TECHNICAL BRIEF No. 1

Ganoderma

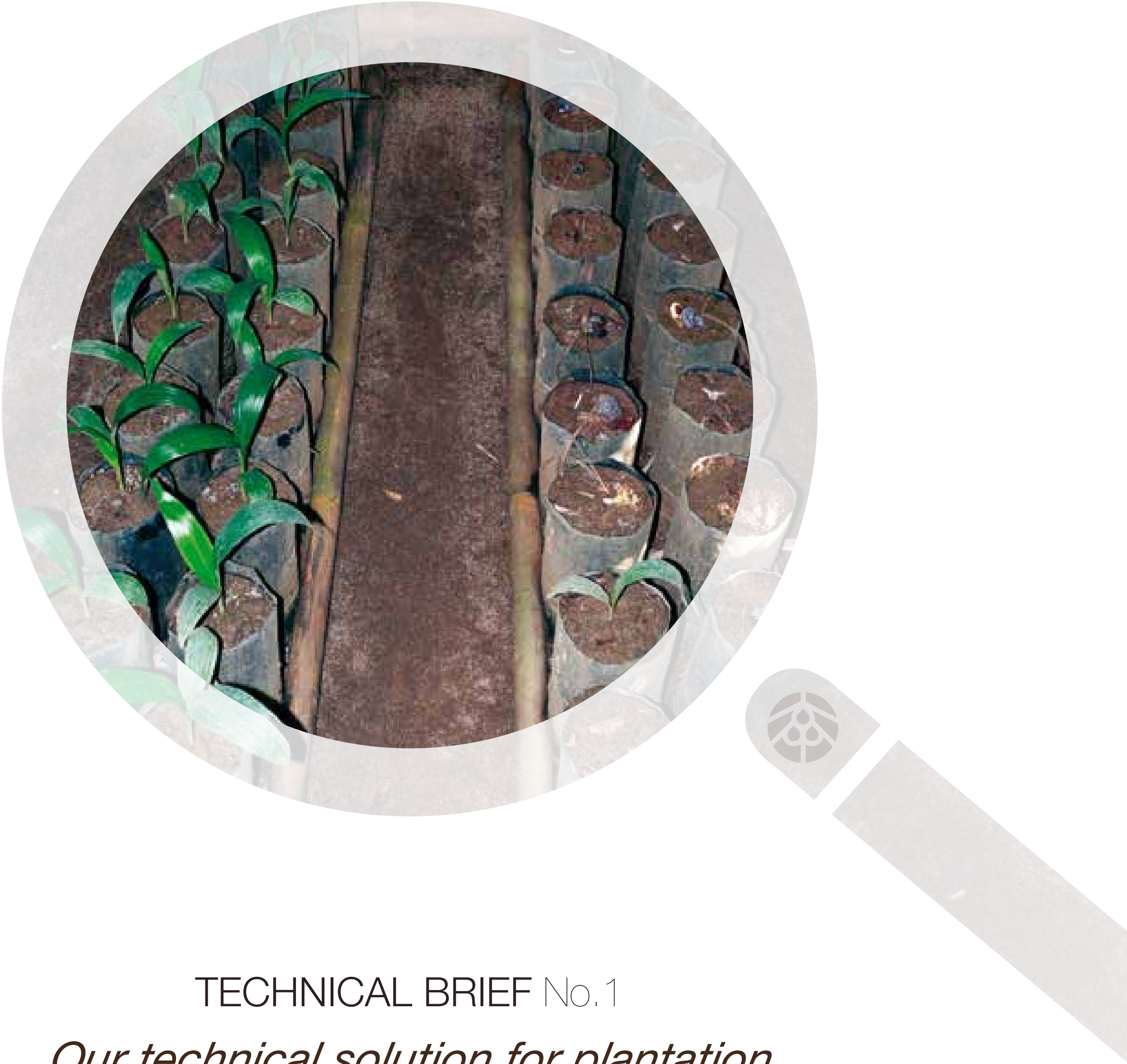
PALMELIT

OIL PALM SEEDS - CIRAD INSIDE

This technical brief is the outcome of research and analyses carried out by PalmElit's scientific teams working with CIRAD and our partners.

Our breeding programmes are located in Asia, Africa and Latin America on 1,600 hectares of experimental plots and 8 seed gardens.

Our main goal:
"guarantee regular incomes for smallholders and agroindustries".



TECHNICAL BRIEF No.1

*Our technical solution for plantation losses caused by **Ganoderma***


Ganoderma

Summary

Ganoderma

Ganoderma is a fungus responsible for oil palm mortality and yield losses on three continents

Oil palm has become a strategic crop as, alone, it supplies 60 million tonnes of oil (OIL WORLD 2016 estimation [1]), i.e. around 30% of world production of the main oils and fats.

Over the last ten years, palm oil production has increased by around 61% and the OECD-FAO outlook [2] forecasts yields of 79 million tonnes by 2026 (up 31.7% on 2016). At the moment, almost 85% of world palm oil production comes from two countries where *Ganoderma* is very common: Indonesia and Malaysia.

In Indonesia, the oil palm areas inventoried in 2015 amounted to 11.3 million hectares (Indonesian oil palm statistics 2015 [3]) and could rise to 17 million hectares by 2025 (Teh C., 2016 [4]), a figure that might be overestimated due to the lack of available land, and the forest and peatland preservation moratoria set in place by the Indonesian government.

CPO production forecasts for Indonesia in 2025 are 44 million tonnes, as opposed to 33 million in 2015. CPO production for Malaysia could reach 24 million tonnes by 2025, as opposed to 20 million in 2015 (© 2016 LMC International [5]).

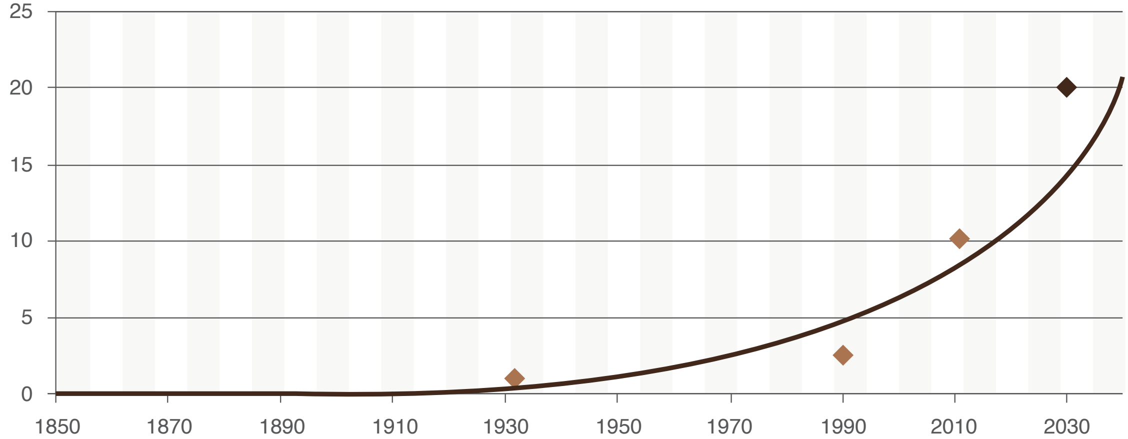
However, these forecasts do not take into account the risk that *Ganoderma* entails for future plantations. Indeed, forecasts largely rely on the hypothesis that old plantations will be replaced, which remains very uncertain, as the damage caused by *Ganoderma* tends to worsen. From one oil palm generation to the next, symptoms appear earlier and more severely, especially in the 3rd and 4th generations (A. Razak Purba et al. 2012 [7]).

Basal Stem Rot caused by *Ganoderma* sometimes destroys up to 80% of oil palm plantings in Southeast Asia, mainly after replanting (Susanto, 2009; Susanto and Huan, 2010 quoted by Durand-Gasselin et al., 2015 [6]).
In addition, *Ganoderma* is becoming increasingly common today in Africa and is starting to spread in Latin America.

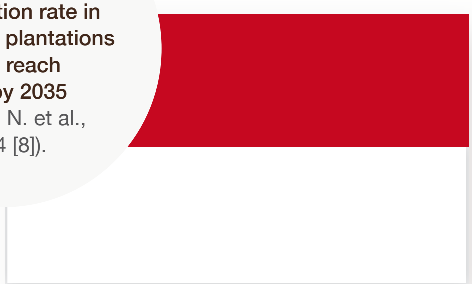
Ganoderma is a lethal fungus that can destroy up to 80% of oil palm plantations in Southeast Asia.

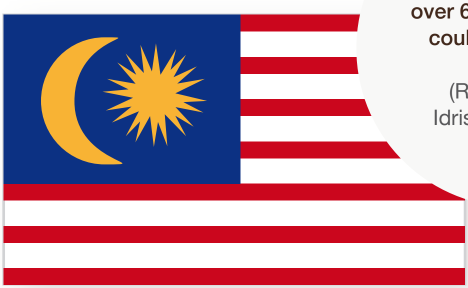
Economic impact in Asia

Ganoderma incidence trends in Indonesia (%)



In INDONESIA:
The infection rate in Indonesian plantations could reach 20% by 2035
(Turnbull N. et al., 2014 [8]).



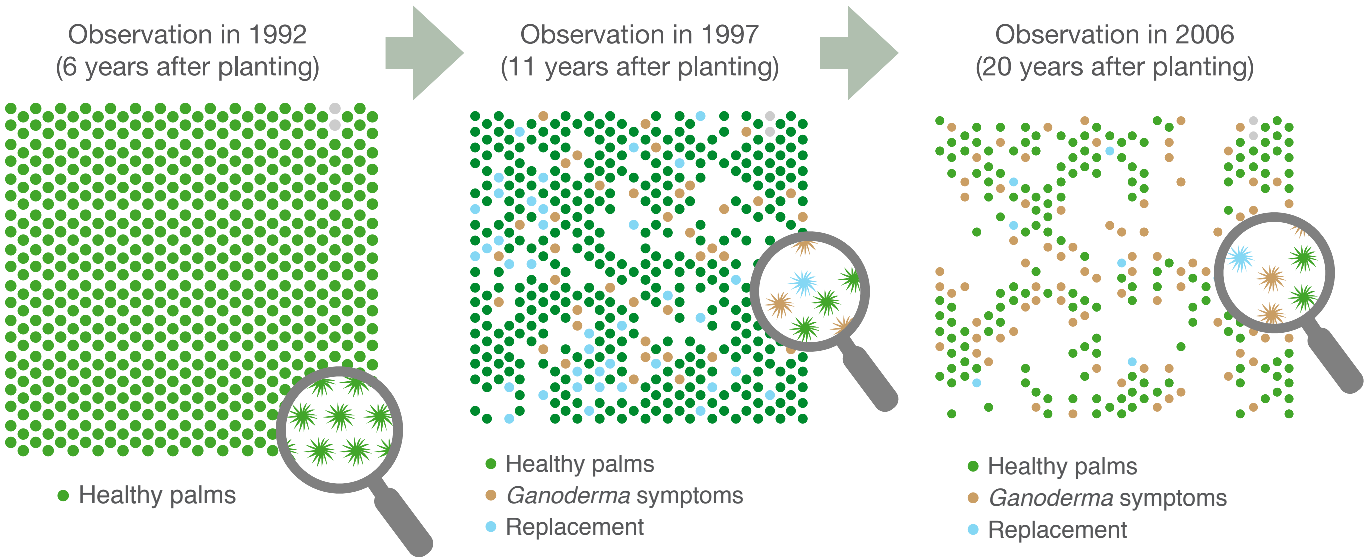


In MALAYSIA:
over 65 million palms could be affected by 2020
(Roslan Abas, Idris Abu Seman, 2012 [9]).

Ganoderma-related mortality

Ganoderma-related mortality trends in an experimental plot in Indonesia

***Ganoderma* incidence in a trial planted in 1986 at Bangun Bandar in Indonesia, at Socfindo (replanting plot, 2nd generation), without taking any particular precautions at the time of replanting.**



Twenty years after planting, in 2006, 284 out of 600 palms had been killed by *Ganoderma*, i.e. around 47% of the initial number, and 71 (11.8%) were infected.

Dissemination pathways

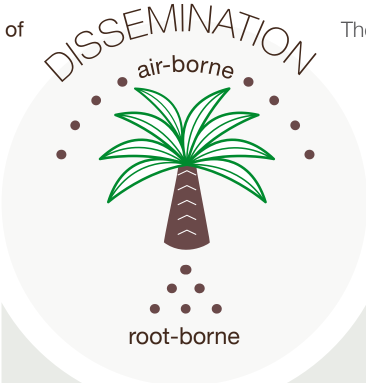
Ganoderma is a root- and air-borne fungus

***Ganoderma* is a fungus belonging to the division of the Basidiomycetes. There are several species of *Ganoderma*, but *Ganoderma boninense* is considered the most aggressive for oil palm** (Khairuddin 1990; Rao 1990 quoted by R. Hushiarian et al., 2013 [10]).

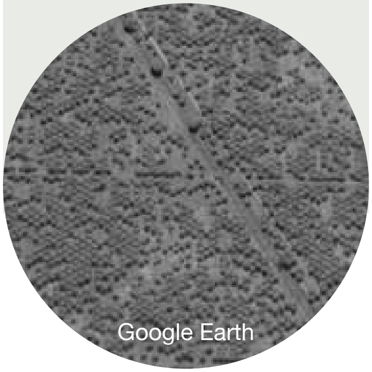
It causes Basal Stem Rot (or BSR) and it is also associated with Upper Stem Rot (or USR), although its direct implication in the latter is not always clearly demonstrated. The disease was described for the first time in 1915 in the Republic of Congo (Wakefield quoted by D.Ariffin et al. [11]) and the first attacks in Indonesia were reported in 1931 (Turner, 1981 quoted by A. Razak Purba et al., 2012 [7]).

It has been found that oil palm plantations after a coconut crop are more affected by the disease than after a rubber crop or forest (Turner 1965a quoted by par R.H.V. Corley and P.B. Tinker, 2016 [12]).

Ganoderma spreads via the roots or is air-borne, but it is difficult today to tell which type of dissemination predominates. Some insects, such as *Oryctes*, could also play a role in spreading spores (Turner and Incorporated Society of Planters, 1981 quoted by R. Hushiarian et al., 2013 [10]).



Plot devastated by *Ganoderma* in Indonesia



The optimum temperature for *Ganoderma* development is between 25 and 30 degrees in *in vitro* cultures and it can be imagined that its development is slowed down at higher temperatures, which would partly explain why the symptoms appear once the palms have reached their full maturity and more effectively shade the soil (Breton et al., 2006 [18]; R. W. Rees et al., 2007 [13]).

The time lapse between the tissues of the oil palm coming into contact with *Ganoderma*, and disease expression, may also explain why it is mostly associated with mature plantations.

However, attacks have occurred in young plantings and, in some zones, 30% palm mortality was seen one or two years after replanting (Hoong 2007 quoted by Roslan Abas and Idris Abu Seman, 2012 [9]). Such attacks are all the more frequent when control methods are not applied.

***Ganoderma* affects the bunch number and average bunch weight, resulting in a drop in FFB and oil yields. A drop in FFB yields of 26 to 45% was found in some plantations displaying a disease infection rate of between 31 and 67%** (Singh 1990 quoted by Idris A.S. 2012 [14]).

Lethal disease symptoms

Ganoderma can kill oil palms in under three years

The first symptoms of the disease resemble those caused by drought: the young fronds have trouble opening and several spears can be seen in the middle of the crown (Turner, 1966 quoted by R.H.V. Corley and P.B. Tinker, 2016 [12]).

Stem rot leads to varying degrees of disruption in the nutritional continuum between the roots and the leaf crown, resulting in chlorosis.
As they age, old fronds wither and droop, forming a skirt around the stem (D. Ariffin, A. S. Idris and G. Singh, 2000 [11]).

At the base of an infected palm, most of the inner tissues are brown and easily decompose, usually leading to the appearance of a cavity.
In most cases, severe development of basal rot will result in the sudden collapse of the palm. Mycelium can be found around the edge of the basal rot inside the tissues.

Lastly, the existence of fruiting bodies on the stem of the oil palm is the most typical symptom of infection by *Ganoderma boninense*.
The time lapse between the first symptoms and death depends on the aggressiveness of the isolate, but also on how resistant or susceptible the oil palm is to the pathogen.

Young oil palms usually die between 6 and 24 months after the first symptoms, while mature palms can survive for more than 3 years (R. W. Rees et al., 2007 [13]).

Control methods

10 *Ganoderma* control methods have been identified

Some of these methods are more or less effective, costly and restrictive when implemented on an industrial scale.

1. **soil mounding** (earthing-up around the foot of the palm)
2. **surgery** to remove diseased tissues
3. **sanitation or removal of affected planting material** (burning, isolation of infected palm placements)
4. **ploughing and harrowing**
5. **fallowing**
6. **use of a cover crop**
7. **chemical treatments**
8. **fertilization**
9. **biological control with *Trichoderma* spp or endophytic bacteria** such as *Pseudomonas*, *Enterobacter* or *Bacillus*
10. **use of planting material displaying genetic resistance**

(Roozbeh Hushiarian et al., 2013 [10])

PalmElit-CIRAD® #G: genetic control

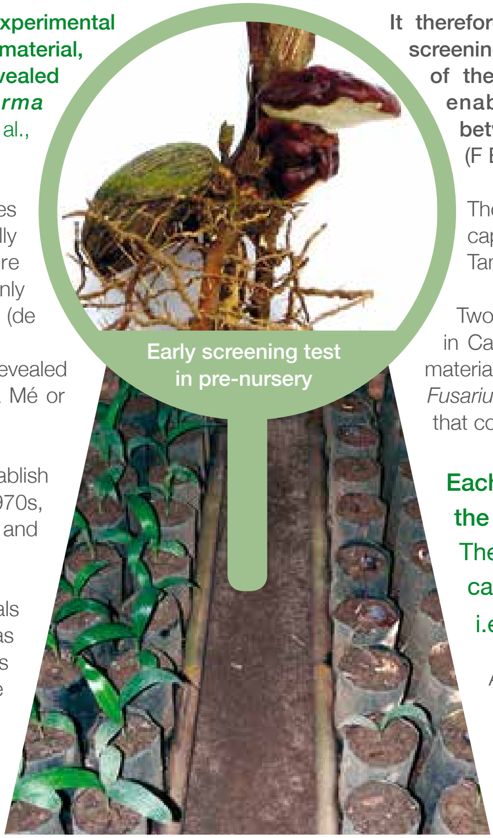
Genetic control: today, our solution is available thanks to screening in the prenursery and the field

In 1970, observations in Indonesia in an experimental plot containing different types of planting material, and in some commercial plantings, revealed differences in reactions to *Ganoderma* depending on genetic origins (Akbar et al., 1971 [15]).

The pure Deli origins, which were sometimes more than 80% destroyed, were generally much more susceptible than the pure La Mé or Yangambi origins, which were only 23.5% affected under the same conditions (de Franqueville et al., 2001 [16]).
Moreover, some notable differences were revealed between families within each of the Deli, La Mé or Yangambi origins.

These observations enabled IRHO* to establish a selection process in Indonesia in the 1970s, and this has been pursued since by CIRAD and PalmElit.

The original process was based on field trials alone and was time-consuming, and it was sometimes difficult to interpret the results as they depended on several variable parameters, such as the previous plant cover, soil type, the quality and quantity of the inoculum, the spatial distribution of the disease and the statistical design of the trial (F Breton et al., 2010, [17]).



Early screening test in pre-nursery

It therefore proved essential to develop an early screening test by carrying out artificial inoculation of the pathogen under controlled conditions, enabling a quick distinction to be made between resistant and susceptible materials (F Breton et al., 2006 [18]).

The results led on to the installation of a large-capacity early screening unit in Indonesia, at Tanah Gambus with our partner Socfindo.

Two additional units have been created in Africa, in Cameroon and Benin, with a view to selecting material with dual resistance to *Ganoderma* and *Fusarium* wilt, another fungal disease that is rife on that continent.

Each prenursery test enables the assessment of 100 crosses.
The statistical analysis for each cross is carried out on 5 replicates of 20 plants, i.e. a total of 10,000 plants for each test.

A sixth replicate is made up for each tested cross, in order to replace any abnormal plantlets identified in the five test replicates. Such replacement is carried out a month after inoculation of the plants in the absence of any disease symptoms, in order

**IRHO, the French Research Institute for Oils and Oilseeds, was founded in 1942 at a time when the World War in Europe was making commodity supplies very difficult, especially oils and fats. Developing oilseed production in some new production zones in Africa was the Institute's prime objective and the oil palm, with its very strong production potential, became the priority species to be improved. IRHO continued its work in Asia and it signed research agreements in 1969 with Socfindo and PNP (Plantations of Indonesia) in Indonesia, and in 1970 with FELDA in Malaysia (Christian Surre, 1993 [20]).*

to preserve the random parameter for subsequent statistical analysis of the results. One test can be organized per month depending on the technical potential of the laboratory and the available nursery area.

The results are obtained between 6 and 8 months after the inoculation of germinated seeds. The prenursery test results are coherent and reproducible. The aim, after numerous independent replications, is to detect parents that pass on good resistance to their progenies.

Parents selected for their resistance in the prenursery are also judged from the results obtained in field trials. The correlation between observations in the field and the resistance screening tests in the prenursery is positive.

Since the first results obtained (F Breton et al., 2010 [0]), the correlation has been confirmed by observing numerous field trials, and it is increasingly strong.

Thanks to these prenursery and field tests, we are now able to select PalmElit-CIRAD® #G planting material that displays intermediate resistance** to *Ganoderma*.

***PalmElit has adopted ISF (International Seed Federation) terminology when defining resistance [19]. Intermediate resistance is defined as the ability of planting material to restrict the growth and development of a given pest (in our case: Ganoderma), while displaying greater symptoms than a high-resistance material under the same conditions. Compared to a susceptible variety, varieties with intermediate resistance display fewer symptoms and less damage under the same conditions.*

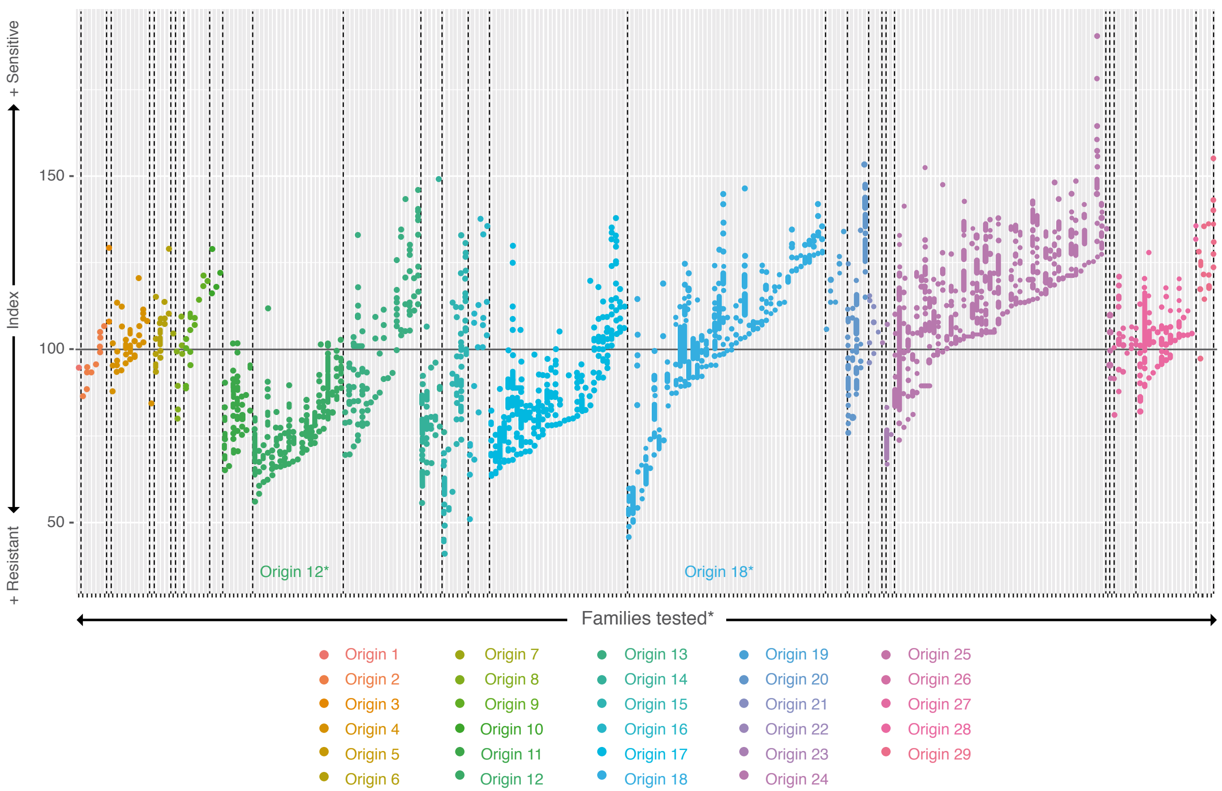
Statistical analysis of the early test

The following graph shows the genetic value for the *Ganoderma* resistance of 2,000 tested parents, spread over 270 families (each family* is represented on the same vertical line) belonging to 29 distinct genetic origins**. A dot represents the value of a parent of the family in question. On average, a parent will have been tested on a total of 12 x 100 plants.The index 100 represents the average resistance level of all the parents tested. The more a parent has a high index, the more it is susceptible to *Ganoderma*. The graph perfectly illustrates between-origin variations, along with within-origin differences between families and within-family differences between individuals of the same family.

We make use of that variability to select resistant material.
For example:

- Taking origin 12: all the families of this origin provide some resistance and only 4 parents (out of 246 tested) have an index over 100.
- Taking origin 18: the result is much more contrasting. Some families are clearly resistant (particularly the first 2), while some other families are much more susceptible.
- In very many cases, high within-family variability can be seen.

Genetic values of *Ganoderma* resistance for the parents assessed by early screening



** A family is a group of palms derived from seeds of the same bunch of a single cross between a female flower and pollen from a single clearly determined palm.*
*** A genetic origin is a set of "ancestor" palms that forms the basis of our breeding programmes.*

PalmElit-CIRAD® #G timeline

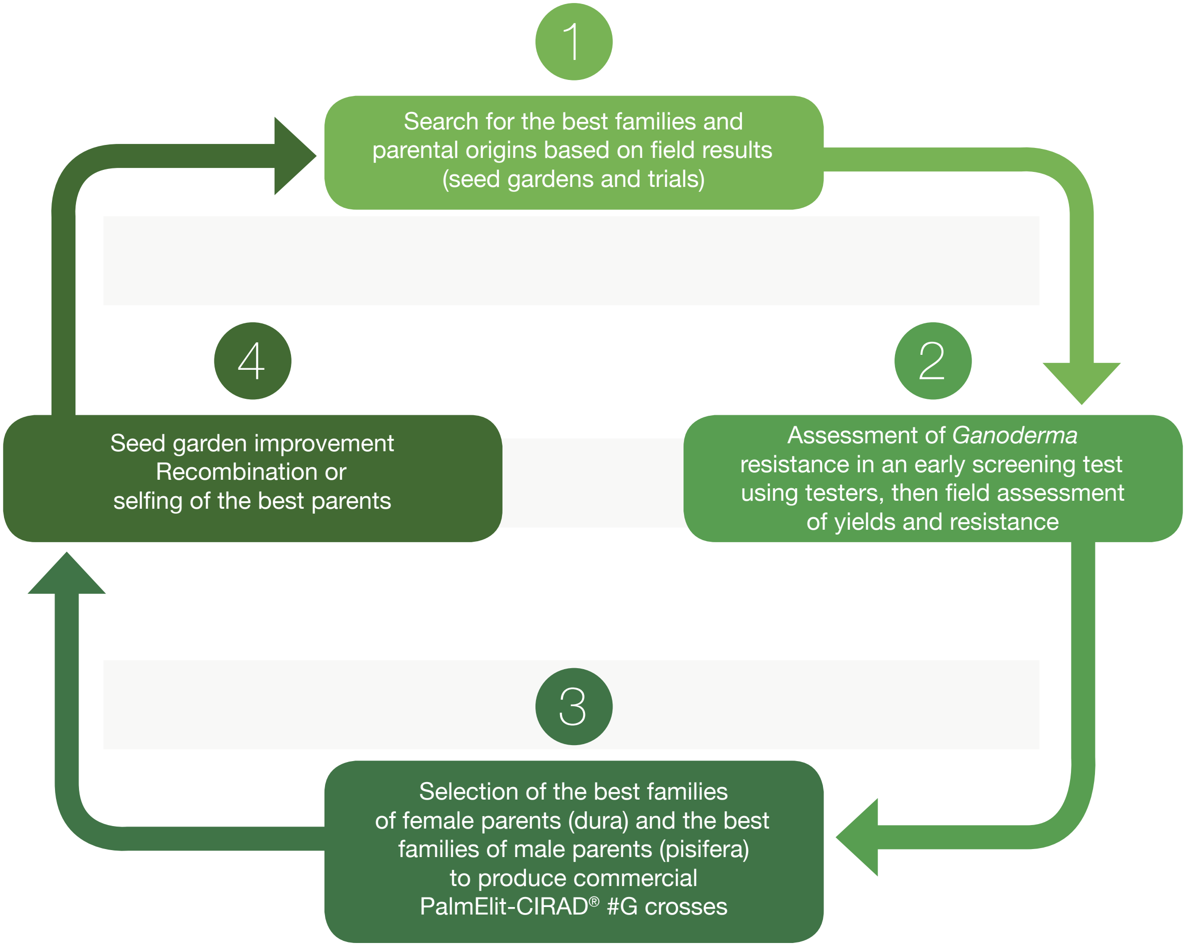
Background to the PalmElit-CIRAD® #G market launch

1974
1975
1979
1995
1999
2000
2001
2002
2005
2007
2012
2013

- 250 hectares of genetic blocks planted at Socfindo in Indonesia
  1st part of the 2nd cycle at AEK KWASAN I (Sumatra)
- Planting of the seed gardens and trials at BANGUN BANDAR (Sumatra)
- Planting of the 2nd selection cycle at AEK LOBA TIMUR (Sumatra)
- Results from the seed gardens and trials at BANGUN BANDAR (Sumatra)
- Development of the prenursery early screening test
- Start of large-scale use of early screening
- Planting of the 2nd and 3rd selection cycles at AEK KWASAN II (Sumatra)
- Market launch of PalmElit-CIRAD® #G planting material in Indonesia
  (Intermediate resistance to *Ganoderma*)

PalmElit-CIRAD® #G breeding cycle

4 stages of PalmElit-CIRAD® selection for *Ganoderma* resistance



Security with PalmElit-CIRAD® #G

The PalmElit-CIRAD® #G genetic solution helps secure plantations against *Ganoderma*

The fact that growers now have access to PalmElit-CIRAD® #G material with intermediate resistance is a major step forward in better disease control.

For an optimum result, PalmElit-CIRAD® #G should be planted in combination with the other control methods, particularly destroying and removing infected plant material, replanting at a maximum distance from the palms of the previous generation, using *Trichoderma*.

Agronomic characteristics

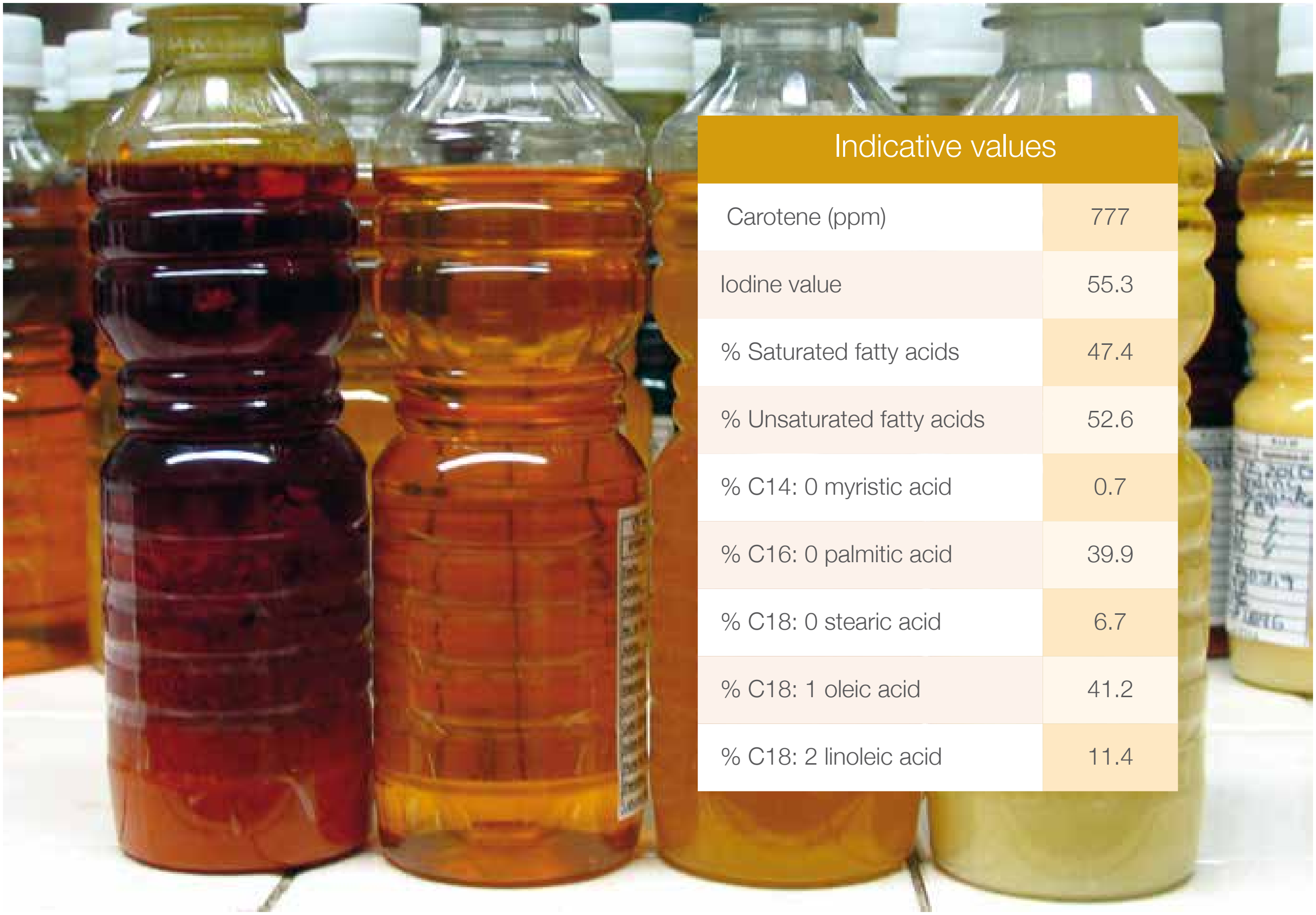
Main characteristics of PalmElit-CIRAD® #G

The values given are indicative only and are representative of the results obtainable under good growing conditions in the absence of diseases or parasites.

Main characteristics with optimum crop management	0 mm water deficit Sandy clay soils	200 mm water deficit	400 mm water deficit
Planting density per hectare	143	143	143
FFB production when mature (> 7 yrs) t/ha/yr	29-32 t	24-27 t	17-20 t
Average bunch weight when mature	< 18 kg	< 18 kg	< 18 kg
Industrial extraction rate (CPO)	26-27%	25-26%	24-25%
Industrial extraction rate (PKO)	2-3%	2-3%	2-3%
Total oil production (CPO) t/ha/yr	7.5-8.5 t	6.0-7.0 t	4.0-5.0 t
Total oil production (CPO + PKO) t/ha/yr	8.0-9.5 t	6.5-8.0 t	4.5-5.5 t
Iodine value (Wijs)	> 55	> 55	> 55
Average vertical growth cm/yr	46-56 cm	44-54 cm	42-52 cm
First harvest	24 months	30 months	36 months

Oil composition

Main characteristics of PalmElit-CIRAD® #G



Indicative values	
Carotene (ppm)	777
Iodine value	55.3
% Saturated fatty acids	47.4
% Unsaturated fatty acids	52.6
% C14: 0 myristic acid	0.7
% C16: 0 palmitic acid	39.9
% C18: 0 stearic acid	6.7
% C18: 1 oleic acid	41.2
% C18: 2 linoleic acid	11.4

Crop management

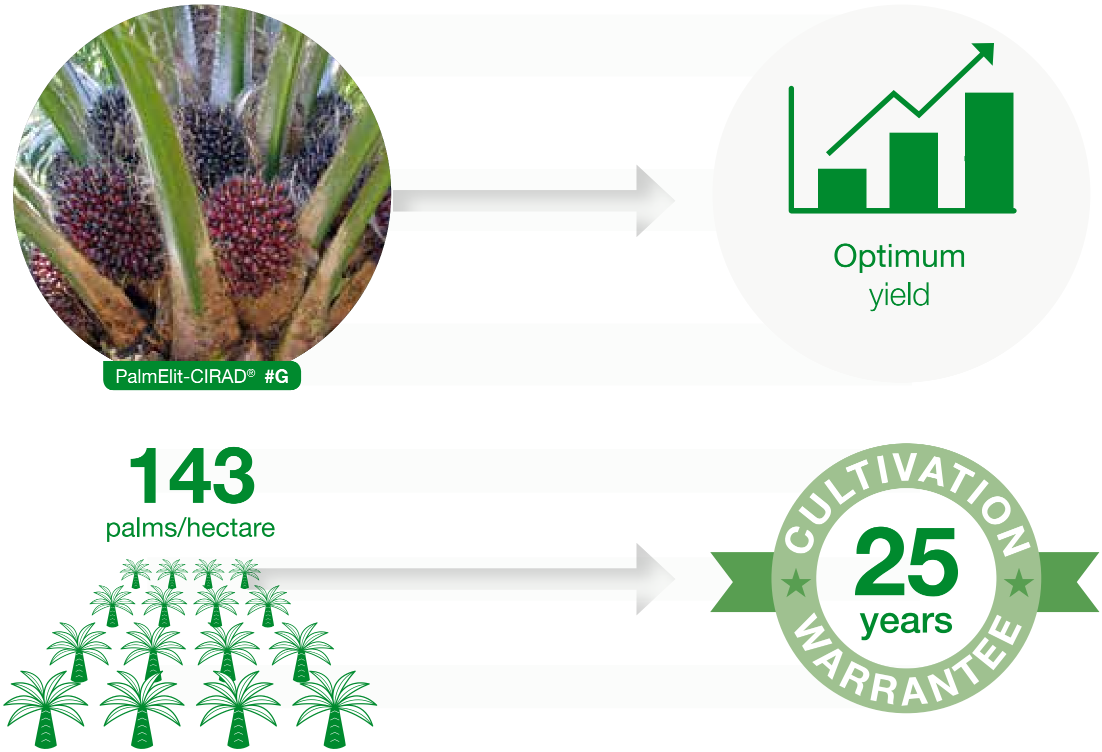
PalmElit-CIRAD® #G does not notably differ from the other *E. guineensis* materials marketed by PalmElit in terms of crop management. To achieve optimum yields, we recommend planting at a density of 143 palms per hectare.

Under optimum conditions, a minimum working life of 25 years is guaranteed, thanks to the low vertical growth rate of PalmElit-CIRAD® #G material.

Under very suitable climatological conditions with no water deficit, hand pollination of bunches may be recommended at the young age or when there is an insufficient number of male inflorescences in anthesis (it is necessary, at all times, to have between 3 and 6 male inflorescences in anthesis per hectare and a sufficient number of pollinating insects to ensure good bunch pollination).

Should any palms display *Ganoderma* symptoms during the working life of the plantation, they should be felled and removed from the plot. Their planting position should be isolated by digging a hole and removing the contaminated soil (see page 21).

PalmElit-CIRAD® #G   Crop management



Recommendations

When replanting in an infected plot, 2 operations are essential:

1. Eliminate sources of infection

Eliminate and remove from the plot any contaminated plant parts, along with old stumps affected by the disease.

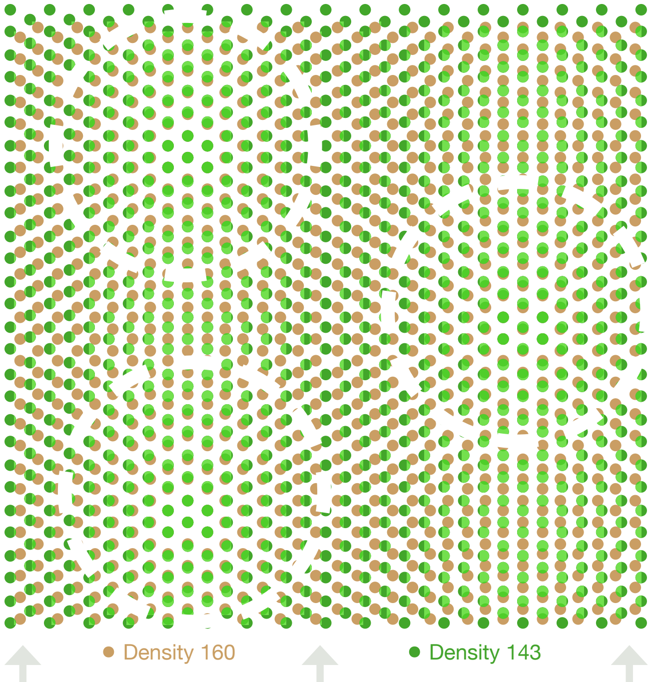
Use an excavator to dig a hole where the old stump was located and remove the larger root debris and the contaminated stem.

A hole measuring 2 m x 2 m x 1.5 m seems very effective in reducing the risks of infecting neighbouring or replanted palms (Idris A.S., 2012 [14]).

2. Replant new palms away from the infected holes

To do this, it is essential to use the same density as the one in the previous plantation.

Starting with another density would make it necessary, in some cases, to replant in the old placements potentially infested with *Ganoderma*.

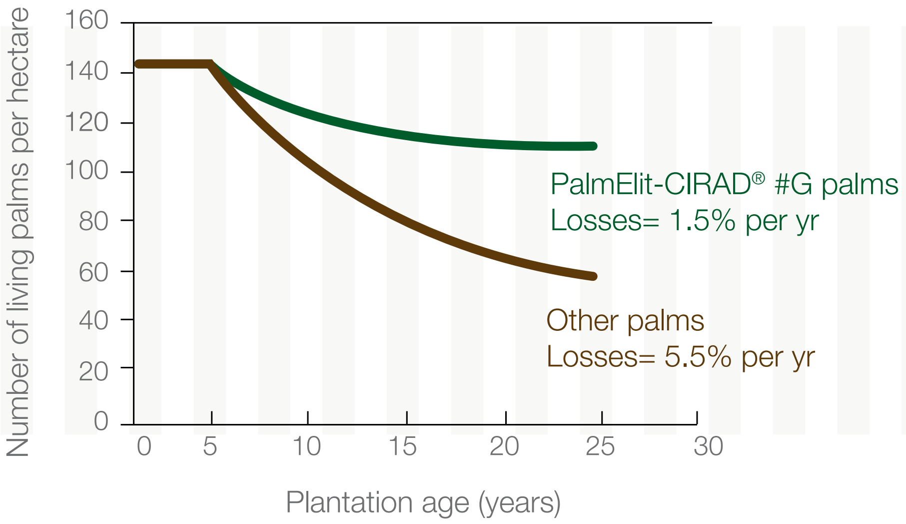


Plot replanted at a density of 160 palms/ha, different from the previous density (143 palms/ha): the new palms sometimes find themselves in exactly the same old placements.

Advantage of PalmElit-CIRAD® #G

In a plantation attacked by *Ganoderma*, the mortality of PalmElit-CIRAD® #G palms is up to 3.5 times less than with a conventional planting material

Simulation of losses caused by *Ganoderma*
Comparison between PalmElit-CIRAD #G palms and other palms



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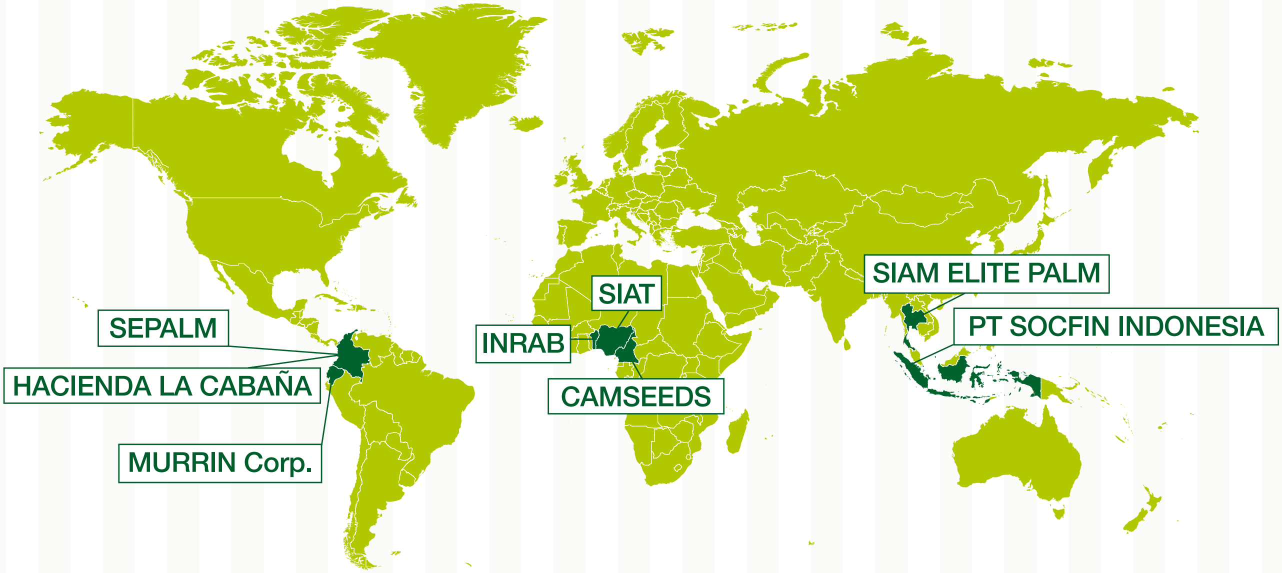
Notes

Notes

Partners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