% of the farmers remained satisfied with the hybrids and the rest preferred to plant Tall variety. In Indonesia, where hybrids have already spread to a large extent, only 5.56% wanted to plant the same coconut hybrids while 99.44% opted for selected local Talls and locally produced hybrids for planting the next time. High yield, early bearing and good nut size were cited as the main reasons for satisfaction with the hybrids. And the major reasons made known by the farmers for their dissatisfaction with hybrids are their being vulnerable to moisture stress, high input requirement and susceptibility to pests and diseases.

Table 1. Farmer's preferences of cultivars, given a second chance (number of responses)
Source: (Rethinam, P, P. Batugal and F.Rognon 2004)

Zone	Tall	Local/ Selected Hybrids	Dwarf	Total
Wet	31	91	43	165
Intermediate	59	75	8	142
Dry	18	46	10	74
TOTAL	**108**	**212**	**61**	**381**

Narrowing the technology gap

Although hybrids are generally known to perform better than the traditional varieties, they are currently being grown in limited areas, less than 0.1 (or even nil) to 14% of cultivated coconut farms in various countries (Table 2). The poor adoptions of hybrids are commonly attributed to inadequate information dissemination on the availability of improved hybrids/varieties, lack of adequate supply and affordability of planting materials, and inadequate management and cultural practices. These factors resulted to failure in narrowing down the productivity gap between the farmers' fields and research stations. Comparing the national yield average in farmers' fields and those of research centers in 15 coconut growing countries, the estimated technology gap in terms of either nuts or copra yield ranged from 33 to 84% (Table 2). To maximize the potentials of using hybrids to increase the income of resource-poor farmers and the total national coconut productivity, an effective campaign to disseminate suitable planting materials should address the reasons cited earlier for the poor adoptions of hybrids. For this purpose, CFC and IPGRI/COGENT published this book to provide guidelines on how to address these concerns (see Chapter 3).

Table 2. Coconut productivity in farmers' field and research stations, and area planted to hybrids
Source: (Batugal, P. and J. Oliver, eds. 2003)

Country	Annual yield: (A) Farmers' Fields/National Average		Annual yield: (B) Research Station/Hybrids		Technology gap [100-(A/B x100)]	Area grown to hybrids (% of production area)
	Nuts	Copra (t ha^{-1})	Nuts	Copra (t ha^{-1})		
South Asia						
Bangladesh	21/palm		69/palm		70	nil
India	6892/ha		23 700/ha		71	14
Sri Lanka	42/palm		63/palm		33	11
Southeast/East Asia						
Indonesia		1.1		3.5	69	5
Malaysia	10 000/ha		23 000/ha		57	n.d.
Philippines		0.78		4-6	84	n.d.
Thailand		1.2-1.5		3.0	55	10
Vietnam	38-40/palm		55-80/palm		42	<0.1
China		1.27		3.6	65	1.5
South Pacific						
Fiji		0.3-0.5		2.0	80	<5
PNG		0.66		2.8-3.6	80	n.d.
Africa						
Ghana	20/palm		n.d.			3
Tanzania	40/palm		80/palm		50	n.d.
LAC						
Jamaica		0.8		3.7	78	n.d.
Mexico		0.65		4.0	84	1

Conclusion

The country reports on recommended hybrids (Batugal 2004) and the APCC surveys on the performance of high-yielding hybrids and farmers' varietal preferences indicated that there is no universal hybrid and that, generally, hybrids perform better than traditional varieties under good rainfall and soil conditions. Based on these analyses, national breeding programmes should be designed to develop and provide either varieties or hybrids that suit specific agroecological conditions and small-scale farmers' needs. In the end, each national coconut breeding programme should be able to propose to farmers a set of well-evaluated varieties including Dwarfs, Talls, and Hybrids.

COGENT is proposing a global breeding programme to address the collective needs of COGENT member countries instead of merely those of individual countries and the adoption of participatory plant breeding approach to incorporate farmers' varietal preference.

Specifically, the proposed breeding programme shall initially aim to: 1) characterize conserved germplasm and farmers' varieties using morphometric and molecular techniques; 2) screen and identify ecotypes tolerant or resistant to LYD and drought; 3) improve yields for specific uses and adaptation; 4) develop varieties which are suitable for the production of high-value products from husk, fibre, shell, meat, water, wood and leaves; 5) develop technical support systems for national breeding programmes (i.e. information, pollen and embryo provision, etc.); and 6) provide a platform to promote the dissemination and use of the results of the above-mentioned coconut breeding projects to narrow the technology gap between the research stations and farmers' fields, and achieve socioeconomic and environmental impact. Ultimately, the programme should be able to significantly increase the choice of hybrid cultivars among coconut growing countries, by maximizing the use of available genetic resources for breeding purposes, and improving the quality of the planting materials for distribution to users or farmers.

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Chapter 3
Management practices for smallholder coconut hybrids production

- Identifying suitable production areas and scaling-up coconut hybrid production for smallholders in developing countries
- Nursery and field management practices to produce vigorous and early bearing high-yielding palms

Identifying suitable production areas and scaling-up coconut hybrid production for smallholders in developing countries

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Introduction

To obtain maximum benefit from coconut hybrid production, there is a need to plant coconut hybrids under the best environmental conditions. Likewise, to maximize benefits to coconut smallholders, there is a need to select needy but committed farmers whose farms are suitable for coconut production to participate in coconut hybrid growing.

In order to achieve the above-mentioned conditions, the following activities should be conducted: (1) identify suitable geographic areas where agro climatic conditions are suitable for growing coconut; (2) identify suitable communities within the identified geographic areas for growing coconut hybrid; (3) identify needy and committed farmers who could participate in the project; and (4) validate farm suitability of candidate farmers to select project participants.

The rationale and procedure for each of these activities are discussed below.

1. Identifying suitable geographic areas for growing coconuts hybrids

The coconut hybrids that are grown commercially are crosses between high yielding dwarf coconuts, (as female parents) and high yielding tall coconuts (as male parents). These Dwarf x Tall coconut hybrids have the genetic capability to yield up to 6.0 t of copra per hectare per year (or about 30 000 nuts per hectare per year).

However, not all areas where the local Tall coconuts or the Dwarf coconuts are growing are also suitable for the cultivation of coconut hybrids. It can be assumed that coconut hybrids can and will grow in these areas, although high yields (i.e., between 4.0 to 6.0 t of copra per hectare per year) could not be ascertained. High yields are only possible when these coconut hybrids are grown in very favourable environmental conditions characterized by:

- Soil rich in organic matter;
- Flat (0-10% slope) and well-drained areas;
- Sufficient and evenly distributed rainfall (150mm rainfall per month or 1800-2000mm rainfall per year);
- Presence of underground water (in the absence of good rainfall);
- Absence of strong winds; and
- Good field management practices (application of the required fertilizers, weeding, and pest control).

Therefore, it is necessary for any national programme to identify geographic areas as characterized above fro planting coconut hybrids.

2. Identify suitable communities for growing hybrid coconuts

A year or two prior to project implementation or field planting, conduct a socioeconomic baseline survey in selected geographic areas to:

- Determine the socioeconomic status of the communities which will be selected to plant hybrids;
- Determine who and how many farmers are interested in joining the project; and
- Prioritize the communities to be involved in the project.

The socioeconomic baseline survey should be conducted at the village level, ideally with the participation of the village officials along with the farmer-participants. A meeting should be organized for this purpose. In this community meeting, discuss or explain the following:

- Objectives of the project;
- Requirements of the project; and
- Roles and responsibilities of the farmer participants.

3. Identifying needy and committed farmers

After the necessary orientation and briefing about the project, request all interested farmers to fill-in the "Socioeconomic Baseline Survey Form" (Annex 1) with the guidance of extension/development workers. The filled-in forms should then be collected and analyzed accordingly in order to determine the socioeconomic status of the participants before the start of the project. Results of the baseline survey will later on serve as the reference material, or benchmark, for project impact study or evaluation at the middle and/or end of the project.

4. Validating farm suitability of selected farmers

Field survey

It is best to conduct the field survey or evaluation during the dry season. The field survey or evaluation is a joint responsibility of the local government unit (LGU) involved in the project and the officers of the Project.

Start the field survey only when the socioeconomic baseline survey has been completed and the prospective farmer participants have been selected based on their socioeconomic status, particularly farm income and landholding.

Inform the farmer participants that the field survey will determine the suitability of their farm for coconut hybrid production and whether high, medium, or low yields are expected.

For the actual field survey, request the farmers to dig a hole at the center of their field measuring 80 x 80 x 110 cm, a day or two prior to actual field evaluation (Annex 2, Fig. 1). Together with the farmer, measure, evaluate, and record the physical qualities of the soil (Annex 3) in his farm using the 'Farmer's Field Profile Survey Form' (Annex 4).

To obtain maximum benefit for smallholders, only farmers with suitable farms should be allowed to participate in coconut hybrid growing.

Annex 1. Socioeconomic baseline survey form

Baseline Survey Information
(AT THE START OF THE PROJECT)

COUNTRY: ________________ PROJECT SITE: ________________________________
Date: __________________________ Interviewer: __________________________________

TO THE INTERVIEWER: PLEASE FILL UP THIS FORM COMPLETELY. IF POSSIBLE, DO NOT LEAVE ANY BLANK

GENERAL

(1) Name of head of household:____

(2) Status: ☐ Single ☐ Married (3) Age: _______ (4) Gender: ☐ M / ☐ F
☐ Others (*specify*):___________ (5) Number of Family Members: ______________

(6) Education: ☐ Elementary ☐ Some High-School ☐ High-school
☐ Some College ☐ College ☐ Post-graduate
☐ No education ☐ Others (i.e., vocational), specify: _________________

(7) Religion: _____________________________ (8) No. of children going to school: __________

FARM INFORMATION

(9) Total Farm Area (*ha*): __________

Plot	Land ownership*	Range of Area in Hectare			
Coconut		0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5
Rice		0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5
Maize		0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5
Others		0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5
Others		0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5
Total area		0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5

* *i.e. land owner, tenant, farmworker*

(10) No. of coconut trees planted on farm and age of trees

Age of trees	1-5 years	6-10	11-20	21-30	31-40	41-50	51-60	Over 70
Number of coconut trees								
Average yield (nr of nuts/tree/year)								

(11) Name(s) of coconut variety(ies) planted on your farm

Varieties Planted (Local Name)	No. of seedlings planted	Year of planting	Source of planting material

SKILLS/TRAINING ATTENDED

(12) a. List present skills related to farming/ agriculture:
____

b. List other skills (e.g. masonry, carpentry, sewing etc):
____

(13) Have you ever attended any skills development training seminar or workshop?
☐ Yes ☐ No
If **YES**, what were they about? ____

SOCIOECONOMIC INFORMATION

(14) Summary of Annual Income by classification ***(this portion is just the summary of the reported income below, so they should tally when totaled)***

Sources	Amount
On-farm (agricultural products produced on the farm) Coconut based (e.g. whole nuts) Others (e.g. rice, maize, vegetables, poultry)	
Off-farm (processed agricultural products) Coconut based (e.g. coco candy, handicrafts) Others (e.g. rice wine, dried mango)	
Non-farm (income from outside the farm)	
TOTAL ANNUAL INCOME	

Sources of annual income

(15) Coconut products produced *(i.e. copra, tender nuts, fibre, shell, etc.)* pls. specify the unit	Estimated Annual Income Derived (*local currency*):				
	Sold	Consumed	Paid in Kind	Stock/ Inventory	Total
1					
2					
3					
Sub-total					
(16) Other major intercrops planted in the coconut farm	Estimated Annual Income Derived (*local currency*):				
	Sold	Consumed	Paid in Kind	Stock/ Inventory	Total
1					
2					
3					
Sub-total					
(17) Income from crops grown separate from the coconut farm	Estimated Annual Income Derived (*local currency*):				
	Sold	Consumed	Paid in Kind	Stock/ Inventory	Total
1					
2					
3					
Sub-total					
(18) Livestock raised in your farm	Estimated Annual Income Derived (*local currency*):				
	Sold	Consumed	Paid in Kind	Stock/ Inventory	Total
1					
2					
3					
Sub-total					
(19) Off-farm income other than coconut based	Estimated Annual Income Derived (*local currency*):				
	Sold	Consumed	Paid in Kind	Stock/ Inventory	Total
1					
2					
3					
Sub-total					
(20) Non farm income (e.g. overseas remittance, public servant, pension)	Estimated Annual Income Derived (*local currency*):				
					Total
1					
2					
3					
Sub-total					
TOTAL ANNUAL INCOME					

SOCIOCULTURAL PROFILE

HEALTH

When a family member gets sick or ill, how often do you seek medical advice/ help/ service (*i.e., see a doctor, traditional healer or go to a clinic or hospital*)?

☐ Never ☐ Sometimes ☐ Frequently ☐ Always

MEMBERSHIP IN ORGANISATION(S)

(21) Before the project have you been or are you still a member of any farmers' cooperative or community based organization? ☐ Yes ☐ No

If **YES**, list the name(s) of the cooperative(s)/organization(s):

Name of coop/CBO	Year	Active member		Position held	Reasons for joining/leaving
		Yes	No		

ACCESS TO AND SOURCES OF FINANCIAL CAPITAL

(22) Are you able to easily obtain loans for financing farm-related activities (e.g. to buy farm inputs, livestock)? ☐ Yes ☐ No

(23) From what source(s) do you obtain capital to finance you farm-related activity(ies)?

☐ Banks ☐ Microfinance/ microcredit ☐ Grants ☐ Subsidies
☐ Own capital ☐ Relatives ☐ Others (pls. specify):_______

If **YES**, list the name(s) of the organisation(s), coops or other financial institution(s), where you were able to obtain these loans from and the corresponding amount:

Organization/credit facility/ other sources	Amount loaned	Interest rate	Amount Repaid

LEVEL OF LIVING INDICATORS

(24) Please check the box that best describes your house at present:

☐ Thatched/palm frond roof, bamboo or wood walls and floors
☐ Wood or bamboo walls, concrete floor with thatched/ palm frond roof
☐ Wood or bamboo walls, concrete floor with galvanized iron roofing
☐ Mostly concrete with galvanized iron/ tile roofing and some wooden structure
☐ With utilities like water and electricity

(25) Ownership of the house

☐ owned ☐ rented ☐ staying with relatives

(26) Source of drinking water

☐ private well ☐ public artesian well ☐ pump ☐ piped pump
☐ bottled water ☐ others, specify

(27) Source of power

☐ kerosene lamp ☐ LPG lamp ☐ electricity ☐ others, specify

(28) Source of fuel of cooking

☐ fire wood ☐ kerosene/gas ☐ electricity ☐ biogas
☐ others, specify ____________________

(29) Type of toilet facility

☐ none ☐ open-pit ☐ closed-pit ☐ flushed/water
☐others, specify ____________________

(30) Please put a check beside the functional appliances that you presently have:

Item		Number of units	Mode of Acquisition	
			Bought	Given
☐	Radio			
☐	TV			
☐	Refrigerator			
☐	Gas stove			
☐	Electric stove			
☐	Wood / coal stove			
☐	Sewing machine			
☐	Telephone/Cell phone			
☐	DVD/VCD			
☐	Stereo cassette/CD player			
☐	Personal computer			
☐	Others			

(31) Please put a check beside the functional means of transport that you presently have:

Item		Number of items	Mode of Acquisition	
			Bought	Given
☐	Bicycle			
☐	Motorcycle			
☐	Car			
☐	Others			

(32) Please put a check beside the functional farm equipment/machinery that you presently have:

Items (indicate items)		Number of items	Mode of Acquisition	
			Bought	Given
☐				
☐				
☐				
☐				

(33) Household expenses

Particulars	Expenses/month
a. ☐ Food	
b. ☐ House rent	
c. ☐ Education	
d. ☐ Medical	
e. ☐ Utilities (i.e, electricity, water, etc)	
f. ☐ Others (specify)______________	
TOTAL	

GENDER AND DECISION MAKING

(34) Involvement of male and female of the household in the coconut farming and coconut processing activities?

Activity	Number of female(s)	Number of Male(s)
Coconut farming activities		
Coconut processing activities		

(35) Who makes the decision on the following? (Please identify)

Particulars	Decision maker (in the household)		
	Male	Female	Both
1. On how most of family income is spent	☐	☐	☐
2. In planting/replanting of coconut	☐	☐	☐
3. In cutting coconut trees	☐	☐	☐
4. On what intercrops or other crops to plant			
Vegetables	☐	☐	☐
Fruit trees	☐	☐	☐
Staple crops	☐	☐	☐
5. Livestock keeping			
Cattle	☐	☐	☐
Goats	☐	☐	☐
Other	☐	☐	☐
6. Poultry keeping	☐	☐	☐
7. Selling agricultural products			
Coconut (whole nuts)	☐	☐	☐
Processed coconut products (indicate):	☐	☐	☐
a.	☐	☐	☐
b.	☐	☐	☐
c.	☐	☐	☐
Vegetables	☐	☐	☐
Fruits	☐	☐	☐
Staple crops	☐	☐	☐
Livestock	☐	☐	☐
Whole animal	☐	☐	☐
Meat	☐	☐	☐
Milk	☐	☐	☐
Poultry			
Whole animal	☐	☐	☐
Eggs	☐	☐	☐

(36) If you are not the owner of the farm, does the land owner allow you to participate in this poverty reduction project? ☐ Yes ☐ No

If **YES**, under what conditions? ____

____

PERCEPTIONS ABOUT THE PROJECT

(37) What are your expectations of the project?

Objectives:

☐ Income increase
☐ Food security enhancement
☐ Food nutrition improvement
☐ Increase biodiversity
☐ Others, specify:

(38) Do you think the coconut biodiversity conservation component of the project could help improve your COMMUNITY's economic condition? ☐ Yes ☐ No

If **YES**, in what way? ______________________________

____

If **NO**, Why? ______________________________

____

(39) Do you think maintaining/conserving the coconut varieties on your farm will improve your livelihood? ☐ Yes ☐ No

If **YES**, in what way can your coconut varieties contribute to the improvement of your livelihood?

____

____

- Thank you very much for your time in answering this survey form -

Annex 2. Preparing for field evaluation[1]

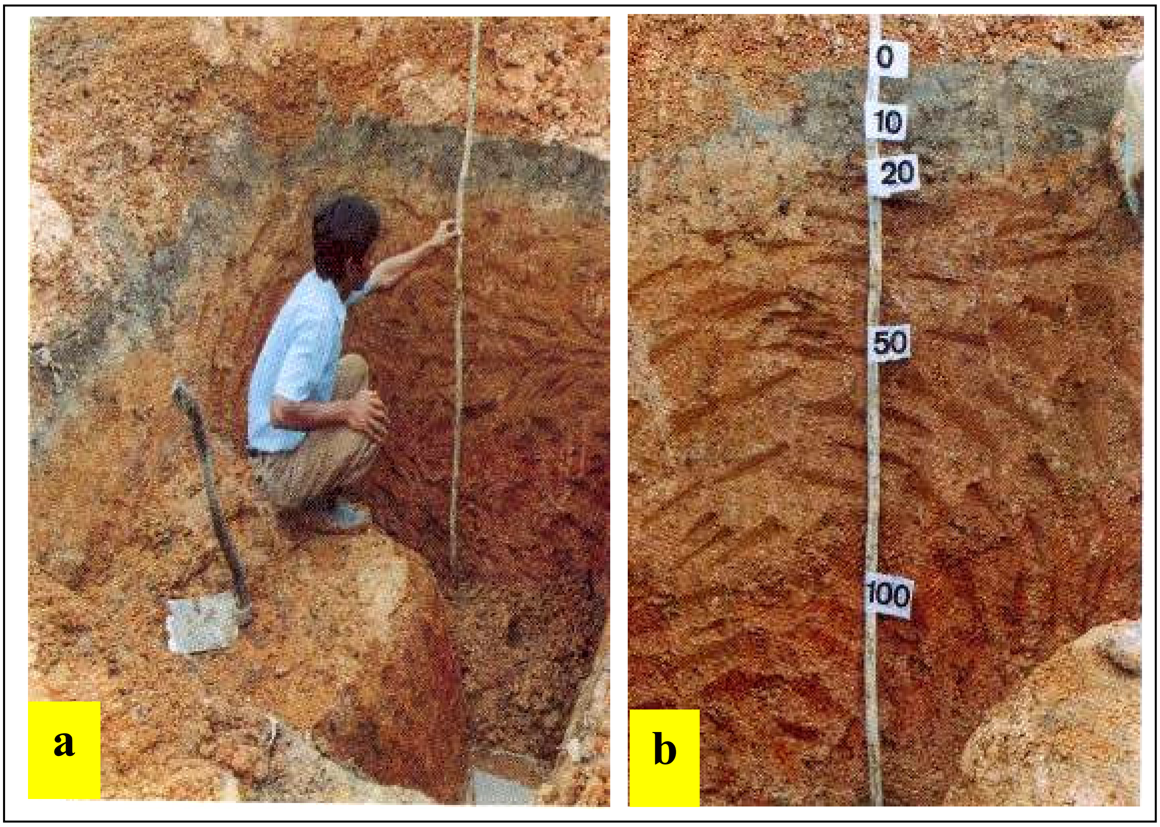


Figure 1. Determining soil depth (top soil, sub-soil)

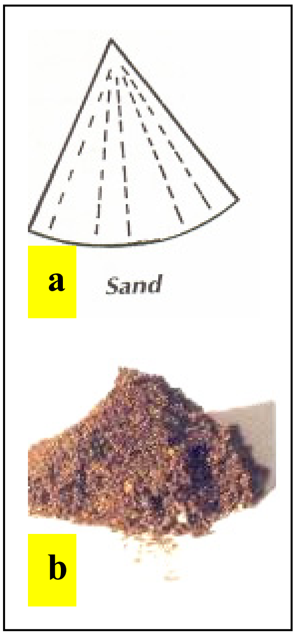


Figure 2. Sand

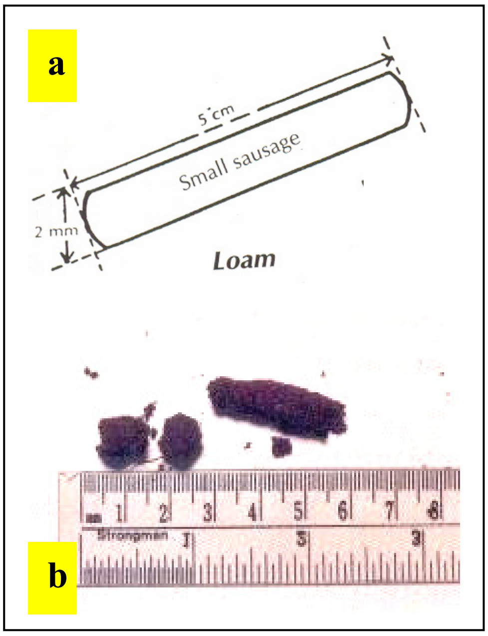


Figure 3. Loam

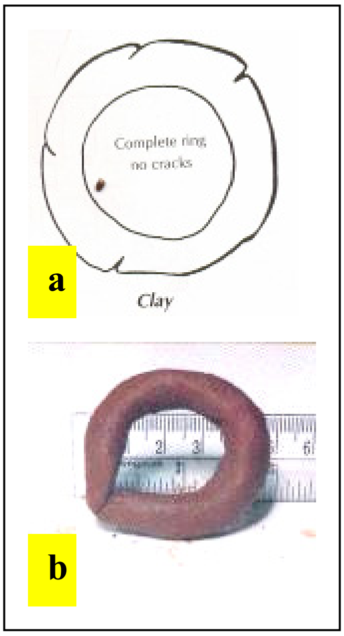


Figure 4. Clay

[1] Extracted from Michel Delabarre and Dante Benigno. 1994. Rubber: A pictorial technical guide for smallholders.

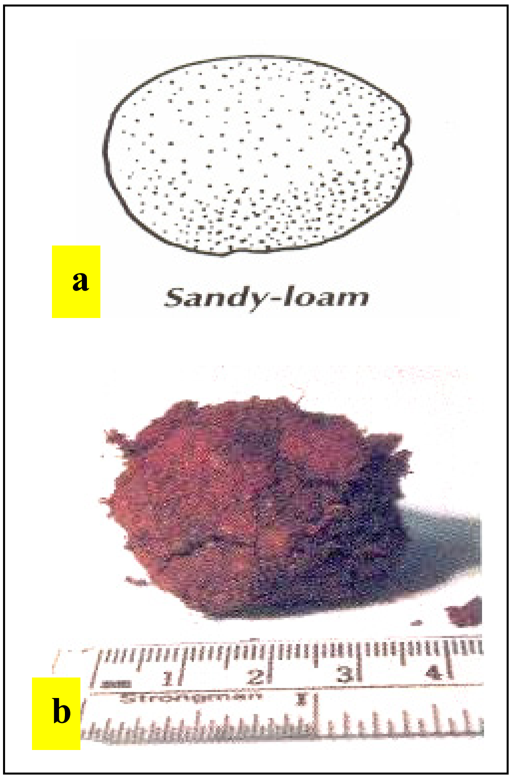


Figure 5. Sandy-loam

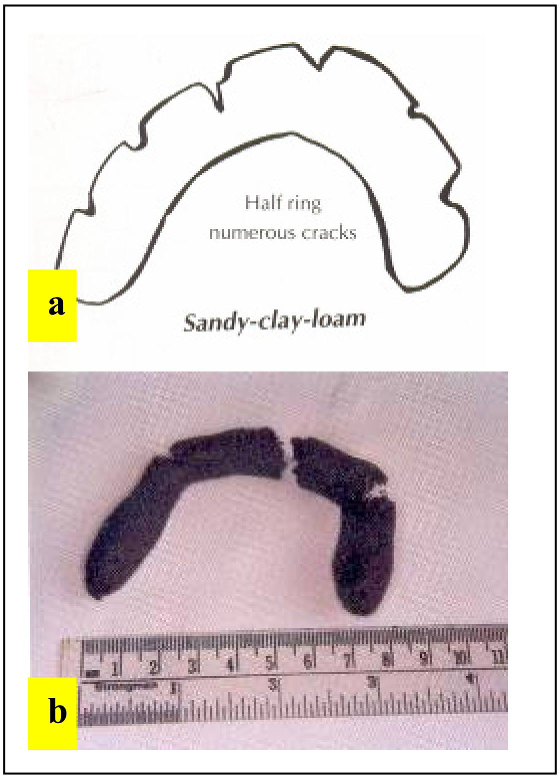


Figure 6. Sandy-clay-loam

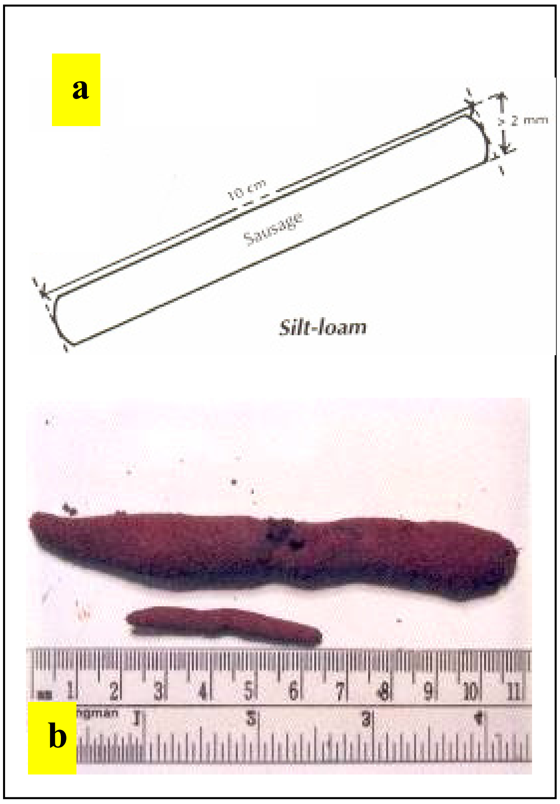


Figure 7. Silt-loam

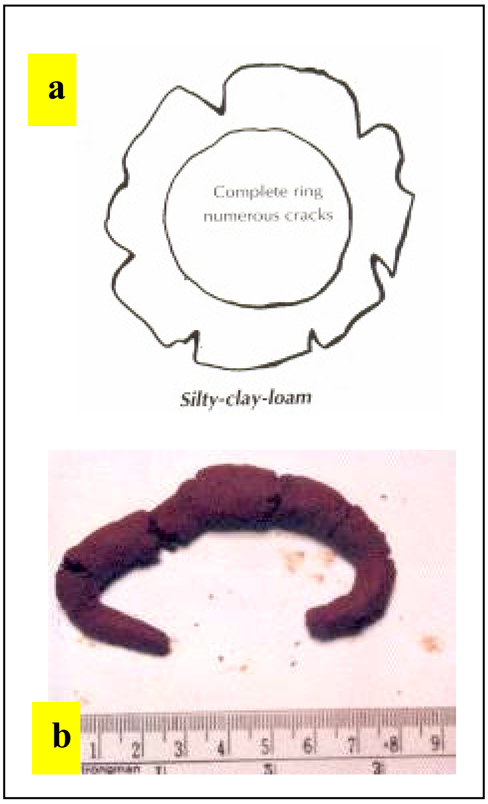
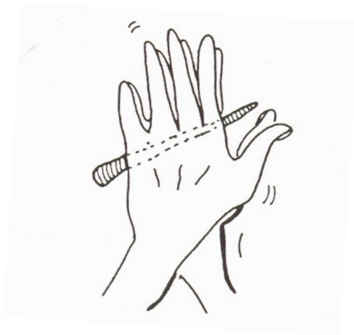


Figure 8. Silt-clay-loam

Annex 3. Determining soil texture



Rolling soil in between palms.

Soil texture is determined by the size and proportion of small mineral particles – sand, silt, loam and clay. To determine soil texture, obtain three spoonful-size samples from (1) topsoil (0-20 cm), (2) subsoil (40-50 cm) and (3) lower subsoil (80-100 cm) *[See Annex 2, Figure 1]* and roll each sample separately between your palms or on a hard flat surface. If the soil is too dry (making it hard and difficult to roll), moisten it a little to facilitate rolling.

1. **SAND** (Annex 2, Fig. 2)
   - Loose, granular, gritty particles of worn or disintegrated rock, finer than gravel but coarser than dust
   - Gritty particles that can run through the fingers forming a **cone** or **pyramid**
   - Pure leached coarse sand

2. **SILT**
   - A sedimentary material consisting of fine mineral particles, intermediate in size between **sand** and **clay**.

3. **LOAM** (Annex 2, Fig. 3)
   - Soil consisting mainly of **sand, silt, clay** and organic matter
   - Soil is considered loamy if:
     - ➢ Slightly feels gritty to touch
     - ➢ Sticks a little to the fingers
     - ➢ Rolls into sausage-shape which breaks up easily at diameter less than 2mm and lengths shorter than 6cm
     - ➢ Contains about 50% sand, 25-50% silt and 7-25% clay

4. **CLAY** (Annex 2, Fig. 4)
   - Any earth that forms a paste when wet and hardens when dry
   - Soil is considered clayey if:
     - ➢ Very hard when dry
     - ➢ Very sticky when wet
     - ➢ Rolls readily into a sausage shape
     - ➢ Readily bends to form a ring without large cracks on the surface
     - ➢ Contains about 60% clay, 20% sand, 20% silt

5. **SANDY LOAM** (Annex 2, Fig. 5)
   - Soil is loose and friable (readily crumbles or brittle)
   - Feels gritty to the touch
   - Does not stick to fingers
   - Can be molded to form a ball of about 2mm diameter
   - Cannot be rolled into a sausage shape
   - Contains about 50-70% sand, 15-20% clay and 10-30% silt

6. **SANDY CLAY**
   - Possible to make a little ball of soil that can be slightly molded without breaking
   - Contains about 75-85% sand and 15-25% clay

7. **SANDY-CLAY-LOAM** (Annex 2, Fig. 6)
   - Feels gritty to the touch when dry
   - Readily forms into sausage-shape which can be bent to form a half-ring with small cracks on the surface
   - Rolls into sausage shape but breaks when rolled to less than 2mm in diameter
   - Contains about 45% sand, 25% silt and 25-35% clay

8. **SILT-LOAM** (Annex 2, Fig. 7)
   - Hard when dry
   - Sticky when wet
   - Readily rolls into a sausage shape without breaking easily at diameters less than 2mm, or lengths longer than 10cm
   - Contains about 50% or more silt and 12-27% clay

9. **SILT-CLAY-LOAM** (Annex 2, Fig. 8)
   - Feels smooth to the touch when dry
   - Readily rolls into a sausage shape
   - Can be bent to form a half to full ring with large cracks on the surface
   - Contains about 27-40% clay and less than 20% sand

Summary of Soil Texture and Class Equivalent

	Soil Class			
	A	**B**	**C**	**D**
Soil Texture	Sandy loam	Silt loam	Silt	Pure coarse sand
	Sandy clay	Silt clay loam	Clay	Gravel & stones
	Sandy clay loam	Shallow peat	Deep Peat	Hard Pan
	Loam			
	Excellent	Good	Poor	Bad

Annex 4. Farmer's field profile survey form

Farmer's Field Profile Survey Form

1. Name of Farmer:______________________________
2. Location of Farm:
   Village ________________ Town: ________________ Province: __________________
3. Farm Area for Coconut Hybrid Planting:______ha
4. Physical Qualities of Soil (please fill out below):

Parameters *(check the class equivalent where appropriate)*	**Class Equivalent**			
	A	**B**	**C**	**D**
1. Soil depth				
● > 110 cm	( )			
● 81-110 cm		( )		
● 50-80 cm			( )	
● < 50 cm				( )
2. Thickness of Top Soil				
● > 12 cm	( )			
● 5-12 cm		( )		
● < 5 cm			( )	
● soil heavily eroded				( )
3. Soil Texture				
● **SANDY LOAM (Annex D, Fig. 5)** > feels gritty to the touch > does not stick to fingers > can be molded to form a ball (about 2cm dia) > cannot be rolled to sausage-shape > contains about 50-70% sand, 15-20% clay and 10-30% silt > soil is loose and friable (readily crumble; brittle)	( )			
● **SANDY CLAY** > possible to make a little ball of soil > can be molded slightly without breaking > contains about 75-85% sand and 15-25% clay	( )			
● **SANDY-CLAY-LOAM (Annex D, Fig. 6)** > feels gritty to the touch when dry > readily forms into sausage-shape; can be bent to form a half-ring with small cracks > sausage breaks when soil is rolled to less than 2mm in diameter > contains about 45% sand, 25% silt and 25-35% clay	( )			
● **LOAM (Annex D, Fig. 3)** > soil consisting mainly of SAND, SILT, CLAY and organic matter > a soil is considered loamy if: - slightly feels gritty to touch - sticks a little to the fingers - will roll into sausage-shape which breaks up easily at diameter less than 2mm and lengths shorter than 6 cm - contains about 50% sand, 25-50% silt and 7-25% clay	( )			
● **SILT-LOAM (Annex D, Fig. 7)** > hard when dry > sticky when wet > rolls into sausage-shape readily without breaking easily at diameters less than 2mm, or lengths longer than 10 cm > contains about 50% or more silt and 12-27% clay		( )		
● **SILT-CLAY-LOAM (Annex D, Fig. 8)** > feels smooth to the touch when dry > readily rolled to sausage-shape > can be bent to form half to full ring with large cracks > contains about 27-40% clay and less than 20% sand		( )		

Parameters *(check the class equivalent where appropriate)*	Class Equivalent			
	A	B	C	D
● **SHALLOW PEAT** > soil well decomposed > peat soil is shallow < 100 cm thick		( )		
● **DEEP PEAT** > soil is deep peat > 100 cm thick			( )	
● **SILT** > a sedimentary material consisting of fine mineral particles, intermediate in size between SAND and CLAY			( )	
● **CLAY (Annex D, Fig. 4)** > any earth that forms a paste when wet and hardens when dry > a soil is considered clayey if: - very hard when dry; very sticky when wet - can be rolled readily into sausage-shape - can be bent to form a ring without large cracks on the surface - contains about 60% clay, 20% sand, 20% silt			( )	
● **SAND (Annex D, Fig. 2)** > loose, granular, gritty particles of worn or disintegrated rock > finer than gravel, coarser than dust > gritty particles that can run through your fingers forming a CONE or PYRAMID > pure leached coarse sand				( )
4. Gravel and stones				
● No gravel / stones	( )			
● 30% gravel/stones (in volume) in the first 50cm of soil		( )		
● 30-50% gravel/stones (in volume) in the first 50 cm of soil			( )	
● >50% gravel/stone (in volume) in the first 50 cm of soil				( )
5. Hard Pan				
● No hard pan within the 110 cm soil depth	( )			
● There is hard pan within the 110 cm soil depth				( )
6. Drainage				
● Good and free drainage; Water table atleast 90 cm below ground level	( )			
● Good to moderate drainage: Water table not higher than 60 cm below ground level		( )		
● Drainage needed for tidal areas and peat soils		( )		
● Poor drainage; Water table not higher than 30 cm below ground level; drainage required			( )	
● Water table stay permanently at 50 cm below ground level; difficult to drain				( )
7. Topography				
● flat (0-10% slope)	( )			
● slopey (11-40% slope)		( )		
● steep (> 40% slope)				( )
8. Rainfall (10 year data)				
a. Average per month				
● 150 mm & above	( )			
● 120 - 149 mm		( )		
● 90 - 119 mm			( )	
● < 90 mm				( )
b. Average per year				
● 1800 mm & above	( )			
● 1500 - 1799 mm		( )		
● 1000 - 1499 mm			( )	
● < 1000 mm				( )
CLASS OF FIELD*				

***Remarks:** (1) Class of field is determined by the parameter with the lowest class (Class A is highest; Class D is lowest); (2) A: > 3.5 tons copra/ha/yr; B: 2.5-3.4 tons; C: 1.5-2.4 tons; D: < 1.5 tons

Nursery and field management practices to produce vigorous and early-bearing high-yielding palms

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Introduction
This chapter was written for the smallholder coconut farmer who will buy the seednuts and grow his own planting material. Hence, this chapter was written using an instructional format to serve as a technoguide on coconut hybrid production. It is assumed here that the smallholder farmer will provide all the investment costs required.

Nursery establishment and management
There are two types of nursery required for the production of coconut hybrid seedlings:
- Seedbed nursery
- Polybag nursery

The seedbed nursery (sometimes called pre-nursery) is where the seednuts are sown for germination purposes only. It is here where the hybrids are selected and the non-hybrids and off-types are culled out, once germinated.
The polybag nursery, on the other hand, is where the germinated and selected hybrid seedlings are transplanted, reared and cared for until ready for field planting.

The seedbed nursery

1. **Location**
   Situate the seedbed near the field to be planted. The area should be relatively flat, well-drained, preferably near a good source of water, and very accessible.

2. **Shed house**
   Depending on the size of the project, construct a multipurpose shed house (4 x 5 m or smaller) that can serve as storage for the agro-inputs, supplies, materials, small tools and equipment needed for both the seedbed and polybag nurseries. Part of the shed house should also serve as an office and rest area for the smallholder and his hired labourers.

3. **Seedbed preparation**
   A one hectare field would require 275 hybrid seednuts to produce about 200 well-selected planting materials. Hence, the seedbed to be prepared, for a hectare field planting, should measure at least 1.0m wide and 11.0m long to facilitate watering and weeding. The seedbed nursery should be fenced to prevent animals from entering.
   a. Cultivate the area for the seedbed to a depth of 30 – 40 cm;
   b. Make an elevated seedbed of 15 – 20 cm high;
   c. Provide a 0.75m pathway between beds, if more seedbeds are needed for a larger field to be planted;

d. Provide a record for each seedbed with the following information:
   - Hybrid name
   - No. sown
   - Date sown
   - Source of seednuts
   - No. of seedbed (if more than one)

   (Note: One seedbed should contain only one hybrid type)

4. Delivery and treatment of seednuts

a. Schedule the delivery of seednuts at least seven months prior to the date of field planting;
b. Seednuts for delivery are usually placed in gunny sacks, which normally accommodate 25 – 30 seednuts;
c. As soon as the seednuts are received, open the sacks and group the nuts as follows:
   - Group 1: Seednuts which germinated in transit
   - Group 2: Seednuts with husks not completely brown
   - Group 3: Seednuts with brown husks
   - Group 4: Seednuts without water

Germinated seednuts. Sow these germinated seednuts immediately in the seedbed and provide a cover over the seedbed to prevent them from wilting or drying out.

Partially brown husks. This indicates that the seednuts were newly harvested. Allow these seednuts to dry-up in the open for at least two weeks before sowing in the seedbed. DO NOT WATER these seednuts during the two-week period. After two weeks, trim the tip of each seednut and sow.

Brown husks. Seednuts with fully brown husks indicate matured nuts are ready for immediate sowing.

Seednuts without water. Discard these seednuts.

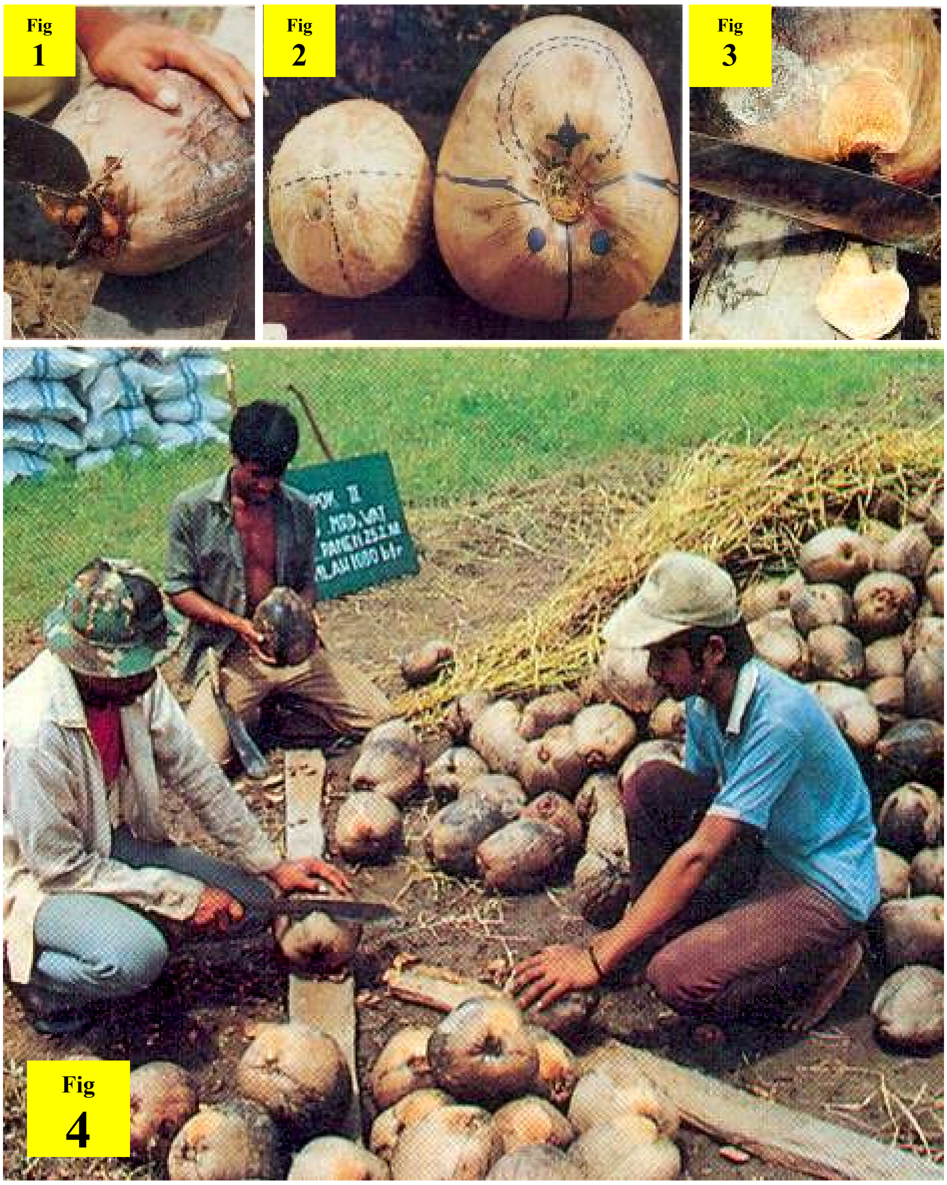
5. Caring for seednuts which germinated while in transit

a. Lay the germinated seednuts side by side with the shoot or sprout upright;
b. Put top soil in the spaces between the nuts, to keep the nuts in place when watering;
c. Construct a roof over the bed, about 1.5m high and 2.0m wide to provide good shade;
d. Use two layers of coconut leaves, or banana leaves, or long grass weeds, e.g. *Imperata cylindrica*, as roof;
e. Keep the seedlings in the bed for about 30 – 45 days (or until all leaves turned green in colour);
f. Water the bed twice per day at 10 litres per square meter of bed per day;
g. Starting on the third week after sowing, thin-out the cover by 1/3; on the fourth week remove another 1/3 of the cover; on the fifth week remove all the cover;
h. A week after the total removal of the cover, plant the good seedlings into polybags and transfer them to the polybag of nursery;
i. Before transplanting in polybag nursery, prune roots to 5 cm long;

j. Water transplanted seedlings twice a day (one litre of water in the morning and another litre in the afternoon for a two-week period; thereafter, follow the normal rate of one litre every two days).

6. **Preparing seednuts for germination**
   To facilitate sprouting and normal development of seedlings, trim the seednuts prior to sowing:
   a. Remove the calyx and peduncle of the seednut with the tip of a machete (Plate 1, Fig. 1);
   b. Determine the area where the shoot will come out (germ end), which is the widest hump of the nut, which is that portion opposite the widest segment of the nut (Plate 1, Fig. 2);
   c. Trim a shallow portion (about 5 cm in diameter and no more than 1 cm deep) nearest the germ end (Plate 1, Fig. 3, 4).

Plate1. Preparing seednuts for germination



7. Sowing trimmed seednuts in the seedbed

a. Place the trimmed seednuts side by side in the seedbed, touching each other in slightly inclined position, i.e., almost upright with the trimmed portion uppermost;
b. Scrape the loosened top-soil, about 10 cm deep, before setting the seednuts;
c. Use the scraped top-soil for filling-in the spaces between the seednuts;
d. Compact the soil by hand while leveling the soil so that only the trimmed portion of the seednut is seen.

8. Watering

a. Water seedbeds twice a day, morning and afternoon;
b. Deliver six litres of water per one square meter of seedbed per day (this is the equivalent of 6 mm rainfall per day);
c. Three hours after watering, check the amount of water delivered, by pressing the trimmed portion of nut with your thumb. Apply strong pressure to force water to come out:
   - If no water comes out, this means the seednuts were UNDERWATERED;
   - If water comes out, but runs down, this means the seednuts are OVERWATERED;
   - If water comes out but does not run down, this means that the seednuts received the right amount of water.

(Note: It is very important to adjust the volume of water delivery when UNDERWATERED or OVERWATERED in order to obtain uniform germination of the seednuts).

d. Check the moisture condition of the seednuts daily.

9. Marking hybrids, non-hybrids and off-types

a. When shoots have emerged and are about 5 cm high, mark the hybrids with white paint; then transplant them to the polybag nursery (Plate 2, Fig 1)
b. Mark the non-hybrids and the off-types (e.g., double shoots, albinos, curbed shoots and other deformities) with red paint (Plate 2, Fig. 2, 3, 4)
c. You should know beforehand the colour indicator for the hybrid (See Table 1) by asking the seednut producer; for the colour-indicator for different crosses between the male and female parents).

Plate 2. Marking hybrids, non-hybrids and off-types

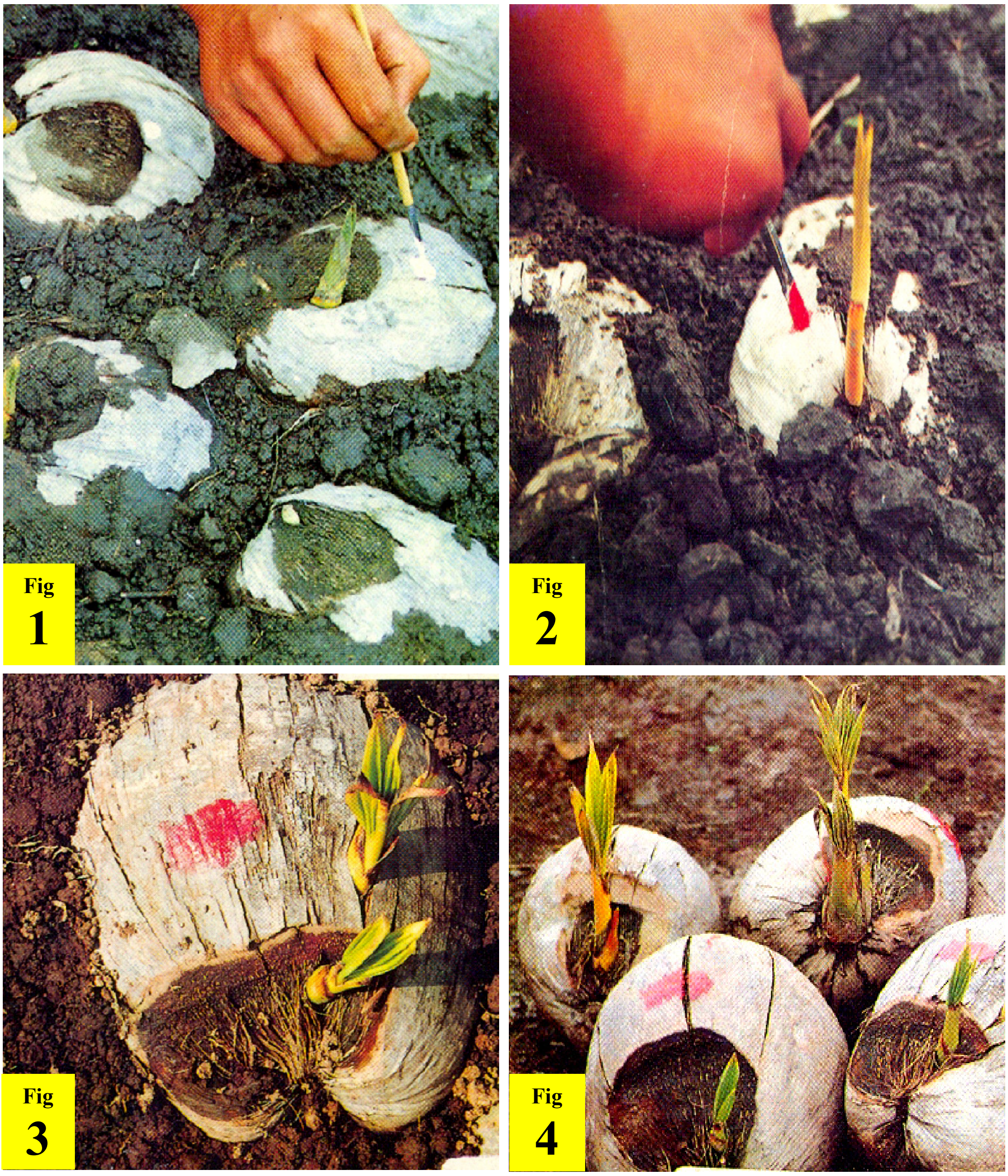


Table 1. Colour indicators for different crosses between the male and female parents

Female parent x Male parent		Shoot color of progenies
Yellow Dwarf **X**	Yellow Dwarf	Yellow
	Red Dwarf	Orange
	Green Tall	Green
	Brown Tall	Brown or Green
Red Dwarf **X**	Yellow Dwarf	Orange
	Red Dwarf	Red
	Green Tall	Bronze
	Brown Tall	Bronze

(Source: R. Bourgoing. 1991. COCONUT: A Pictorial Technical Guide for Smallholders. IRHO/ CIRAD. Pp. 99)

10. Refilling seedbed with soil

When 40 – 50% of germinated seednuts have been removed, refill vacant spaces with top soil in order not to destabilize the other ungerminated seednuts and to promote high germination rate.

11. Pricking and transporting

a. Uproot the marked germinated hybrid seednuts (with shoots of 5 cm or more in height), using an iron hook which is dug onto one side of the nut husk (Plate 3, Fig. 1, 2);
b. Pull out the hooked seednuts with all the main roots (if the soil is heavy or clayey, roots must be cut first with a sharp machete or 'bolo' before pulling the seednut; if this is not done, the bottom of the shoot might be damaged);
c. Just before transplanting the pricked seednuts, cut-back all protruding roots to 5 cm long with sharp pruning scissors (Plate 3, Fig. 3);
d. Transport prepared seedlings in a stretcher, preferably made of empty fertilizer bags or bamboo slats (Plate 3, Fig. 4);
e. See to it that each seedling is laid down on its side ensuring that the cut roots and the shoot are not damaged or injured when bringing the seedlings to the polybag nursery; three layers of seedlings can be placed per stretcher;
f. Before planting in polybags, carefully lay each seedling on its side on top of the polybag full of soil to prevent damage to shoot and roots (Plate 3, Fig. 5)..

(Note: The seednuts that germinated first should be placed on the first row (eastern side) of the polybagged nursery, then succeeding nuts in succeeding rows towards the western side of the nursery.)

Plate 3. Pricking and transporting

13. 12. Closing the seedbed(s)

a. Close the seedbed (no more selection is done), when:
   - 14 weeks had elapsed from start of seednut germination, or
   - 70% of the total seednut population has germinated (the 70% germination rate includes the hybrids, non-hybrids and off-types);

b. When 70% germination level had been reached, before the 14th week and there are still hybrids that germinated with shoots below 5 cm, extend the closure of the seedbed for one more week to allow these hybrids to grow before transplanting them to the polybag nursery;

c. After this one week extension, close the seedbed by burning on burying all the remaining germinating and ungerminated seednuts to prevent the planting of the discarded materials.

The polybag nursery

1. Location

It is best to have the polybag nursery nearest the seedbed nursery, to minimize damage to seedlings when transporting and transferring to polybags.

2. Preparing the polybags

The ideal plastic bag for the coconut hybrid is the black polyethylene bag measuring 40 cm wide, 40 cm long and 0.20 mm thick.

a. At the bottom of the polybag (last 10 cm high) provide three rows of holes at 7cm distance between rows; holes should be 5 cm in diameter and distanced at 5 cm between holes (Plate 4, Fig. 1);

b. Before filling the polybag with soil, turn it inside out (reversing); to do this, place both hands inside the bag, grasp the corners then pull out until the polybag is completely reversed (Plate 4, Fig. 2); the bottom of the polybag is now rounded and can stand firmly (Plate 4, Fig. 3).

3. Preparing the soil for the polybag

a. Use top soil for the polybag;

b. Sieve top soil with a wire-mesh sieve to remove large lumps of soil, stones, and plant debris (Plate 4, Fig. 4);

c. Place sieved soil into polybag, filling it up to the brim (Plate 4, Fig. 5);

d. Distribute the soil-filled polybags in groups in strategic locations of the nursery to reduce handling cost (Plate 4, Fig. 6)

Plate 4. Preparing the polybag and soil

4. Laying-out the polybag nursery

a. For rapid lining and staking make a 'template marker', made up of wooden frame: 4.0 m long and 0.51 m wide (two-row system); on the wooden frame, mark the corners of the 60x60x60 cm triangle with white paint; a dozen triangles in the wooden frame can be made (Plate 5, Fig. 1);
b. Or make a three-row template marker (Plate 5, Fig. 2, 3);
c. Line the nursery with a rope on a North to South orientation; lay down the template along the rope then put sticks or markers (about 30 cm long) on the corners of the triangle where the polybags will be laid down;
d. Make as many rows as needed.

5. Placement of polybags

a. Place the soil-filled polybags behind the sticks oriented North to South (Plate 5, Fig. 3);
b. See to it that the polybags are equidistant from each other and in straight rows to facilitate movement within the nursery when watering, weeding, fertilizing and spraying with pesticides.

6. Transplanting and watering

(Note: Set the polybagged seedlings in the same order as they germinated, i.e., the seedlings that germinated first are placed in the first row in the eastern side of the nursery moving westward in accordance with the order or succession of germination.)

a. Carefully remove the seedling laid on top of the polybag filled with soil (Plate 6, Fig. 1);
b. Carefully lay down the seedling at one side of the polybag, preferably on a clean plastic sheet (Plate 6, Fig. 1);
c. Remove about a third of the soil from the polybag, placing the soil on the clean sheet of plastic with the seedling (Plate 6, Fig. 1);
d. After removing a third of soil, place the seedling inside the polybag seeing to it that the shoot is at the centre and in an upright position; the nut slightly inclined, trimmed part uppermost, about 2 cm below the rim of the polybag (Plate 6, Fig. 2);
e. Put back the removed soil into the polybag until the nut is almost covered; compact the soil with your hand (fingertips) (Plate 6, Fig. 3);

Plate 5. Laying-out the polybag nursery

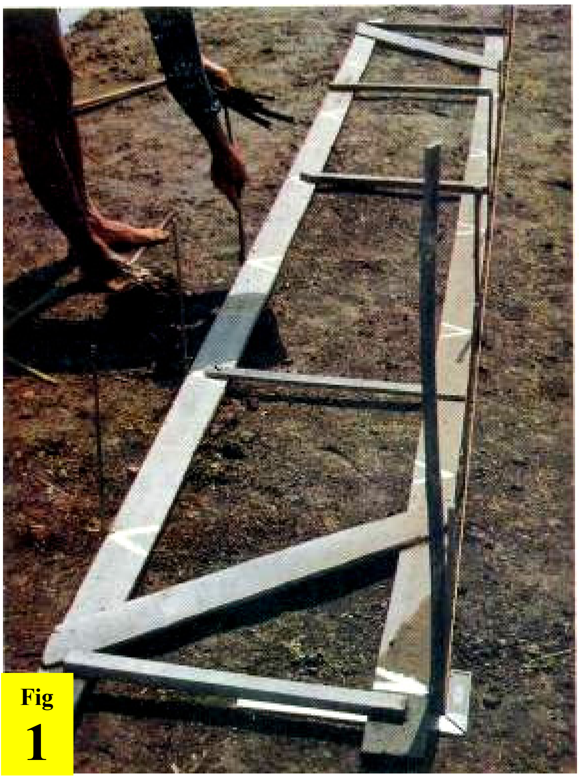


Fig 1

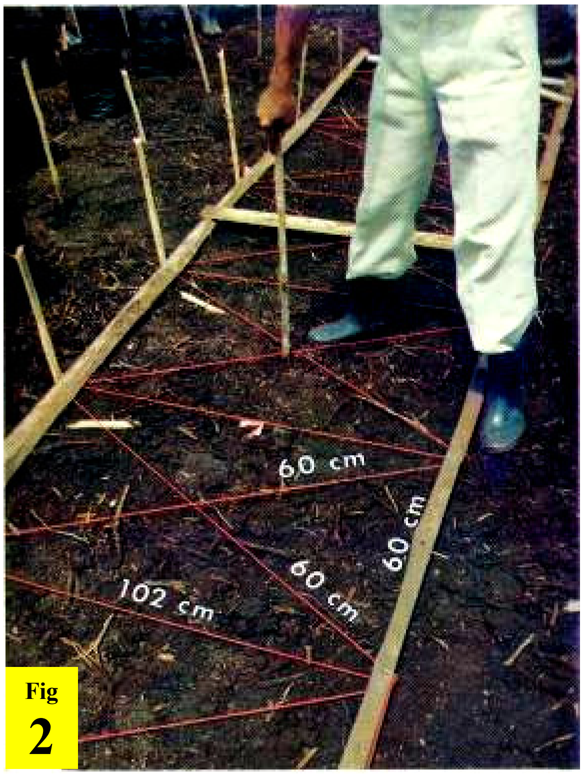


Fig 2

Fig 3

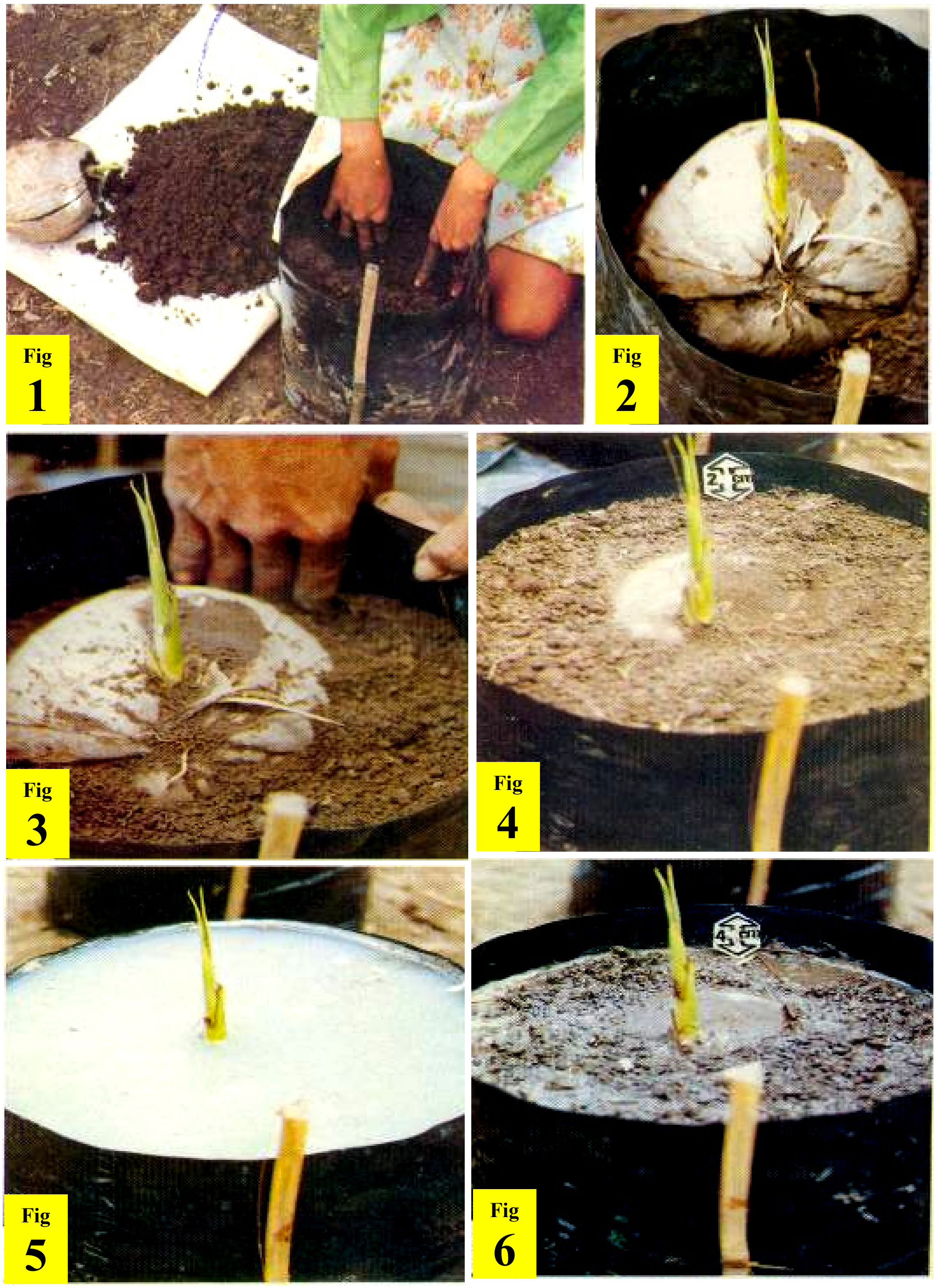
f. Add more soil as necessary and compact it until the soil level is 2 cm below the rim of the polybag and the trimmed portion of the nut is at the same level as the soil (Plate 6, Fig. 4);
g. Within two hours after transplanting, water the seedlings up to the brim of the polybag in order to bring the soil moisture content to full capacity and to get better soil compaction (Plate 6, Fig. 5);
h. When the soil in the polybag is down to more than 4 cm, one week after transplanting, add some soil to maintain the height of the soil at 4 cm below the rim of the polybag (Plate 6, Fig 6).

7. Maintenance

a. Watering
   - When seedlings are 1 – 3 months old, the water requirement per seedling is one litre every two days;
   - When seedlings are 4 – 6 months old, the water requirement per seedling is two litres every three days;
   - When there is sufficient rain (over 20 mm) do not water the seedlings.

b. Weeding
   - Manual weeding should be done once a month or as needed, just before the scheduled fertilizer application;
   - Remove all weeds growing in the polybag and between polybags;
   - Weeding can also be done by spraying herbicides between polybags, seeing to it that the seedlings are not sprayed.

Plate 6. Transplanting and watering



c. Fertilizing

The recommended fertilizers and dosages for polybagged seedlings are shown in Table 2 below.

Table 2. Recommended fertilizer for polybagged seedlings

Fertilizers, dosages & schedules of application per polybagged seedling (gm/plant)										
Fertilizers		**Age of seedling (months)**								**Total (gm/plt)**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
N	Urea or	5	5	5	10	10	10	15	15	75
	Ammonium Sulfate (NH_4SO_4)	10	10	10	15	15	15	20	20	115
P	Triple Super Phosphate (TSP)	10	0	10	0	10	0	10	0	40
K	Potassium Chloride (KCl)	10	10	10	15	15	15	20	20	115
Mg	Kieserite or	5	5	5	10	10	10	15	15	75
	Dolomite	20	0	0	30	0	0	40	0	90
Cu	Copper Sulphate ($CuSO_4$)	0	0	0	5	0	0	0	0	5
Fe	Ferrous Sulphate ($FeSO_4$)	0	0	0	10	0	0	0	0	10

(Source: R. Bourgoing. 1991. COCONUT: A Pictorial Technical Guide for Smallholders. IRHO/ CIRAD. Pp. 123)

- TSP is applied from the first to the third day of each scheduled month;
- Urea or Ammonium Sulfate (NH_4SO_4), KCl, Kieserite or Dolomite are applied from the 15th to the 20th day of each scheduled month;
- Dolomite is first applied at transplanting time at 20 gm per polybag
  - Mix Dolomite with the soil at the bottom of polybag just before transplanting the seedling into the polybag;
- Application of $CuSO_4$ (25% Cu) and $FeSO_4$ (20% Fe) are only required in peat soil areas:
  - Apply once on the fourth month just after the N, K, Mg application.

d. Culling

Culling is the removal of all undesirable seedlings from the polybag nursery. This process is done once a month starting from the second month of transplanting up to field planting time.

- Mark all seedlings to be culled out by painting a white <u>letter X</u> on one side of the polybag;
- On the second month after transplanting, cull-out:
  - Non-hybrid seedlings
  - Dead seedlings
- On the third month after transplanting, cull-out:
  - Seedlings with double shoots
  - Seedlings with stunted growth
  - Seedlings with long thin leaves
  - Seedlings with abnormal leaf emissions

- On the fourth month after transplanting, cull-out:
  - All dead seedlings
  - Diseased seedlings

- On the fifth month after transplanting it is expected that all the seedlings in the nursery are hybrids, hence, only the hybrid seedlings with poor growth or vigor should be culled out.

[Note: All culled seedlings must be immediately removed from the polybag, piled up and burned or buried]

e. Preparing polybagged seedlings for transplanting in the field
- Two weeks before the scheduled transplanting date, do the following:
  (i) Repair all damaged polybags, i.e., torn, by wrapping them with left-over polybags which are tied tightly in place with nylon raffia or any suitable tying material;
  (ii) Determine and mark the planting depth of the seedlings:
    - If seedling is to be transplanted at six months from polybagging, measure from the top of the nut to 6 cm up the base of the seedling, then mark the height with white paint;
    - If seedling is to be transplanted at seven months, measure 7 cm up the base of seedling and mark with white paint;
    - If seedling is to be transplanted at eight months, measure 8 cm up the base seedling and mark with white paint, and so on.
  (iii) Cut-back all roots protruding out of the polybag at the side and bottom with a sharp pruning scissors, or with a sharp sickle; while doing this operation be sure not to damage the bottom of the polybag and/or spill the soil of the polybag;
  (iv) Carry seedling properly by supporting the bottom of the polybag with the palm of one hand and holding the stem of the seedling with the other hand.
- One or two days before lifting the seedlings for the field, water them to capacity;
- If the weather is dry, water the seedlings one hour before distributing them on the field to prevent unnecessary drying up of seedlings should there be a delay in transplanting and also to prevent breakage of the polybag at planting time.

Field establishment and management

The coconut palm, like any other crop, requires a well-prepared land before planting. The well-prepared land could, likewise, be used for the planting of cash crops as intercrops during the first three years of coconut establishment. Or the cleared land could just be planted to leguminous cover crops (LCC) to keep down the weeds and provide natural source of nitrogen.

Land clearing

1. Land clearing could be done a year before the scheduled planting of the coconut hybrid, if maximum utilization of the land is required for intercrops; or land clearing could be done a few months prior to planting of the coconut hybrid, if monocropping is practiced.
2. Do land clearing at the start of the dry season so that the cut trees, shrubs, stumps, weeds and other plants could dry up easily then burned before plowing and harrowing are done.

3. Completely burn plant debris to eliminate breeding sites for the *Oryctes* beetle – the major insect pest of young coconuts.
4. If the land to be planted is with old coconut palms, proper disposal of the coconut crown and trunk are necessary in order to eliminate a breeding place for the *Oryctes* beetle:
   a. With an axe or chainsaw, cut down the coconut palm at about 50 cm from ground level or at the highest level where the roots emanate;
   b. As soon as the palm is felled, cut all the leaves at the crown; then cut the growing point (cabbage) from the main trunk:
      - Sell the cabbage, or
      - Use it as food, or
      - Cut it in half or split it into four parts and dry under the sun so that it will not become a breeding material for the *Oryctes* beetle.
   c. From the top end of the trunk where the cabbage was cut or separated, measure 3 meters down the trunk and cut it, (this is a soft portion of the stem), then chop it into meter-long sizes;
   d. Split it in half and expose the cut side under the sun for rapid drying and later on burn it or use it as fuel.
   e. For the rest of the trunk you may:
      - Sell it as log or saw it as lumber, or
      - Use it as a building material, or
      - Split it in half and dry the split side-up under the sun, and later on burn it or use it as fuel.

Land preparation

1. It is best that the land be plowed and harrowed right after land clearing and could either be planted to:
   a. Food crops as intercrops; or
   b. Leguminous cover crops (*Centrosema pubescens, Calopogonium mucunoides*, and *Pueraria javanica;* a mixture of seeds could be sown at the rate of 15 – 20 kg/ha)
2. Plow the field to a depth of 30-40 cm.
3. Harrow the field 2-3 times to remove plant debris and to pulverize the soil.
4. Fence the whole field to keep away stray animals.

Planting system and distance of planting

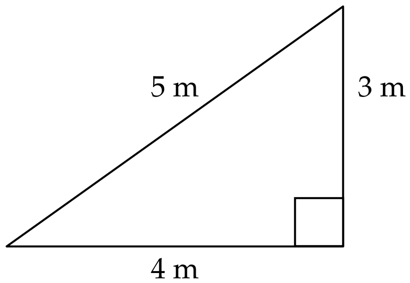
1. The planting system and the distance of planting to be adopted will depend on whether the coconut will be grown as a monocultured crop or with intercrops throughout the life of the coconut.
2. For monocultured coconut, the triangular system of planting is recommended because more trees could be planted per hectare. The distance of planting and the density per hectare vary according to the following hybrid type:

Table 3. Planting distance

Hybrid	Planting Distance		Density Per Ha (no. of palms)
	Between Palms	Between Rows	
Tall x Tall	9.0 M	7.8 m	143
Dwarf x Tall	8.5 m	7.35 m	160
Dwarf x Dwarf	8.0 M	6.9 m	180

3. For coconuts with intercrops, the square method of planting, at a distance of 10 meters, is recommended in order that the intercrops receive enough sunlight.

4. Start the first planting row at the easternmost part of the field, then move westward for the succeeding rows.
5. All coconut planting rows should be oriented North to South so that the coconut palms receive enough sunlight throughout the day. With a compass, determine first the widest East-West dimension of the field; establish base line to as far as possible (Plate 7, Fig. 1);
   a. Using the East-West baseline as reference line, establish the North-South planting row using the 3, 4, 5 method of establishing perpendiculars (Plate 7, Fig. 2), i.e., make a right-angled triangle wherein the upright (vertical) leg is 3 meters long, the horizontal leg is 4 meters long and the inclined leg connecting the 3 and 4 meter legs is 5 meters long as shown below:



   b. The planting design recommended here is for 160 trees per hectare, i.e., 8.5 meters triangular planting with 7.35 meter distance between rows.

4. To establish the 8.5 m x 8.5 m x 8.5 m triangular distance of planting, do the following:
   a. Measure a 19 m length of a 2.0 mm diameter nylon rope (preferably red colour); at each end tie a wooden handle (Plate 7, Fig.3);
   b. Fold the nylon rope equally in two to get the mid-part of the rope; mark this mid-part by tying tightly a 10 cm long nylon blue ribbon (Plate 7, Fig.3);
   c. From this marked centre of the nylon rope, measure 8.5m in one direction and another 8.5m in the other direction (Plate 7, Fig. 3);
   d. Then measure also a 50 m long red nylon rope (2.0 mm diameter); place wooden handles at each end
      - At every 8.5 m long, put in place (by tightly tying) a 10 cm long blue nylon ribbon as planting point markers throughout the length of this red nylon rope.
   e. Stretch this marked 50 m long red nylon rope along the designated planting rows (North-South orientation)
      - Place bamboo or wooden pegs at every 8.5 m distance marked by the blue nylon ribbons for the whole length of the rope; these are the planting points or where the holes will be dug (Plate 7, Fig. 4).
   f. Get the marked 19 m long red nylon rope and make a triangle as shown in Plate 7, Fig. 4.
   g. Place a bamboo or wooden peg inside the empty angle at each triangle
      - Continue doing the lining and staking until the whole field is completely lined and staked.

Plate 7. Lining and staking

Fig 1

Fig 2

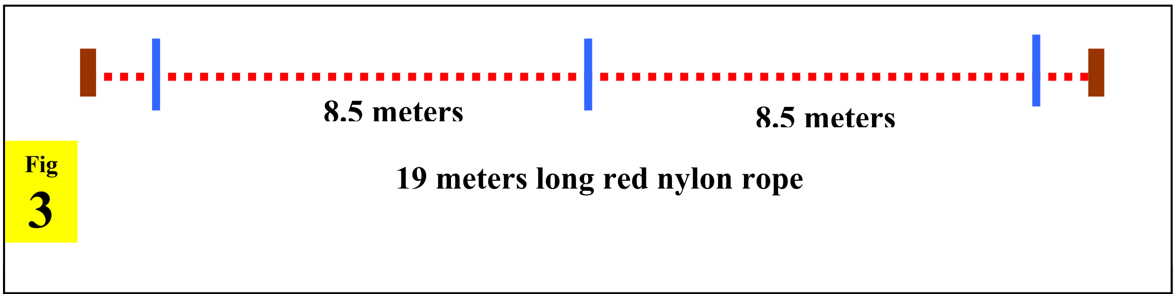


Fig 3

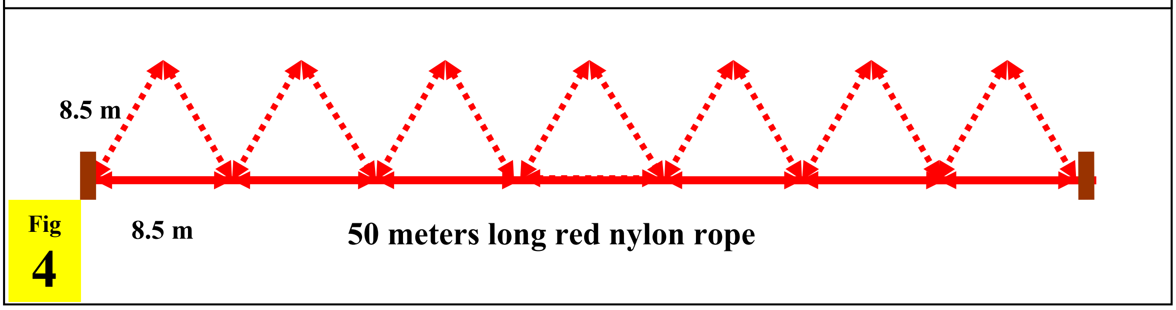


Fig 4

Holing

The size of the hole depends on soil-type. For heavy soils (i.e. clay content is 50% or more) the size of the hole should be 80 cm wide x 80 cm long and 80 cm deep. For light and medium light soils (sandy loam to clay loam), the size of the hole should be 60 cm wide, 60 cm long and 60 cm deep.

1. Make a 60 cm or 80 cm square template or a 'hole-marker' made of wood or bamboo.
2. Place this template in the area where the hole will be dug; see to it that the planting stick is at the centre of the template:
   a. Mark the four corners of the template with short wooden or bamboo pegs;
   b. Remove the template and the planting stick; line the edges of the hole with a hoe;
   c. Dig the hole; place the topsoil on one side of the hole and the sub-soil on the other side of the hole.

3. Check the hole if the width, length, and depth are of standard size (80x80x80 cm) or (60x60x60 cm) by using a measuring stick:
   a. Nail a 60 cm or 80 cm long horizontal stick into a 100 cm long vertical stick (looks like a 'cross');
   b. Nail this 60 cm or 80 cm long horizontal stick at a height of 60 cm or 80 cm from one end of the 100 cm vertical stick;
   c. Place this measuring stick (or 'cross') inside the dug hole and check if the desired measurements were attained or not;
   d. Place back the planting stick at the centre of the hole using the 'cross' as guide for the centre of the hole.

(Note: On the average, 15 – 20 holes can be dug per man-day)

Planting

1. Distribute one polybagged seedling per planting hole by placing the seedling on one side of the hole.
2. Before planting, check the depth and width of the planting hole if of standard size, using the 'cross' stick used as a measuring instrument during the digging of the holes:
   a. If the hole is not deep enough, dig it to proper depth (e.g., 60 cm);
   b. If the hole is too deep, adjust depth by filling the bottom of the hole with topsoil then compact the soil.
3. Using a meter long stick, measure the required depth for the seedling from the bottom of the polybag to the white marker at the stem-base of the seedling, the white marker should be in level with the top portion of the hole.
4. As soon as the required depth is measured, mix 350 gm TSP with the topsoil (previously heaped on one side of the hole) and place the mixed fertilizer-soil at the bottom of the hole up to the level to which the bottom of the seedling should be set (i.e., 60 cm or 80 cm deep measured from the top portion of the hole).
5. Transplant the seedling:
   a. Remove the bottom of the polybag with a sharp knife at 5 cm high from the bottom;
   b. Place the seedling (with the cut-bottom polybag) into the centre of the hole; see to it that the stem-base of the seedling is at level with the top portion of the hole;
   c. Slowly pull-up the polybag; place top-soil into the hole; compact it; add top-soil then compact it again until the soil level is slightly higher than the white marker on the stem-base of the seedling;
   d. Level the soil in a slightly convex shape so that the white marker is barely visible.

Maintenance

1. Replanting

   Replanting should be done within the first year of planting and at the start of the second year after field planting:

   a. Survey the whole field and count how many palms will be replaced;

   b. Replace palms that are:
      - Dead or dying
      - Severely damaged by the *Oryctes* beetle
      - Heavily infested with leaf sucking insects
      - Heavily infected with leafspots
      - Damaged by wild pigs and other animals
      - Stunted in growth

   c. Get your supplies from the remaining polybagged seedlings in your nursery; there should be at least 40 seedlings left for replacement.

   d. Prepare over-aged seedlings for field replacement as follows:
      - Uproot carefully the seedling by cutting all roots protruding at the sides and bottom of the polybag;
      - Lay down the seedling;
      - Grasp all the leaves and cut down to a third of the leaves, (measuring from the tip of the longest leaf;
      - Mark with white paint the planting depth in relation to the age of the seedling:
        - 9 cm from top of nut for transplanting at 9 months old
        - 10 cm from top of nut for transplanting at 10 months old
        - 12 cm from top of nut for transplanting at 12 months old
        - 13 cm from top of nut for transplanting at 13 months old
      - Plant the replacement seedlings as described in previous sections.

2. Intercropping

   Intercropping annual and perennial crops with coconuts is a common practice in most, if not all coconut growing countries of the world. The kind of intercrop to grow depends on the growers' preferences, whether just for food or subsistence as an additional source of income or both.

   a. When growing intercrops under or between the hybrid coconuts, the following agronomic factors should be taken into consideration:
      - The intercrop should be suitable to the prevailing soil and climatic conditions in the area
      - The intercrop should not have an economic life longer than the coconut hybrid
      - The intercrop should not grow taller than the coconut hybrid
      - The intercrop should be shade tolerant
      - The intercrop should not interfere with the growth of the coconut hybrid
      - The yields obtained from the intercrop and the coconut hybrid should be greater in monetary terms than that of the hybrid when grown as monocrop
      - The intercrop should not have the same pests/diseases as that of the hybrid coconut
      - The coconut hybrid should continue to yield at an economic level unaffected by the previous intercrops, be they annual or perennial crops

   b. From the point of view of intensive cropping, the following should be considered:

- Pattern of growth of the coconut hybrid
- Soil and energy utilization, and
- Interception of sunlight by the hybrid's canopy

c. The life span of the coconut hybrid (e.g. Dwarf x Tall), from the point of view of intensive cropping, could be divided into three distinct phases:
   - **<u>Phase 1: 1 – 4 years old</u>**, considered as the vegetative stage, is suitable for the intercropping of annual crops or relatively short duration crops which do not compete or hamper the normal growth and development of the hybrid. The spaces between the rows that could be intercropped depend on age of palm:
     - 1st year, 60% of the field could be intercropped with annuals
     - 2nd year, 50% of the field could be intercropped with annuals
     - 3rd year, 30% of the field could be intercropped with annuals
     - 4th year, no more intercropping of annual crops
   - **<u>Phase 2: 5 – 10 years old</u>**, considered as the hybrids' early stage of maturity. The spaces between the rows could be intercropped with perennial trees which tolerate shading.
   - **<u>Phase 3: above 10 years old</u>**, considered as mature stage. There is considerable lateral sunlight and reflected light available. A number of annual and perennial crops could be grown as MULTI-STOREY crops, (Consult your extension worker on the recommended crops in your area).

Cover cropping

a. Secure seeds of the following leguminous cover crops (LCC): *Centrosema pubescens*, *Calopogonium mucunoides*, and *Pueraria javanica*

b. For a one hectare coconut planting the seed requirement would be: 2 kg seeds for each of the three above mentioned LCCs:
   - Mix the 6 kg of LCC seeds with 12 kg TSP fertilizer (Plate 7, Fig.1)

c. As soon as the field to be planted with coconut hybrid is cleared, plowed and harrowed, the (LCC) seeds could be sown along the designated tree rows; or as soon as the annual intercrop has been harvested:
   - Make two furrows, 70 cm apart, 5 cm deep and a meter short of the planting hole (if no plantings done yet) or a meter short from the base of the coconut palm (Plate 7, Fig. 2);
   - Between two planting holes or two coconut palms spread evenly in the 2 furrows 110 gm of the seed/fertilizer mixture (Plate 7, Fig. 2, 3);
   - Cover the seeds/fertilizer mixture with soil, about 1 cm thick.

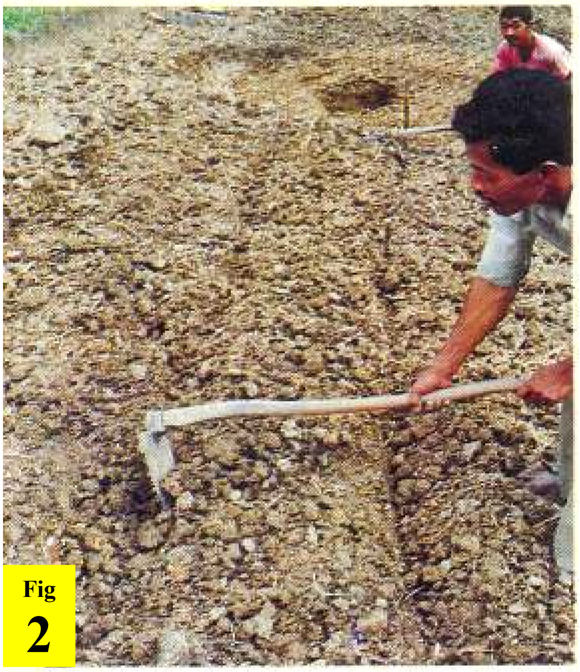
[Note: Make a measuring cup by cutting the bottom of a 500 ml plastic bottle to a height that will contain 110 gm of the LCC seed / fertilizer mixture. From this filled-up measuring cup, evenly distribute or spread the mixture in the two furrows. To do this properly, place a small amount of the mixture on your hand, then use your thumb to push out bits of the mixture into the furrow]

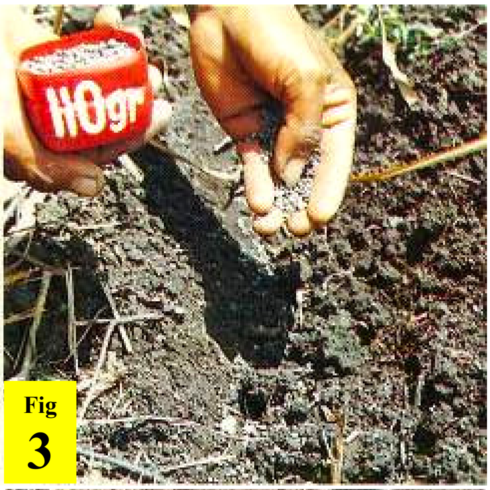
d. One month after the germination of the LCCs, apply TSP fertilizer again:
   - Weed first both sides of the LCC rows before placing the fertilizer;
   - With a measuring cup of 590 gm capacity, scoop up the TSP and spread evenly on both sides of the two LCC rows between the two coconut palms;
   - Cover the fertilizer with a thin layer of soil.

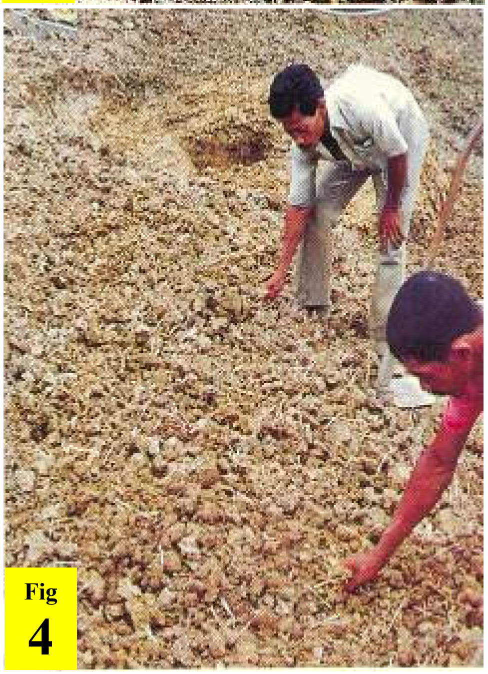
(Note: One hectare coconut planting requires 188 kg TSP for all the LCCs growing along the tree rows.)

Plate 8. Cover cropping

e.







After the third year of intercropping, allow the LCCs to creep over and cover the interrows so that on the fourth year after planting, the whole field will be covered with LCC.

Circle weeding

a. Circle weeding is done yearly, just before the fertilizer application.

b. The recommended standard radius of the circle to be weeded is related to the age of the coconut palm:
- Year 1 – 2 = 1.0 meter
- Year 3 = 1.5 meters
- Year 4 onwards = 2.0 meters

c. During the first year of planting, circle weed by shallow hoeing only:
- Do not dig closer than 20 cm from the base of the palm
- Pulverize dug soil
- Remove all rhizomes of *Imperata cylindrica,* if found

d. When circle is free of weeds, apply the required fertilizer(s).

e. After year 2, LCC would have been well established and would have crept into the circle:
- Open up the circle by pulling LCC vines
- Uproot also other weeds growing within the circle
- Open up LCC covered circles every two months during the rainy season
- Use the cut LCC vines as mulch during the dry season

f. If *Imperata cylindrica* is growing densely in the circle:
- Slash it first to allow new growth
- When new growth reached 40 cm. in height, spray with herbicide, e.g. Glyphosate

g. While weeding, DO NOT CUT ANY COCONUT LEAVES even when leaflets are already dry. Just let the dried frond fall-off naturally because as long as the leaf stalk is not completely dry, it has a nutritional function to the coconut tree.

Fertilization

a. A month after transplanting, broadcast the following fertilizers, one after the other in the circle with a radius of 50 cm:
- TSP = 100 gm/palm
- KCl = 200 gm/palm
- Kieserite = 50 gm/palm
  or
  Dolomite = 75 gm/palm
- Urea = 200 gm/palm
  or
  Ammonium Sulfate = 300gm/palm

To simplify applications, the fertilizers maybe mixed and applied together.

[Note: As soon as the last fertilizer (Urea or Ammonium Sulfate) has been broadcast, cover the fertilizers thinly with soil about 1 – 2 cm thick.]

b. For succeeding years (i.e., Years 1, 2, 3, 4, 5) after field planting:
- Circle weed first (follow the recommended radius of the circle)
- Apply the required fertilizers (see Annex 3) within the circle:
  - Year 1 = 50 cm radius
  - Year 2 = 100 cm radius
  - Year 3 = 150 cm radius
  - Year 4 & up = 200 cm radius
- Cover fertilizers with soil, about 1 – 2 cm thick, by raking.

Soil and leaf analyses

For a more efficient fertilizer usage, soil analysis should be done prior to field planting so that the right kind of fertilizers and their dosages could be applied at the start of field planting up to the time that results of leaf analysis are available.

In the absence of soil analysis, the recommended standard fertilizers and dosages should be followed, until such time that leaf analysis could be done, which is at year 4 from field planting. The recommended fertilizer schedule and dosage for palms 1-5 years after field planting is shown in Table 4 below.

Table 4. Recommended fertilizer schedule and dosages for palms 1-5 years after field planting

FERTILIZER	YEAR I (160 trees/ha)				YEAR II		YEAR III		YEAR IV		YEAR V	
	Planting hole		Circle		(160 tr/Ha)		(160 tr/Ha)		(160 tr/Ha)		(160 tr/Ha)	
	(g/tr)*	(Kg/Ha)	(g/tr)*	(Kg/Ha)	(g/tr)*	(Kg/Ha)	(g/tr)*	(Kg/Ha)	(g/tr)*	(Kg/Ha)	(g/tr)*	(Kg/Ha)
UREA	-	-	200	32	500	80	600	96	900	144	900	135
or												
AMM. SULPHATE	-	-	300	48	750	120	900	144	1000	160	1000	150
TSP (1)	350	56	100	16	450	72	500	80	500	80	500	75
K Cl (2)	-	-	200	32	500	80	1000	160	1500	240	1800	270
KIESERITE	-	-	50	8	200	32	300	48	400	64	500	75
or												
DOLOMITE	-	-	75	12	300	48	450	72	600	96	750	112.5
BORAX	-	-	-	-	10	1.6	20	3.2	-	-	-	-
COPPER SULPHATE (3)	-	-	30	4.8	-	-	-	-	-	-	-	-

(Source: R. Bourgoing. 1991. COCONUT: A Pictorial Technical Guide for Smallholders. IRHO/ CIRAD. Annex 12, Pp 272.)

(1) : Triple Super Phosphate
(2) : Potassium Chloride
(3) : Copper Sulphate (25% Cu 0) is only required in peat soil areas. The dosage recommended here is for shallow peat (< 1m deep).

*Dosage (gram per tree) should be split applied; 50% of dosage applied at start of rainy season, the other 50% towards the end of the rainy season.

Results of soil analysis indicate what soil nutrients are present in the soil and in what quantities. Results of leaf analysis show what nutrients were absorbed by the plant. Leaf analysis should be done yearly thereafter.

The agricultural scientists and/or extension workers involved in coconut research, development and extension could teach the right techniques for gathering soil and leaf samples for analysis in laboratories of their own institutions or in those of other government agencies.

Controlling *Oryctes rhinoceros* beetle

In many countries, the *Oryctes* beetle is the most important pest of young coconuts. It is therefore necessary to monitor their presence and control them by various means:

a. Proper disposal of all felled coconuts during land clearing, to eliminate breeding places either by:
   - Selling the logs
   - Burning the logs and other parts of the coconut
   - Early covering of the felled coconuts with LCCs

b. Killing the *Oryctes* beetle by piercing the body with an iron hook;

c. Covercropping is also reported to decrease *Oryctes* population as it renders the environment not suitable for Oryctes growth and reproduction.

d. If infestation is low, make at least two survey rounds per week; make daily rounds if infestation is high;

e. If *Oryctes* beetle is not controlled, infested trees will be stunted.

Chapter 4
Strategies for increasing incomes from coconut hybrids farming

- Coconut-based intercropping, animal and feed/fodder production and community-managed production of high-quality planting materials
- Using village-level technologies for producing high-value coconut-based products to enhance incomes of resource-poor coconut farmers

Coconut-based intercropping, animal and feed/fodder production and community-managed production of high-quality planting materials

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Introduction

Monoculture or the planting of coconut crop as a sole crop has not given good returns to coconut farmers. In fact, this practice, which majority of coconut farmers follow, has made them poor. When planting coconut seedlings in new farms, farmers usually wait five to seven years before their first harvest. If they do not plant other cash crops on the same farm, they soon find out that income comes late and conclude that coconut is not an attractive crop to grow. If their coconut trees are old and yields are declining, their farms become even less profitable.

The total coconut farm productivity can be increased to enhance income and food security through intercropping coconut with cash and food crops, animal and feed/fodder production, production of high-quality planting materials and diversification of high-value coconut products. The first three topics are discussed here, while the fourth is treated in a separate article. Although most of the data presented here were obtained from trials using the existing traditional coconut varieties, the same income generating activities could be practiced to increase incomes of smallholders from newly planted high-yielding coconut hybrids.

Intercropping

Intercropping or the growing of cash and food security crops between coconut palms, either in newly planted or in old coconut plantations, provides higher total farm income and food security than planting coconuts alone. Besides, it takes time, usually 3-5 years for coconut hybrids and 5-7 years for most traditional coconut varieties, to reach bearing age. During this non-bearing period, farmers' incomes are usually negligible if no other income-generating activities are undertaken on the farm. Hence, it is important that coconut farmers are encouraged to grow short-term crops between coconuts. In the Philippines, net farm incomes of US$ 771/ha/year can be derived by growing coconuts with maize (Magat 2004a), US$ 4995 over a 3-year cropping cycle with papaya, pineapple and peanut (Magat 2004b), and US$ 180 for Year 1 and US$ 1028.40 for Year 2 with banana (Magat 2004c). Further investigations of mixed intercrops grown under coconut in the Philippines showed that gross incomes of US$ 5411 can be derived from intercropping coconut and durian; US$ 7018 with coconut, durian and papaya; and US$ 7232 with coconut, durian, papaya and taro (Table 1). In India, a number of food security and vegetable crops grown between coconut palms can contribute additional income of US$ 210 to US$ 2178 per hectare (Rajagopal 2005, Table 2).

Table 1. Estimated yields and incomes of coconut and intercrops by different multi-storey intercropping models per hectare per crop at full bearing age
(Source: Carlos 2002)

Cropping System	Effective Area (%)	Yields (T)		Income (US$)	
		Canopy	Hedge	Canopy	Hedge
Coconut alone	100	1.0	1.0	178.57	178.57
Coconut	100	3.5	3.5	625	625
Durian, Yr 5-10	100	5570 fruits	5570 fruits	4785.71	4785.71
Sub-total	***200***			***5410.71***	***5410.71***
Coconut	100	3.5	3.5	625	625
Durian, Yr 5-10	100	5570 fruits	5570 fruits	4785.71	4785.71
Papaya, Yr 2-4	87.5	30 000*	36 000“	1607.14	1928.57
Sub-total	***287.5***			***7017.85***	***7339.28***
Coconut	100	3.5	3.5	625	625
Durian, Yr 5-10	100	5570 fruits	5,570 fruits	4785.71	4785.71
Papaya, Yr 2-4	87.5	30 000 fruits	36 000 fruits	1607.14	1928.57
Taro, 6 months	67	7.2	10.5	214.29	321.43
Sub-Total	***354.5***			***7232.14***	***7660.71***

Assumptions:

1. Coconut palms occupy 25 % of the land area; their roots extend up to 2 m from the bole.
2. Yields under canopy for annuals = 56% of yields under full sun. This is the product of 75% light by 75% land area available for sun-loving intercrops.
3. The yield for durian is average for the 5th-10th yrs of bearing.
4. Taro or another annual will be cultivated for only one cropping.

Table 2. Economics of a coconut-based intercropping system in India
(Source: Rajagopal 2005)

Cropping system	Net return (US$/ ha)	Net returns above coconut monocrop (US$ per ha)
Coconut monocrop	1163	-
Coconut + Tapioca	1486	321
Coconut + Groundnut	1374	210
Coconut + Bhendi	1535	371
Coconut + Cumbu Napier	3342	2178
Coconut + Rice	1436	272
Coconut + Ragi	1374	210
Coconut + Banana	1696	532
Coconut + Snake Gourd	1436	272
Coconut + Bitter Gourd	1510	346

A combination of short-term and long-term crops can be profitably intercropped with coconut (Carlos 2002). Figure 1 shows the layout for planting a 2-storey crop; Figure 2, a 3-storey crop; Figure 3 a 4-storey crop; and Figure 4 a 5-storey crop.

In the 'Poverty reduction in coconut growing communities' project of IPGRI/COGENT (Batugal and Oliver 2005), which was funded by the Asian Development Bank and implemented from 2002 to 2004, intercropping trials were further conducted to test the viability of growing cash and food security crops between and under coconut palms. Test cash crops included pineapple, papaya, banana, cacao, vanilla, black pepper planted in existing coconut plantations; and cucumber, chillies, gourd, long beans, tomatoes, amaranth, and other local vegetables planted in new or existing coconut farms. Production of food security crops such as taro, yam, sweet potatoes and cassava and feed crops such as maize, grass and *Gliricidia* for fodder were also tested. The results of these trials indicated that intercropping not only increased incomes by 2-3 folds but also enhanced food security and nutrition of poor coconut farmers' homesteads.

The two-storey intercropping system

Perennial, biennial, or an annual crop may be planted under the coconut. Examples of these are mangosteen for perennials, banana for biennials, and corn for annuals (Figure 1). For hybrids which are planted at high density, intercropping with annuals should be done only for the first five years.

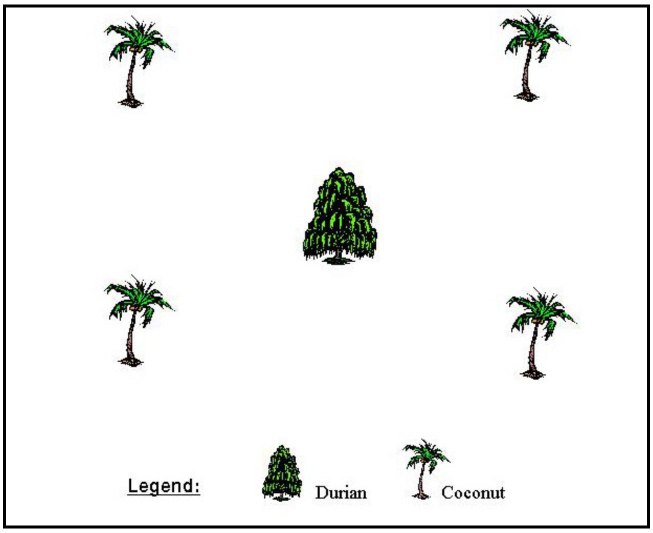

Figure 1. Two-storey coconut intercropping system
(Source: Carlos 2002)

The three-storey intercropping system

This may be a combination of a perennial and an annual crop, perennial and biennial crops, biennial and biennial crops, or biennial and annual crops. Examples of these are coconut/ durian/ peanut; coconut/ durian/ banana; coconut/ papaya/ pineapple; and coconut/papaya/chili (Fig. 2).

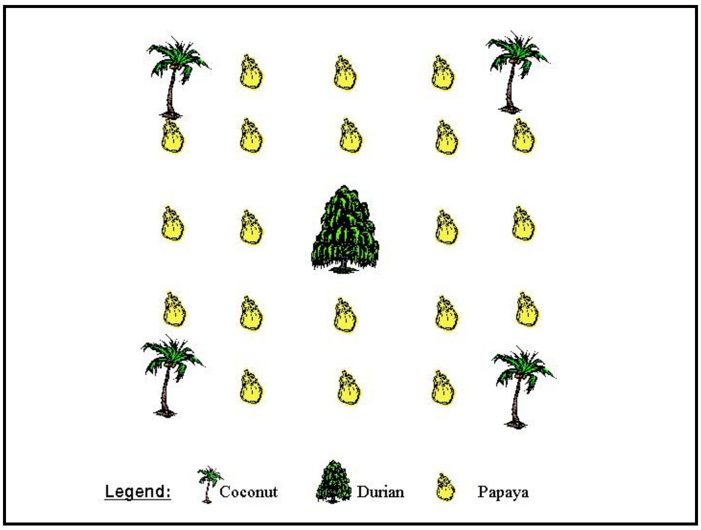

Figure 2. Three-storey coconut intercropping system
(Source: Carlos 2002)

The four-storey intercropping system

This sub-system may involve a combination of the perennials, biennials and annuals; perennials, perennials and biennials; perennials, biennials and biennials; or perennials, biennials and annuals. Some of the specific examples include:1) coconut/ coffee/ papaya/ peanut; 2) coconut/ cacao/ black pepper/ pineapple; 3) coconut/ mango/ papaya/ pineapple; and 4) coconut/ durian/ papaya/ taro (Figure 3).

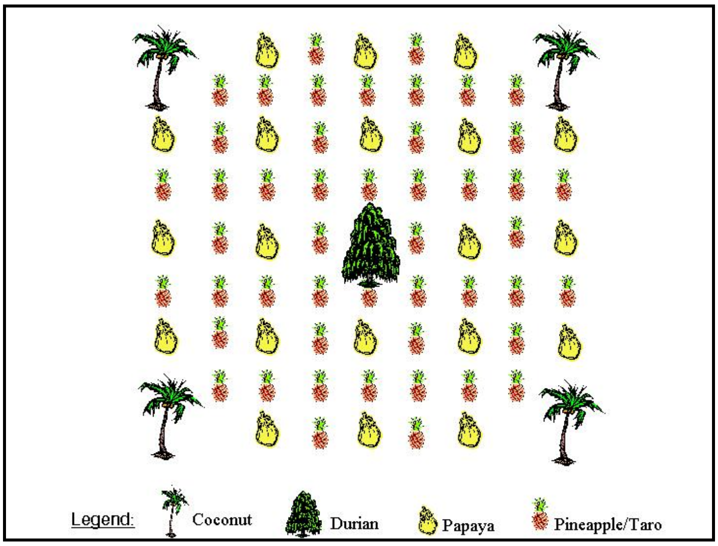

Figure 3. Four-storey coconut intercropping system
(Source: Carlos 2002)

Multiple-storey intercropping system

There can be more, multi-storey coconut intercropping models (as shown in Figure 4) but the system gets more complicated and unmanageable as the number of species increases.

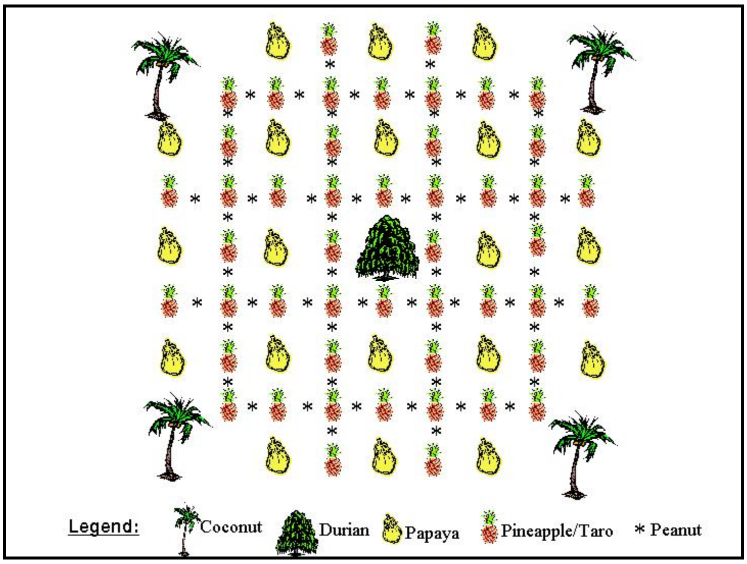

Figure 4. Five-storey coconut intercropping system
(Source: Carlos 2002)

The coconut provides partial shade and a favourable microclimate for growing the cash, food security and feed crops. The farm operations needed to produce these intercrops control the weeds, provide the coconut with residual fertilizer and water, and increase the overall organic matter content and the water holding capacity of the soil. Some farmers