TECHNICAL BRIEF No. 3

Fusarium oxysporum f. sp. *elaeidis* (Foe)

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. 3

Our genetic answer to plantation losses caused by

Fusarium oxysporum **f. sp.** ***elaeidis*** **(Foe)**


Fusarium oxysporum f. sp. *elaeidis* (Foe)

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1. Introduction

Case of fusariosis in an old palm stand in Ghana

Oil palm *Fusarium* wilt, which was first discovered in **1946** in **Congo-Kinshasa (Democratic Republic of Congo)**, is attributed to a soil-borne fungus **"*Fusarium oxysporum* f. sp. *elaeidis*" *(Foe)***, and remains today the most serious and widespread oil palm disease in Africa, potentially causing over 50% plantation losses.

On the American continent, some isolated foci appeared in **South America (Brazil and Ecuador)** in the **1980s**, but the disease has so far remained marginal there. Oil palm *Fusarium* wilt has never been found in **Southeast Asia**.

Today, the most effective operational control method is to use planting material selected for its high genetic resistance, while respecting certain cultural practices discussed below.

Plantation destroyed by Fusarium wilt in Cameroon

Symptoms of fusariosis on mature palms in Liberia

2. Economic impact of oil palm *Fusarium* wilt in Africa

2.1. The situation in Africa

In 2020 (in the formal economy), African palm oil output amounted to around 3 million tonnes produced on approximately 1.7 million hectares (5 million counting natural palm groves).

Overall, Africa has a high oils and fats deficit and African palm oil imports currently stand at over 8 Mt.
The African continent produces 8 Mt of animal and vegetable oils and fats, while it consumes 18 Mt.[19]

The continent is keen to reduce its imports, so it is seeking to develop and intensify oil palm cultivation in an eco-friendly manner. Growing high-yielding oil palms with durable strong resistance to *Fusarium* wilt fits in particularly well with that ambition.

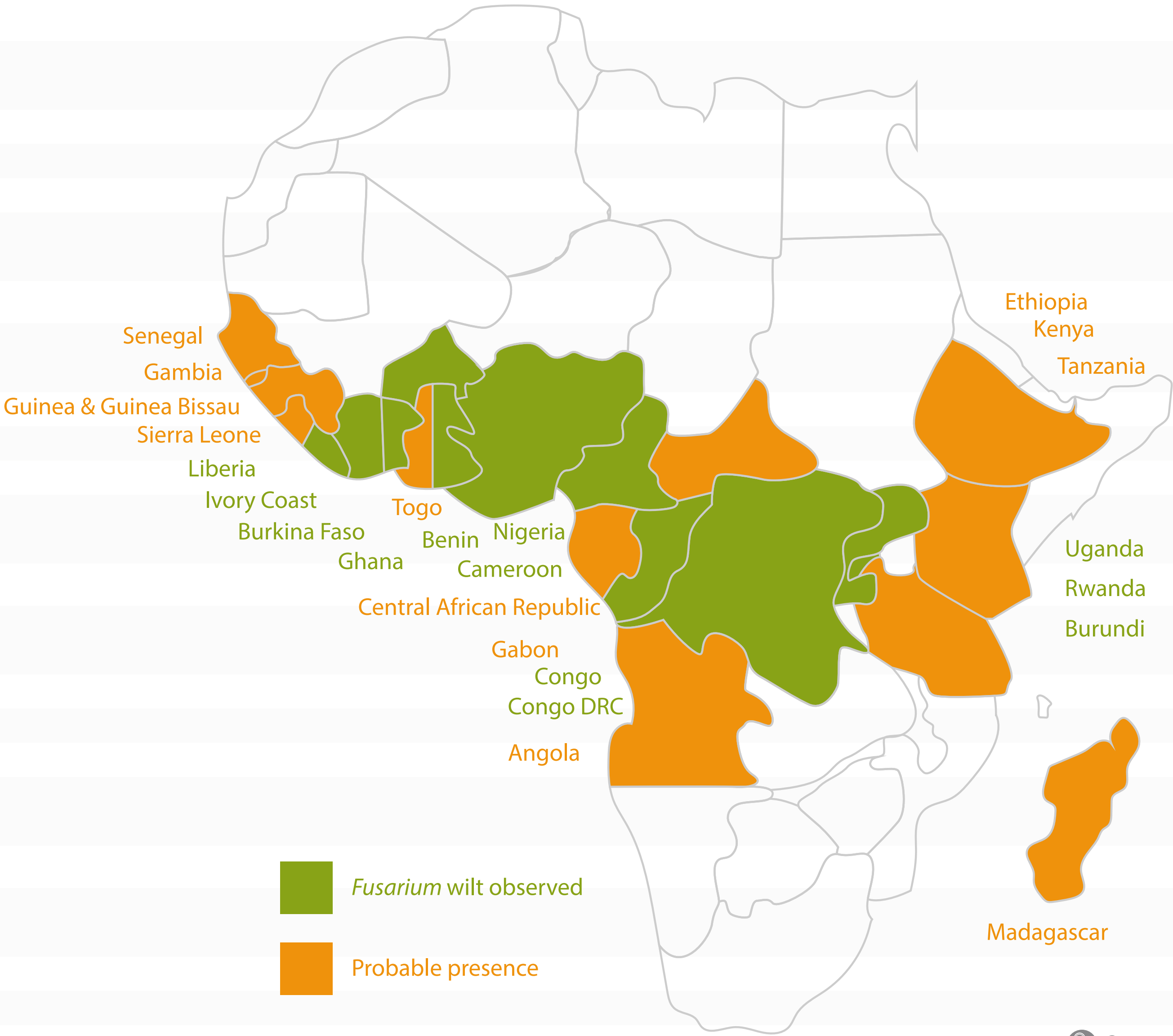
2.2. Discovery, localization and severity of the disease

The symptoms of this disease were first noticed in 1946 by growers in Congo-Kinshasa (Democratic Republic of Congo) and were described for the first time in a publication by Wardlaw who, the same year, isolated a type of *Fusarium oxysporum* from some diseased palms. It was given the name *Fusarium oxysporum* f. sp. *elaeidis (Foe)*.

A few years later, Fraselle, Guldentops and Prendergast proved the virulence of that *Fusarium* on oil palms by inoculation. Its existence has now been proven in many countries (Fig.1).

Fig.1 Countries on the African continent where *Fusarium* wilt cases have been seen or suspected

Up to 70 % of palms were found to be affected by *Fusarium* wilt for certain crosses [15] in a study carried out in Ivory Coast.



3. Symptoms

Fusarium wilt symptoms take several forms that depend on various factors, such as the age of the palm, its environment, crop management and the degree of resistance exhibited by the planting material.

3.1. External symptoms

In the prenursery and nursery

Symptoms of fusariosis after inoculation in prenursery

Symptoms are very rare in the early stages of oil palm cultivation in the pre-nursery and nursery, but they become clearly visible if artificial inoculations are carried out:

Growth is slowed or even halted in the event of early infection. Petiole length is reduced and the youngest fronds are shorter and narrower than the older fronds, giving the palm a flat-top growth habit; the fronds become paler in colour and may sometimes have perforations along the midribs, which become totally necrotized, leading to the death of the palm. Palms may also exhibit symptoms similar to those caused by water stress, especially visible on older fronds (Mepsted et al. (1995a) quoted by Corley, R H V and Tinker, P B (2016) [4]).

In the field

ON IMMATURE PALMS

Before the first harvest, *Fusarium* wilt causes often unilateral yellow and brown discoloration of a frond in the middle of the crown. That symptom then spreads to neighbouring fronds on the same level in the spiral, then to the lower fronds. The palm may dry out completely and die within two months of the first symptoms appearing [8 11]. However, depending on the degree of resistance exhibited by the planting material, the most resistant palms can recover partially or even totally.

ON MATURE PALMS

There are two types of *Fusarium* wilt on mature palms:

- An acute (or typical) form, characterized by the desiccation of lower fronds and breakage of the rachis a third along its length. Young fronds grow more slowly, are shorter and turn yellow. The palm may dry out completely and die within two to three months of the first symptoms occurring [3].

- A chronic form, typified by desiccation of the fronds, which ultimately “collapse”, and the appearance of several spears (two to four, or even more), which only open very slowly. The stem shrinks in its upper section and takes on the form of a "pencil point" [11] . A few small bunches may still be produced before the palm dies, often several years after the first symptoms appear.

No difference in pathogen race has been found between the two forms of *Fusarium* wilt, acute or chronic. [1]
The differences in symptoms observed seem linked to the type of planting material used.

TABLE 1

***FUSARIUM* WILT SYMPTOMS AT DIFFERENT STAGES OF OIL PALM DEVELOPMENT**

(Renard J.L, de Franqueville H. Oléagineux, Vol. 44, No. 7 -July 1989 [11])

STAGE	Lower leaves	Middle leaves	Upper leaves	Spear	Petioles	Stem	Roots	Bunches
Prenursery	Normal		Stunted		Short	Brown fibres	Healthy brown core	
Nursery	Normal		Stunted - yellowing	Stunted	Short brown fibres	Brown fibres	Healthy brown core	
Early age (1-4 years)	Normal	Yellowing	Normal	Normal	Brown fibres	Brown fibres in a single area	+/- healthy brown core	+/- developped inflorescences and/or bunches
				Bearing palms				
Typical symptoms	Dry split	Normal	Short yellowing	+/- normal	Some brown fibres	Brown fibres	Healthy brown core rare	Normal sometimes dry
Chronic symptoms	Short green leaves			3 to 6 cloved	Some brown fibres	Brown fibres	+/- healthy brown core	Small sometimes dry

Black fibres in a palm stem with *Fusarium* wilt


Fusarium wilt typical form


Fusarium wilt chronic form – damaged stem


Fusarium wilt chronic form

3.2. Internal symptoms

Typical internal symptoms include a discoloration of most of the vascular bundles of the xylem (fibres), which first turn orange, then brown. Dissection of the root bulb of young seedlings inoculated during early screening for *Fusarium* wilt in the prenursery reveals typical browning of the fibres in a susceptible material [22]. The pathogen spreads into the vascular tissues of the roots at the root/stem interface. It then colonizes the stem vessels.

Once the vessels are totally blocked, they become necrotized and turn black.[3]
The extent of vessel necrosis varies considerably, affecting certain parts of the stem.
The first leaf symptoms occur once it reaches the apex.

In young oil palms, vessel discoloration can be seen in the rachis of fronds showing the symptoms of an infection.

It should be noted that, in old palms, blackening of the vessels does not necessarily mean the presence of *Fusarium* wilt. This discoloration is normal in palms over 20 years old, where it tends to fade at the top of the stem.

On the other hand, in wilt-infected palms the black discoloration worsens in the upper sections of the stem (Moureau 1952 quoted by Corley, R H V and Tinker, P B (2016)) [4].

Apparent brown fibres in the petiole of a wilt-infected palm

Apparent black fibres in the stem of a wilt-infected palm

4. Consequences of the disease

4.1. Yield losses

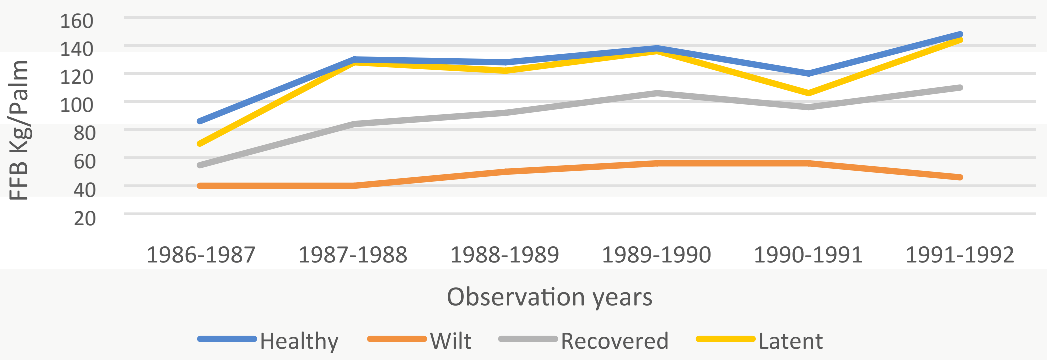
Foe development first leads to yield losses. On palms affected by the acute form, bunch abortions occur before the palm dies.

A trial set up in 1981 in Ivory Coast, in a zone severely affected by *Fusarium* wilt, was regularly monitored from the outset for the appearance and persistence of disease symptoms. Individual palm yields were recorded from 1986 to 1992 to assess how *Fusarium* wilt affected the number of bunches produced, their average weight and overall FFB yield.

Four categories of oil palms were defined: healthy palms, diseased palms with obvious symptoms, palms first classed as diseased, but which totally recovered, and palms with latent disease (the disease was detected by taking stem tissue samples).[7]

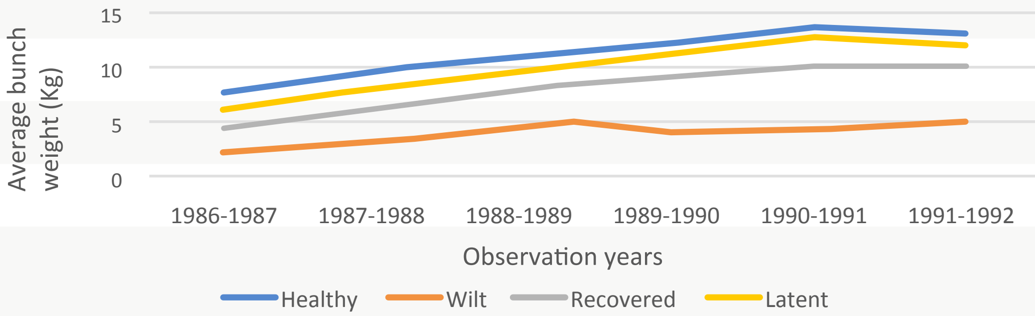
A comparison of the FFB yields of diseased palms versus healthy palms for a planting material susceptible to *Foe* revealed losses estimated at around 80% over the full 6 years of observations (Fig.2).

Fig.2 Study of *Fusarium* wilt impact on the FFB yields of a susceptible planting material



A comparison of the average bunch weight for diseased palms versus healthy palms of a planting material susceptible to *Foe* showed an estimated drop of around 64%, on average, over the full 6 years of observations (Fig.3).

Fig.3 Study of the impact of *Fusarium* wilt on the average bunch weight of a susceptible planting material



4.2. Palm mortality

Frond desiccation and palm death are partly caused by destruction of the roots, and partly by clogging of the xylem vessels with the gels and gums produced by the plant in reaction to pathogen entry [4]. With the acute form of the disease, attacks can kill the palm within two months of the first symptoms appearing in the case of an immature plantation, or within 3-4 months in a mature plantation [11]. With the chronic form, palms can vegetate for several years before dying suddenly after a severe dry season [11].

4.3. In replanted plots or extensions

Figure 4 shows how the disease developed on a particularly susceptible cross planted at the same time in a plot where the previous plant cover had not been oil palm (extension) and in a plot where the previous plant cover was oil palm (replanting), in which strong disease incidence had been found.

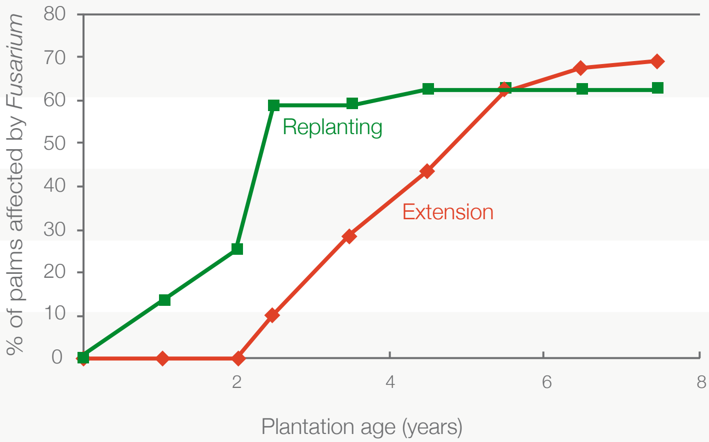
Although these are extreme experimental conditions, the trial clearly illustrated the additional precautions needed when replanting, to more effectively secure the investment made.

- In the replanted plot, *Fusarium* wilt symptoms occurred right from the first year. The disease then spread rapidly up to 3 years after planting, reaching a *Fusarium* wilt rate of over 60%.

- In the plot planted with oil palm for the first time, symptoms started appearing a little later, at around 2 years after planting. In a rare situation, due to the extreme susceptibility of the cross used in this trial, the *Fusarium* wilt rate at the end of the trial was similar to that in the replanted plot, but it was reached after 5 years, rather than 2 in the previous case.

In all cases, disease incidence in a planted plot depends on the planting material used (resistant or susceptible), the type of soil, the environment (climate, topography) and crop management. The health status of the previous plantation, for which cases of latent *Fusarium* wilt that are difficult to detect need to be taken into account, is a further factor to be considered when replanting.

Fig.4 Disease incidence in the field on a *Foe*-susceptible planting material

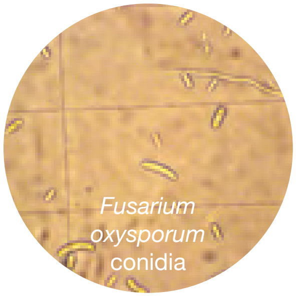


5. Propagation process and factors conducive to pathogen development

5.1. Propagation process

VIA THE SOIL AND PLANT DEBRIS

Foe is a soil-borne fungus that produces macroconidia and microconidia (spores involved in asexual propagation), as well as chlamydospores (thick-walled spores involved in vegetative propagation). It is the chlamydospores that enable the survival of the fungus in plant debris (e.g., felled old palm stems) and in the soil.



The fungus invades the roots and develops in the stem via the xylem vessels [2], causing them to become blocked by the gums and tyloses produced in reaction to its presence.
It is essential to avoid collecting topsoil to fill prenursery and nursery bags in zones likely to be infected by *Foe*, or any other harmful organism.[16] [17]


Chromolaena odorata eupatorium

VIA HOST PLANTS
The fungus may be harboured by host plants, frequently weeds that are often encountered in oil palm plantations, such as: *Amaranthus spinosus, Mariscus alternifolius, Imperata cylindrica, Eupatorium oderatum* [5], hence **the importance of effectively controlling the development of such weeds.**

VIA OIL PALM SEEDS OR THE SEEDS OF LEGUME COVER CROPS [1]
To date, no cases of disease transmission have been reported via oil palm seeds previously treated with fungicides. Some cases of transmission via untreated legume cover crop seeds have been reported in Latin America (Brazil in 1983 and Ecuador in 1986 [11]), those seeds had been collected in regions where *Foe* was present.

Choosing a certified seed supplier provides the guarantee of receiving disease-free seeds.


Seed preparation, separation and conditioning at “la Cabaña”(Colombia)


Storage

5.2. Factors that can influence *Foe* development

Foe development depends on several factors, including crop management.
Many observations have been made of the various abiotic factors possibly involved in *Foe* development. Those observations are sometimes contradictory.
Although no aspect of crop management is 100% effective against the disease, **introducing and maintaining good practices, and choosing a planting material selected for its resistance, will be a winning combination to help ensure truly effective *Foe* control.**

5.2.1 Abiotic factors

We would draw attention to certain studies that have linked a given abiotic factor to *Fusarium* development. Most of them have not been confirmed and these observations need to be considered with caution.

CLIMATE

There would seem to be a close link between *Fusarium* wilt development and a prolonged dry season, which is typical of the oil palm environment in West Africa; disease incidence is seemingly greater in regions with a higher annual water deficit [3]. In a severe dry spell, dead roots in the superficial layer of the soil could be a portal of entry for the pathogen [3].

SOILS

The infectious potential of a soil results from interaction between the pathogen population and the receptiveness of the soil, i.e. all the biotic and abiotic factors that govern the survival and activity of the pathogen in the soil (Bouhot, 1980 ; Alabouvette et al., 1982 quoted by Abadie C. et Al.).[14]
For soil-related factors, more inoculum has been found in light sandy soils than in clays. Soils with a low organic matter content, a low pH, and which are leached or have a low exchange capacity, would also seem to be at risk [3].
Poorly drained soils are conducive to root asphyxia and are also a risk factor for disease development.

TOPOGRAPHY

Bottomlands (often poorly drained) would seem to be propitious to disease expression [13] [18].

PLANTING AND CROP MANAGEMENT

Planting

Replanting in oil palm plots that were severely infested is a high-risk situation. **It is essential never to plant young palms too close to the positions of the old palms.** [13] **Likewise, it is unwise to change the planting density when replanting in an old plot,** to prevent certain new palms being planted in the former positions of potentially contaminated old palms (see § 7.2.1.).

Crop management

A vigorous palm would seem to be less susceptible to the disease than a less vigorous palm. [3]

However, this observation is somewhat difficult to generalize. The relation is not found in our selections and we know of some extremely vigorous palms that are highly susceptible and others that are highly resistant, or conversely palms lacking in vigour that are highly resistant.

Palms displaying obvious *Fusarium* wilt symptoms must be eradicated to limit disease spread and pathogen persistence in the soil. Chain-sawing should be avoided as it scatters sawdust on the ground from infected stems.

Fertilization

- Potassium appears to have a beneficial effect in controlling *Foe* development. Significantly fewer disease cases are found when there is no potassium deficiency. However, the effect of potassium fertilization only becomes noteworthy 9 years after the first applications [10] [13], and cannot durably control disease development: some well-managed plantations have suffered serious *Fusarium* wilt attacks (we have seen this in Cameroon at certain sites belonging to one of our partners).
- De Franqueville and Diabaté reported that applying EFB in the weeded circle right from planting is conducive to *Fusarium* wilt incidence if the soil is pre-infested by the pathogen [14]. No such incidence has been found in mature plantations after applying EFB in the interrow [8].
- Planting the legume cover crop *Calopogonium caeruleumis is* also a factor that promotes *Foe* development [9] [13]. On the other hand, Pueraria would tend to reduce *Foe* levels in the soil according to a study published in 1996 [14], but this has never been confirmed.

Irrigation

In the event of a long dry spell, irrigation would help to prevent superficial root death, which appears to facilitate pathogen penetration into the plant. [3]

5.2.2 Biotic factors

PLANTING MATERIAL

The severity of a disease depends on the receptiveness of a cultivated plant to the pathogen attacking it. **A planting material selected for its resistance to a given pathogen is less receptive than a susceptible material.**

WEEDS AND LEGUME COVER CROP SEEDS (see §5.1 – p.18)

6. Control methods

6.1 Genetic control: an effective method

It is only by choosing a planting material that is adapted and certified highly resistant* that ***Fusarium*** wilt development can be durably prevented in a plantation. Even so, it is very important to continue respecting the crop management rules described above, to combine all the conditions required for effectively controlling the disease.

6.1.1 PalmElit selection: a well-oiled process

PalmElit-CIRAD® seeds with high resistance to *Fusarium* wilt are the culmination of breeding work launched over 60 years ago.

The search for resistant planting material began in 1957 when Prendergast succeeded in inoculating Foe on nursery seedlings in Nigeria.

Today, resistance is greatly suspected of being polygenic. Based on our experience of planting material reactions at different experimental sites, such as Dabou in Ivory Coast, Sèmè-Podji in Benin and Dibombari in Cameroon (contrasting geographical zones in terms of climatic conditions and the genetic variability of the pathogen), we found a similar resistance response for a given planting material whatever the geographical zone or pathogen strains with which it was tested. The ubiquitous nature of resistance to different *Fusarium* strains is now proven.

**PalmElit has adopted the definitions of resistance of the ISF (International Seed Federation) [12]. High Resistance is the ability of the oil palm to highly restrict the growth and/or development of a given pest and/or the damage it causes under normal pest pressure when compared to a susceptible palm. A High Resistance palm may, however, exhibit some symptoms or damage under heavy pest pressure. A susceptible variety will exhibit more symptoms and more damage under the same conditions.*

PalmElit has developed a large-scale early screening set-up in the prenursery to measure *Foe* resistance in the crosses we are working on. We systematically assess the parental palms of these varieties. We can thus be sure of the resistance of the planting material we select. To date, a database of almost 24,000 crosses has been compiled, thanks to ongoing collaboration between plant pathologists and geneticists, with strong back-up from our statisticians.
Two hundred crosses are compared in each screening test, each with 8 replications of 20 seedlings. All the tests are interconnected by a range of control crosses with known resistance levels.

Observations in plantations have demonstrated the excellent correlation between early screening results obtained in the prenursery and the performance of the material in the field. Early screening in the prenursery is reliable and reveals *Fusarium*-resistant planting material.
The FFB and CPO yields of materials selected for their resistance are monitored, so that all the parents used in crosses that do not achieve the fixed objectives can be ruled out.

6.1.2 A large-scale set-up supervised by plant pathologists

PalmElit and its partners have two *Foe* resistance screening laboratories: one in Benin at Sèmè Podji near Cotonou, in partnership with **INRAB*** and **CRA-PP***, and the other in Cameroon, in partnership with **CAMSEEDS***.

The early screening tests and experimental trials of *Foe*-resistant materials are monitored by PalmElit's breeders and plant pathologists, backed up by scientists from **CIRAD** and our local partners.

PalmElit statisticians, based in Montpellier, are in charge of data coherence checking and analysis.

- **In Benin, with INRAB,** 3 screening tests are carried out per year at Sèmè-Podji, i.e., more than 100,000 seedlings tested annually; 175 hectares of plots are reserved for selection, and 50 hectares for seed gardens.
- **In Cameroon, our partner CAMSEEDS** also has a plant pathology laboratory and a prenursery devoted to early screening for *Fusarium* resistance at Dibombari (Littoral region). Likewise, 3 early screening tests, i.e., over 100,000 seedlings, are carried out each year.

* CRA-PP (Centre de Recherche Agricoles sur les Plantes Pérennes) is a department of l'INRAB (Institut National de la Recherche Agronomique du Bénin), based in Pobè, Benin.
* CAMSEEDS is a seed research and production unit based in Cameroon. It belongs to the SOCFIN group.

6.1.3 How does early screening work?

Inoculum is prepared from *Fusarium oxysporum* f.sp. *elaeidis* strains isolated from diseased palms; a particularly aggressive local strain is chosen. Given the ubiquitous nature of resistance, a single strain can be used for screening (see § 6.1.1).

Prenursery seedlings are inoculated around a month and a half after the seeds are planted. At least every 4 weeks, an intermediate observation of external symptoms is carried out and the final test result is obtained 4.5 to 5 months after inoculation. Internal symptoms are then observed, as well external symptoms.

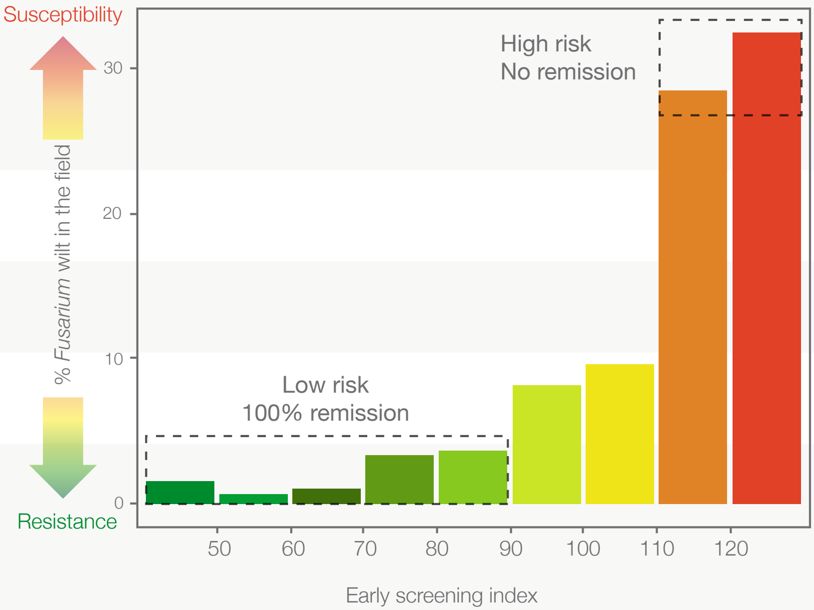

Conservation of strains of *Fusarium* and *Ganoderma*


Strain of *Fusarium* grown in a Petri dish


Cultivation of *Fusarium* in Roux flasks

A resistance measuring index is used to interpret the results. The performance of a given cross is based on the percentage of wilt-infected plants for the cross and the average percentage of wilt-infected plants for the control crosses. The higher the index, the more the cross is considered susceptible (Fig.5).

Fig.5 Early screening in the prenursery: an effective tool for selecting *Fusarium* resistance



Some further statistical analyses making use of the genetic design implemented during screening tests enable us to assess the value of each parent and select those that transmit the greatest resistance. It is those parents that are used to produce #F seeds. The traditional index, as described above, has been completed with a genetic value expressed for each potential parent in the form of a resistance ratio.

The following graph (Fig 6) gives the genetic value for the *Fusarium* resistance of 1,694 tested parents, spread over 144 families (each family* is represented by the same vertical line) belonging to 14 distinct genetic origins**. A dot represents the value of a parent from the family in question. The index 100 represents the average level of resistance of all the tested parents. The higher the index, the more the parent is susceptible to *Fusarium*. The graph perfectly illustrates between-origin variations, as well as within-origin differences that include differences between and within families.

Symptoms of fusariosis in an early screening

Seedling inoculation at Sèmè Podji (Benin)

Fusarium susceptible seedling

Dead plant of *Fusarium*

Internal symptoms

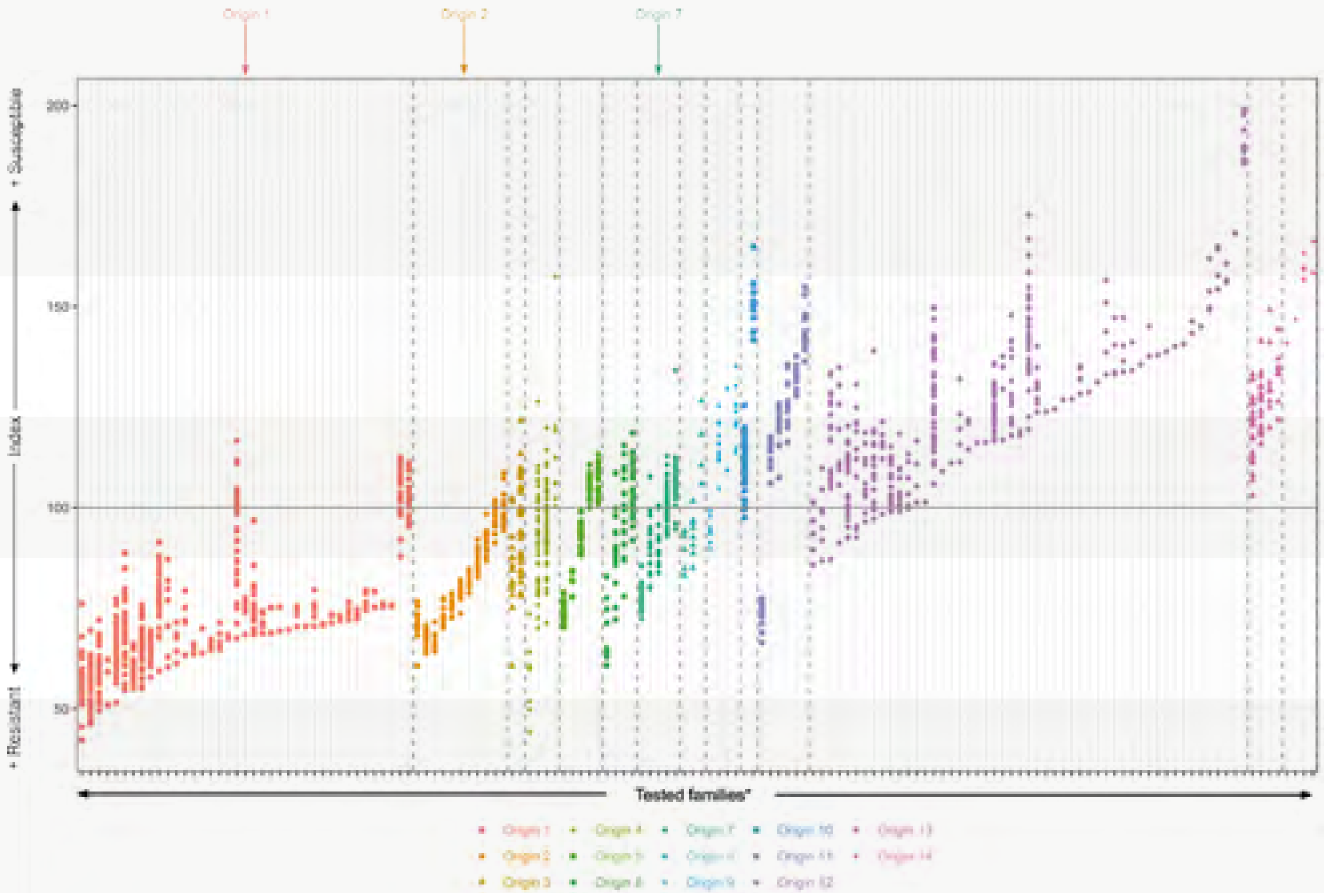
Resistant plant

Susceptible plant

PalmElit uses this variability to select resistant palms. For example:

- Origin 1 is clearly the most resistant origin.
- Origin 7 shows different degrees of *Foe* resistance and, moreover, it is also resistant to *Ganoderma* [20] a second major disease on which PalmElit is working to offer the African market a planting material with dual *Fusarium – Ganoderma* resistance.
- Origin 2 was obtained by crossing some promising palms of origin 7 with some resistant palms of origin 1. Certain families with good resistance levels against both *Fusarium* and *Ganoderma* can be selected within this origin.

Fig.6 Genetic value of parents having undergone early screening for *Fusarium* resistance



** A family is a group of individuals produced from seeds of the same origin, derived from a single cross between a female inflorescence and pollen from a single clearly determined palm.*

*** A genetic origin refers to the “ancestral” individuals that comprise it. The ancestors considered form the basis of our breeding programmes.*

6.1.4 Correlation between early screening in the prenursery and resistance in the field

The finest study of the correlation between resistance expressed in early screening tests and that found in the field was carried out by IRHO. The Dabou experimental station is located in Ivory Coast, in a savannah zone where *Fusarium* wilt is particularly rife.

In the 1950s, the station was planted with *dura x pisifera* crosses whose parents were known and indexed by the plantation. In this way, it was possible to identify the first sources of resistance to *Fusarium* wilt. In addition, once early screening had been developed, a large number of these crosses were tested in the prenursery.

By comparing the index obtained with early screening and the *Fusarium* wilt damage seen in the field, it was possible to draw up a graph illustrating the Field/Early Screening correlation based on over 170 crosses (see Fig.5).

It is clear that an index under 90 provides considerable security for growers: few cases of *Fusarium* wilt are found in the field, plus they are only temporary and have no impact on yields.

6.1.5 Constructing a *Foe*-resistant cross

Each of the female parents (usually Deli *dura*) and each of the male parents (usually *pisifera* palms of La Mé, Nigeria or Yangambi origin), were scored and divided into 7 categories according to the index attributed to them. The categories, females and males, were scored 1 for the least resistant to 7 for the most resistant.

Resistance to *Fusarium* wilt is primarily transmitted additively, i.e. the cross cumulates the level of resistance of the female parent (*dura*) and that of the male parent (*pisifera*).

To produce a *Foe*-resistant cross, only a score over 11 (combined *dura* and *pisifera* scores) is taken into account. This corresponds to an index below 90 which, according to figure 5, provides high security for growers (Table 3).

TABLE 3
CORRELATION BETWEEN THE EXPECTED SCORE AND THE OBSERVED INDEX.

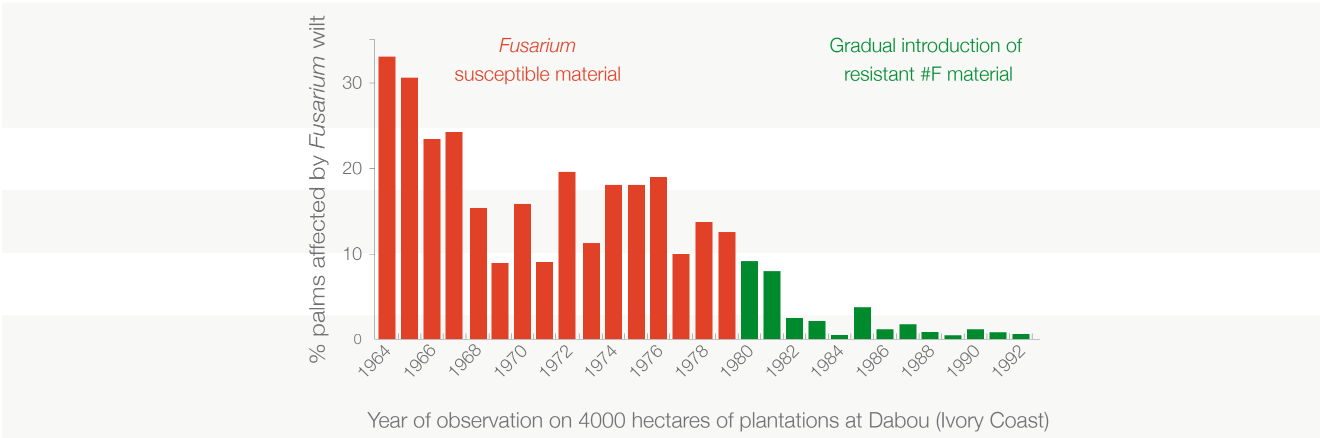
Score (expectation) of *pisifera* palms (families or individuals)

Score (expectation) of *dura* palms (families)	1	2	3	4	5	6	7
1	177	150		118	125	157	67
2	145	138		115	117	104	92
3	146	130	121	115	110	104	93
4	138	124		102	100	92	81
5	123	110		100	93	86	73
6	121	104		81	78	68	58
7		113		86	68	58	46

6.1.6 Marketing of PalmElit-CIRAD® #F highly *Foe*-resistant planting material - Impact on the disease

The first *Fusarium* wilt-resistant material became available in the 1980s. Resistance levels have been improved by successive selection operations and, today, our material is highly resistant to the point that 100% remission has been seen for the very rare cases observed.

Fig.7 Decline in mortality thanks to the dissemination of #F resistant material



7. The PalmElit-CIRAD® DExLM genetic solution carrying the #F option helps secure plantations against *Fusarium*

PalmElit-CIRAD® DExLM planting material carrying the #F option can be offered with 3 other options depending on the requirements of each grower:

#F #S DExLM **#G #F #S DExLM** **#F #I #S DExLM**

- **Option #G –** Intermediate resistance* to *Ganoderma*.
- **Option # S –** Reduced vertical growth rate.
- **Option # I –** Oil protection from rapid acidification.

These options do not affect PalmElit-CIRAD® DExLM planting material bunch and oil yields, or oil composition.

** See definitions of resistance in § 6.1*

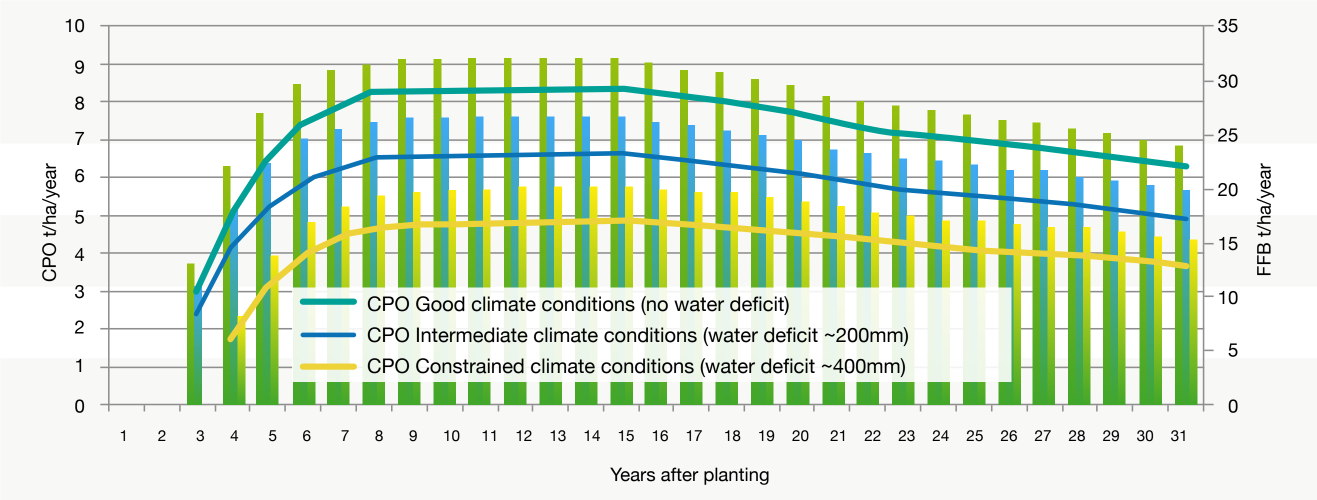
7.1 Characteristics of PalmElit-CIRAD® DExLM planting material

These data are purely indicative and are representative of the results achievable under good growing conditions and in the absence of diseases or parasites.

	Deli x La Mé *Tenera* PalmElit-CIRAD® DExLM		
	Average values on sandy-clay soils*2 (Planting density: 143 palms/ha)		
	No water deficit	Water deficit ~200 mm/year	Water deficit ~400 mm/year
Tenera hybrid	Yes		
Annual vertical growth in cm	46 to 56 cm	44 to 54 cm	42 to 52 cm
Drought tolerance	Tolerant		
Bunch production (FFB) for mature palms, (Age > 7 years) t/ha/year under true conditions	30-32 t	25-27 t	18-20 t
Bunch production (FFB) for mature palms, (Age > 7 year) t/ha/year under experimental conditions*3	31,5–33,6 t	26,2–28,3 t	18,9–21 t
Average bunch weight, mature palms	< 18 kg	< 18 kg	< 18 kg
Mill extraction rate (CPO OER)	> 26 %	> 25 %	> 24 %
Laboratory extraction rate (CPO O/B) *3	~30 %	~29 %	~28 %
Mill extraction rate (PKO)	2-3 %	2-3 %	2-3 %
Laboratory extraction rate (PKO) *3	2,5-3,5%	2,5-3,5%	2,5-3,5%
Mill oil yield (CPO) t /ha/year	7,8–8,5 t	6,2–6,8 t	4,3–4,7 t
Mill oil yield (CPO+PKO) t /ha/year	> 8,4 t	> 6,7 t	> 4,6 t
Iodine value (Wijs)	> 54	> 54	> 54
First harvest at:	2 years	2,5 years	3 years

These data come from PalmElit experimental plots for conditions without a water deficit, and were estimated for the conditions with a water deficit of 200 and 400 mm. They may vary depending on crop management.
**2 It should be noted that the genetic performance of any oil palm variety is affected by cultural practices and environmental conditions: soil type, climatic conditions. One of the factors with the greatest impact is the water deficit (drought).*
Our data come from trials on medium quality sandy soil, where our variety can produce 31 tonnes, but under excellent conditions we have recorded yields of up to 45 tonnes.
**3 In this table we have added the FFB yield and OER extraction rate values obtained in the laboratory and in the mill under true conditions. There is always a difference of 15% between the oil extraction rate (CPO OER) values obtained in the mill and those obtained in the laboratory, the mill rate being lower.*
For FFB yields, there is generally a difference of 5% between the values obtained in genetic trials and those estimated under actual plantation conditions.
To conclude, all the differences in performance between the results obtained in the laboratory and genetic trials, compared to those obtained in the mill and plantation, amount to around 20%.

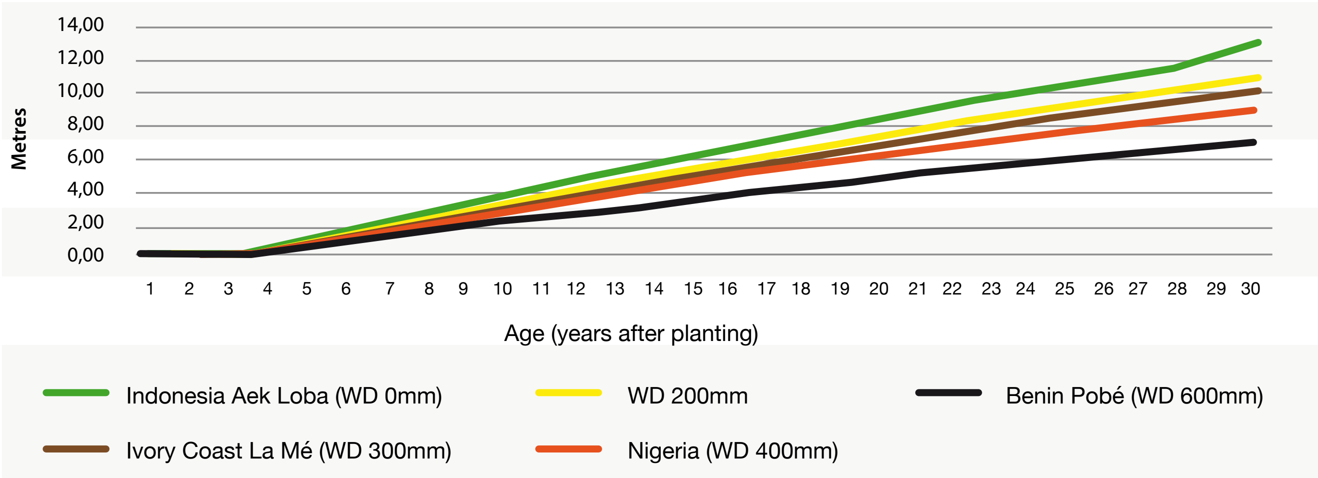
Fig.8 FFB & CPO yield profile for PalmElit-CIRAD® DExLM



Vertical growth rate for PalmElit-CIRAD® DExLM planting material

The growth curves depending on the water deficit (WD) indicated below are indicative only and the data may vary depending on climatic factors, soil characteristics and crop management.

Fig.9 Growth curves (stem height in metres) for different environments and water deficits PalmElit-CIRAD® DExLM



Oil composition of PalmElit-CIRAD® DExLM planting material (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

7.2 Crop management

The PalmElit-CIRAD® planting material providing protection against *Fusarium* wilt (#F) does not call for any notable difference in crop management compared to the other *E. guineensis* materials marketed by PalmElit. For optimum yields, PalmElit recommends a planting density of 143 palms per hectare.

Under optimum conditions, a minimum working life of 25 years is guaranteed thanks to the slow vertical growth rate of PalmElit-CIRAD® planting material carrying the #F option.

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

7.2.1 General rules when considering replanting

Replanting success relies on the health status of the first generation palms being replaced, and on the choice of future planting material.

If the plot was severely infested by *Fusarium* and infected palms were not eradicated as and when they occurred, the health status of the replanted palms is bound to be affected. **Nevertheless, the degree of infestation will depend on the degree of resistance exhibited by the chosen planting material.** Systematic elimination of palms affected by chronic *Fusarium* wilt, which can vegetate for several years, is strongly recommended.[9]

New palms should be replanted along the old planting row, but at equal distances from the positions of the previous palms. A change in planting density should also be avoided, so as not to end up replanting new palms in the same positions as the previous palms, which can be major sources of inoculum. See figure 10.

Fig.10

TO BE AVOIDED

Plot replanted at a density of 160 palms/ha, different from previously (143 palms/ha): in some places the new palms find themselves in exactly the same positions as the old palms.

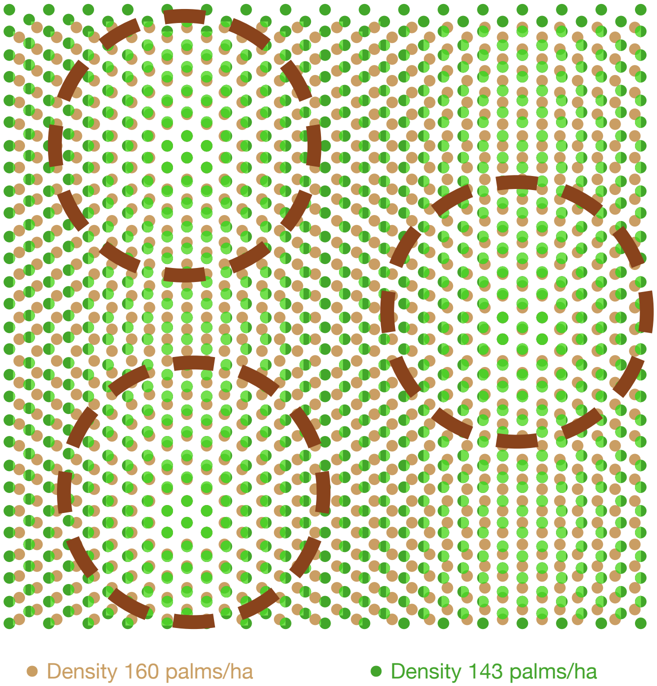
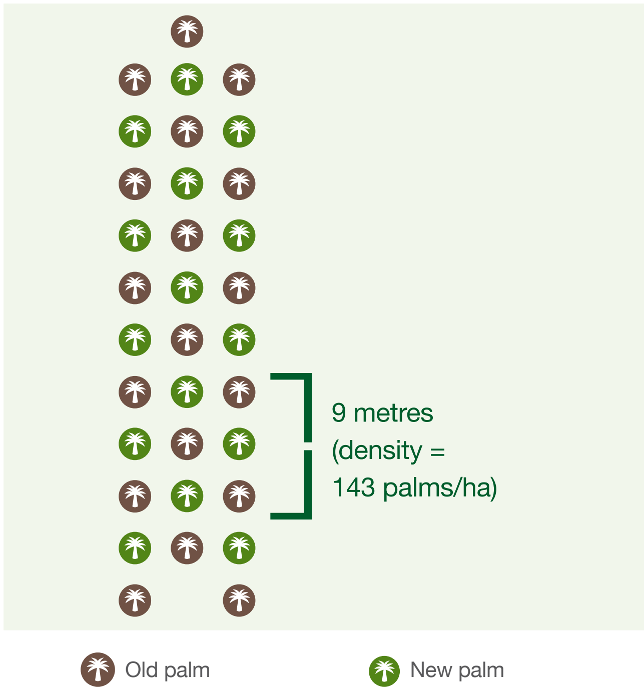


Fig.11

RECOMMENDED

Replanting at the same density along the same row between the previous palms.



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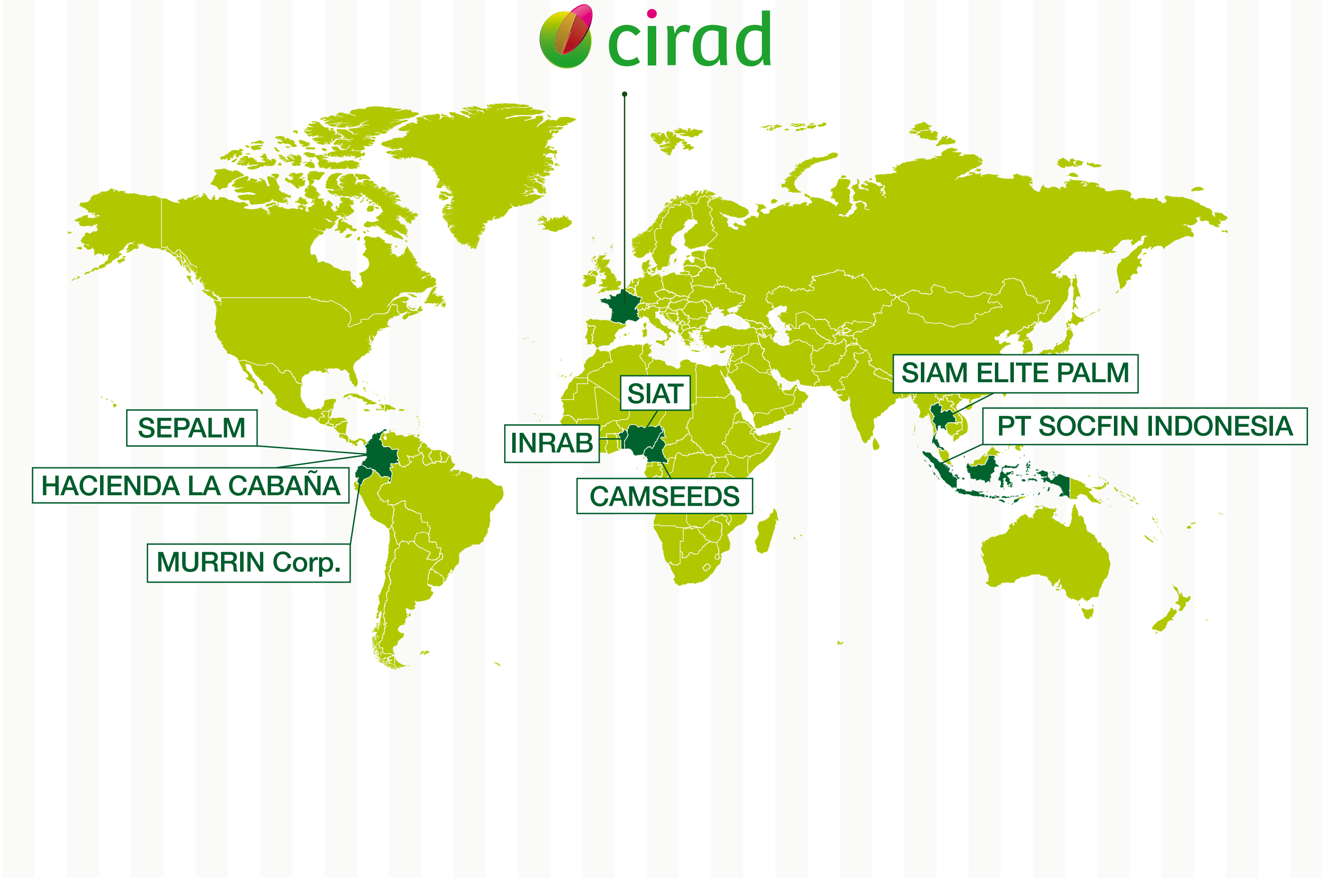
Partners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