



Using Oil Palm Segregation Genetics to Decipher Illegitimate Seed Distribution Channels to Smallholder Farmers in Cameroon

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Abstract

Planting material or seed is the most determinant factor for oil palm productivity along side agro climatological and management considerations. A study was conducted to determine the different varieties of oil palm planted in smallholders' plantations, the distribution channels for oil palm seeds and all the actors involved in the seed trade sector in Cameroon. This is a bid to secure the supply of only improved planting materials to smallholder farmers. 230 oil palm smallholder plantations were surveyed and individual palms were subjected to varietal determination. The Chi-Square Test (χ^2) for Fixed Ratio Hypothesis ($\alpha = 0.05$) was used to determine whether the observed ratio deviates significantly from the Mendellian hypothesized genetic segregation ratio. Up to 65% of smallholder farms were found to be planted with poor planting material distributed in the different Mendellian ratios; 100% Dura, 50% Tenera and 50% Dura (1:1), 25% Dura, 50% Tenera and 25% Pisifera (1:2:1). The source of this poor quality planting material for these farms was deduced to come from private nursery entrepreneurs and workers of industrial plantations such as the Cameroon Development Corporation (CDC), Cameroon Palm Oil Company (SOCAPALM), Common Initiative Groups (CIG's) and Non-Governmental Organisations (NGO's). Farmers supplied by government services especially the Ministry of Agriculture and Rural Development and some of its specialized development projects all received good quality material. Thus, this is the only means now available which can assure the distribution of seeds good quality seeds

Key Words: genetic segregation ratio, illegitimate seeds, climate change, seed distribution

A. Introduction

Agriculture is the backbone of Cameroonian economy. More than 75% of the population is dependent on agriculture and related sectors. Agriculture in Cameroon is mainly rudimentary with the use of slash and burns techniques especially in subsistence farming which makes up 85% of Cameroonian agriculture.

Agriculture, especially the cultivation of oil palm has been seen as one of the most important causes of climate change (Hasanah, Komarudin, Dray & Ghazoul, 2019). Agriculture does not only convert large expanses of forests into monoculture plantations, but also as a great emitter of Green House Gases (GHG) emission into the atmosphere (deAlmeida, Vieira, Silvio, & Ferraz, 2020). Cameroon is ranked 62nd among emitters of Green House Gases in the world. The country is ranked at the 148th level on the globe in terms of GDP per capita. Therefore, it is a relatively high producer of GHG for a less industrialized nation. This high GHG level is from agriculture and related sectors.

Constraints in oil palm production in Cameroon include the use of poor seed material, rudimentary planting techniques, and Fresh Fruit Theft (Ajambang & Ijang, 2016), pollination success Li, Tschardtke, Saintes, Buchori & Grass (2019). This has caused productivity (1.2 tons CPO/ha/yr) to remain low, (MINADER, 2011; Hoyle & Levang, 2012) when compared to 4.5 tons CPO/ha/yr for South East Asian countries. This has a great impact on climate change because more forests shall be converted to increase production by surface area expansion.

Cultivation of the oil palm (*Elaeis guineensis* Jacq.) has expanded tremendously in recent years. The Oil Palm is a major source of vegetable oils in Cameroon where annual production stands at over 150 000 MT (Bakoume & Mahbob, 2005). Its major uses include human consumption, soap and candle industry and kernel cake for animal production.

The drop in prices of cocoa and coffee that were the major export crops, associated to the increase in consumption of palm oil due to population growth has led farmers to embark on oil palm cultivation. Moreover, increased plantings are to be expected with the use of palm oil in the bio diesel industry.

Oil palm is commonly divided into three types based on their shell thickness (*sh*). The *sh* gene had been discovered by Beinaert & Vanderweyen, (1941). The *Dura* has a shell thickness between 2 to 8 mm; the *Tenera* 0.2 to 2 mm and the *Pisifera* has no shell. The fleshy mesocarp of *Dura* yields between 15 to 17%, oil that of *Tenera* yields between 21 to 23% oil and *Pisifera* more than 23% oil. The *Pisifera* mostly aborts its fruits and thereby produces virtually empty bunches, thus it is not cultivated on large scale for commercial purpose. The commercially planted and high yielding variety *Tenera* is a hybrid obtained from *Dura* mother parent and *Pisifera* male parent (Fig. 1). Among the three types of oil palm *Dura*, *Pisifera* and *Tenera* commonly found on smallholders' plantations in Cameroon, the hybrid *Tenera* had been adopted as the unique planting material. Oil palm selection and breeding has made it possible to have an oil yield of up to 4.5 t/ha/yr in a plantation cultivated with improved *Tenera* seeds. There are two oil palm seed production centres in Cameroon that include the Specialised Centre for Oil Palm Research (CEREPAH) of the Institute of Agricultural Research for Development (IRAD) at La Dibamba and the PAMOL Plantations at Lobe. Seed production at CEREPAH dates back as from 1985 and consists of reproducing the best crosses identified in the *Dura* x *Pisifera* and *Dura* x *Tenera* progeny tests. Oil palm has undergone two successful breeding cycles. The first cycle resulted in a genetic progress of 18% in oil yield while the second represented 36% of the best progenies of the "Expérience Internationale" (First Inter – origin crosses). Today 100% of all oil palm seeds supplied by CEREPAH are of the second breeding cycle. CEREPAH has projected the production and distribution of over 15 million seeds of which 50% will be vascular wilt tolerant in the next five years (MINRESI, 2008).

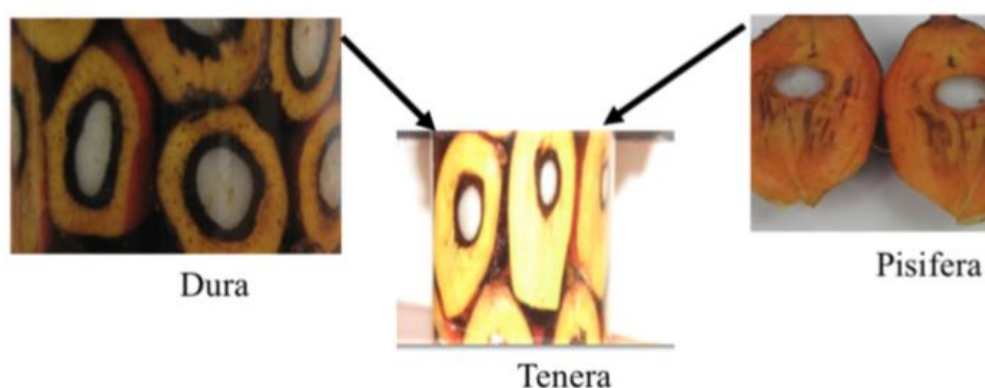


Fig. 1. The different types of oil palm planted by farmers

Recent studies on oil palm smallholdings in the Western Highlands of Cameroon reveal that the supply of improved planting material is a major hindrance to oil palm development (Ngoko, Bakoume Djoukeng, Tchamo, Imele & Adon. (2004); Bakoumé & Mahbob, 2005). This is the case with farms far away from agro industrial plantation (Cheyns & Rafflegeau, 2005). Whereas the development of oil palm small holder plantations started around the agro industrial plantations who supplied high quality planting material and modern cropping techniques to the surrounding farmers (Rafflegeau & Ndigui, 2001). The principal distributors of planting material to the small holder farmers in areas far away from agro industries include elites, private individuals, CIG's, NGO's and Government services (Bahoya, 1999). Differences in variety for oil palm cannot be made at the seedling stage until when the crop starts production four years after planting. Most farmers are ignorant of what variety they are planting although all of them may be aiming to plant the improved variety Tenera. Losses in time and money are enormous after discovering four years later that the farmer had been deceived by unscrupulous seed merchants. According to Kandi, Das & Sable (2013), the simplest and most efficient seed distribution system is to establish a central marketing cell that will supply all other channels.

The Cameroonian seed law signed by Prime Ministerial decree No. 2005/3091/PM of 29th August 2005 fixes the modality of production, quality control and commercialisation of seeds. Seed producers and distributors have to conform to the provisions of this law with respect to quality. Therefore, all farmers are advised to plant certified quality seeds. Most of the time farmers are duped by some unscrupulous seed agents who supply them with poor unproductive seeds. This is possible with most perennials especially oil palm where seed quality cannot be distinguished at the seed or nursery state. Also, these seed suppliers pretend that the seeds are from the right source whereas; they are just out to make some money.

The objective of this study was to find the quality of seed planted and detect the different possible distribution channels of illegitimate seeds that are supplied to farmers.

B. Materials and methods

1. Zone of study

The study was carried out in a series of smallholder plantations in Cameroon. The zone is located in the bimodal rainfall forest with two rainy seasons and two dry seasons. The mean annual rainfall is 1300-2000 mm and the annual temperature mean is 24 °C. Palm oil cultivation was newly introduced in the zone (during the last ten years).

2. Analysing the type of planting material by varietal determination in the field

In the zone, a total of 230 oil palm smallholder plantations were visited. All the farms visited were already in production and could make up at least a hectare. This was to ensure that the process for varietal determination for oil palm could well be carried out. Some physical characteristics which are conventionally used to distinguish between the different oil palm varieties were used. This included the size of the trees, the quantity of fruit mesocarp and shell thickness.

Table 1. Number of smallholder farmers per subdivision surveyed.

Sub divisions	Number
1	90
2	70
3	40
4	30
Total	230

1 = Ambam, 2 = Kye Ossi, 3 = Meyo Centre, 4 = Ma'an

Size of trees: All trees planted at the same time with uniform density and given the same upkeep are supposed to be the same in both trunk height and stem width except they are of different varieties. The Dura has a slow growth rate of 20 to 30 cm/yr; the Tenera has a growth rate of 25 to 75 cm/yr while the Pisifera has a growth rate of 50 to 100 cm/yr. Hence it is possible to distinguish the three varieties from neighbouring trees planted in the same year.

Quantity of fruit mesocarp: This varies greatly among descendants of the same variety and also the breeding cycle.

3. Oil Palm Varietal Determination and The Punnett Square

The genetically determining and most sure character used in variety determination in oil palm is the shell thickness. For the Dura, it is between 2 to 8 mm, 0.2 to 2 mm for Tenera and a fibre ring surrounding the ring and Pisifera has no shell (Beinaert & Vanderweyen, 1941; Hartley, 1988). Fortunately, this character follows the patterns of Mendelian inheritance for gene segregation and independent assortment making it easier to identify the genotype from the phenotype. These genes are;

- i. (sh+/sh+) for thick shell *Dura* type (DD)
- ii. (sh-/sh-) for shellless *Pisifera* type (PP)
- iii. (sh+/sh-) for thin shell *Tenera* type (T or DP)

Sampling was done on 50% of all the trees found on each plot, which is considered as our experimental unit. A plot in this sense means a piece of land cultivated with material from the same origin and in the same year of planting. Only trees carrying mature fruit bunches were sampled. Five fruits were collected from each tree and with the use of a very sharp cutlass, the fruits cut through the middle to estimate the thickness of the shell. A Punnett Square is a graphical representation that shows all the possible genotype combinations of offsprings arising from a particular cross or breeding event. It shows the different segregated genotypes that two parents can produce when crossed. Assuming that all traits exhibit independent assortment. A Punnett square grid containing 80 boxes (fig. 2) was used to indicate whether the tree sampled from its shell thickness is a Dura, Pisifera or Tenera. Each variety is expressed as a percentage of the 80 trees sampled. The Chi-Square Test for a Fixed Ratio Hypothesis ($p = 0.05$) was used to determine whether the observed ratio deviate significantly from the Mendelian hypothesized genetic segregation ratio.

D	D	P	T	D	D	D	P	P	D
T	T	T	P	T	P	P	T	T	T
T	D	T	D	P	D	D	D	T	T
T	T	P	P	T	P	T	P	P	T
T	D	P	D	D	T	T	D	T	P
T	T	T	P	T	P	T	P	P	T
D	T	D	P	T	T	T	T	D	T
T	D	T	T	T	D	T	T	T	P

The Formula for Chi Square Is

$$\chi^2_c = \sum \frac{(O_i - E_i)^2}{E_i}$$

where:

c = degrees of freedom

O = observed value(s)

E = expected value(s)

Fig. 2. Punnett Square used in sampling oil palm

D = Dura, P = Pisifera, T = Tenera

3. Principles of Segregation Analysis

Segregation analysis is a statistical approach based on the genetics of Gregor Mendel that makes assumptions to determine if the pattern of phenotypes observed is consistent with the genetic inheritance of a major gene for that trait. This statistical model is applied to explain the best fit pattern of inheritance and distribution of a trait. Tizaoui & Kchoul, (2012) used segregation genetics associated with the chi-square test to study transgene inheritance in tobacco. Weigel & Glazebrook, (2008) identified new mutants in *Arabidopsis* using segregation analysis.

4. Identifying oil palm seed acquisition channels and the actors involved

Focus Group Discussions (FGD) and Key Informant Interviews (KII) were done in all the sub divisions. In the case of KIIs, only agricultural officers and local administrative and traditional authorities were concerned. The FGD included the KII tam and other main actors in the seed distribution chain. Information obtained from the FGD and the KIIs were used to develop a semi-

structured questionnaire used in collecting data in households. This was used to interview, on purposive sampling, the farmers on the date of planting, the sizes of their farm, the supposed variety planted, the motivation behind the cultivation of oil palm, knowledge of the different oil palm varieties, their supplier for planting material, the difficulties they face in obtaining planting material and how these difficulties can be overcome. All the above data was reported into an excel spread sheet. The information was taken to the farms to determine who supplied what variety. The Chi-Square Test for Independence in a Contingency Table ($p = 0.05$ and 0.01) was used to determine whether a number of socio economic factors influence the choice of variety planted.

C. Findings and Discussions

1. *Varieties of oil palm planted in smallholders' plantations*

From the analysis of the type of planting material on smallholder plantations, we found out that three varieties of oil palm were present in most of the farms. 80 farms (35%) out of the 230 sampled were planted with improved planting material or 100% Tenera. 150 (65%) out of the 230 farms were planted with bad quality planting material (fig. 3) represented in three particular cases as follows;

1. Plots planted with 100% Dura,
2. Plots with 50% Tenera and 50% Dura and
3. Plots containing 50% Tenera, 25% Dura and 25% Pisifera.
4. Plots with 100% of Tenera

Analysis from socio economic data showed that all the farmers (100%) intended to plant the improved variety of the oil palm (Table. 2).

Table. 2. Variety of oil palm supposedly planted by farmers from interviews

S. division	variety	Frequency	Per cent
1	Improve	90	100.0
2	Improve	70	100.0
3	Improve	40	100.0
4	Improve	30	100.0

N.B. 1 = Ambam, 2 = Kye Ossi, 3 = Meyo Centre, 4 = Ma'an.

But after the field varietal determination, there were large discrepancies from their intentions of planting Tenera and what they actually planted (Table. 3).

Table. 3. Variety actually planted by farmers after verification (at least 4 years later)

Sub Division	Variety planted	No. of farms	%	Total no. of farms
AMBAM	Improved	50	55,6	90
	Poor	40	44,4	
KYE OSI	Improved	20	28,6	70
	Poor	50	71,4	
MEYO CENTRE	Improved	10	25,0	40
	Poor	30	75,0	
MA'AN	Improved	0	0,0	30
	Poor	30	100,0	
TOTAL	Improved	80	35,0	230
	Poor	150	65,0	

2. Channels of oil palm planting materials acquisition and actors involved

According to the results obtained from farmers' interviews, planting material is obtained the following four channels;

1. Staff of the Ministry of Agriculture and Rural Development (MINADER)
2. NGOs
3. Private nursery operators and
4. Workers of the Institute of Agricultural Research for Development (IRAD)

Figure 3 shows the different suppliers of oil palm planting material to farmers and the associated quality that they supply. This result is a combination of both the interviews and the actual field variety determination.

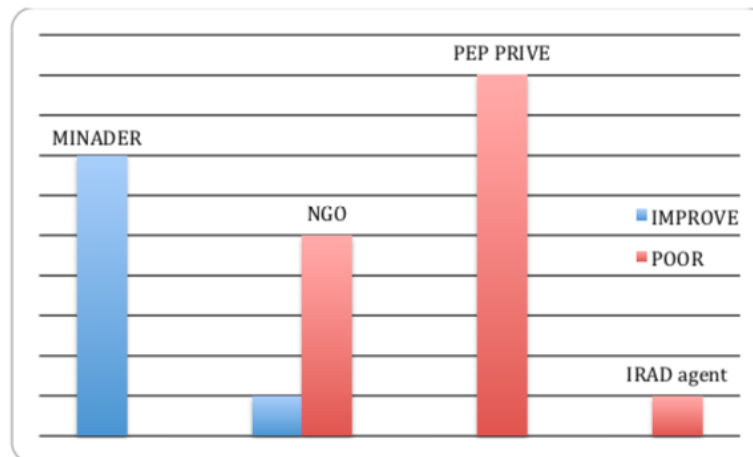


Fig. 3. Representation of the different suppliers and the quality of planting material supplied.

The staff of MINADER supplied planting materials to 70 farmers and 100% of that material was improved seed. The NGOs supplied planting materials to 60 farmers, of which 10 were improved and 50 poor quality. Private nursery owners sold planting materials to 90 farmers and 100% of that material was poor. IRAD agent supplied oil palm plants to 10 farmers, all of which was of bad quality

3. Knowledge of the existence of different varieties of oil palm

All farmers intended to plant only high quality seeds in their farms. It was found out that neither ignorance nor awareness of the differences in oil palm variety influenced the choice of material planted ($p = 0.05$). This signifies that the preferences of the farmers to plant the high yielding variety were not met. Also, the reasons for planting oil palm from our survey, which included income search, mode or because it is the trending business of the time, source of youth employment, for subsistence or for securing land did not influence the choice of variety planted. Hence, the hypothesis that people plant just any thing to occupy their land for security purposes was rejected.

4. Composition of the different farms

The farms planted with poor quality material had the following representation after field variety analyses.

- Farms planted with 100% Dura,
- Farms with 50% Tenera and 50% Dura and
- Farms containing 25% Dura 50% Tenera and 25% Pisifera.

These ratios were obtained after analysis of the counts per genotypic class using the Chi square prediction for classical genetic ratios. The few farms that did not respect any particular known ratio were discarded since no valid inference could be drawn from them.

➤ Case of Farms with 50% Tenera and 50% Dura

The corresponding χ^2 tabular value at $n - 1$ degrees of freedom is 3.841 at $\alpha = 0.05$ which is far greater than the observed value of 0.45. We then conclude that the results uphold the hypothesis of the standard ratio of 1:1.

Table 4: Representation of data for case of farms with 50% Dura and 50% Tenera

Genotypic Class	Observed	Expected	$(O - E)^2$	$(O - E)^2/E$
Sh+/Sh+	106	100	36	0.36
Sh+/Sh-	97	100	9	0.09
				$\chi^2 = 0.45$

➤ **Case of Farms containing 25% Dura 50% Tenera and 25% Pisifera**

Table 5: Representation of data for case of farms with 25% Dura, 50% Tenera and 25% Pisifera (1:2:1).

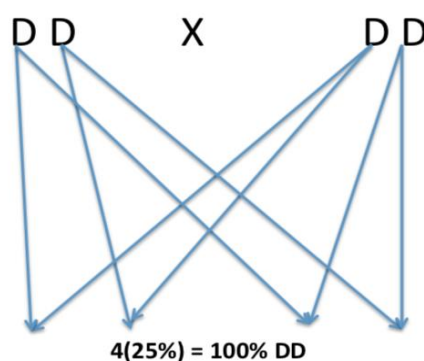
Genotypic Class	Observed	Expected	$(O - E)^2$	$(O - E)^2/E$
Sh+/Sh+	45	50	25	0.5
Sh-/Sh-	52	50	4	0.08
Sh+/Sh-	103	100	9	0.09
				$\chi^2 = 0.67$

The corresponding χ^2 tabular value at $n - 1$ degrees of freedom is 5.991 at $\alpha = 0.05$ which is far greater than the observed value of 0.67. We then conclude that the results uphold the hypothesis of the standard ratio of 1:2:1. The results obtained showed that 65% of smallholder farmers cultivate bad quality material composed of a mixture of all the three varieties. This result may be slightly different to that obtained in areas closed to agro industries by Rafflegeau & Ndigui (2001). Smallholder farms planted around agro industrial plantations benefit from the know-how of these industries.

From the three cases observed (farms planted with 100% Dura, farms with 50% Tenera and 50% Dura and farms containing 50% Tenera, 25% Dura and 25% Pisifera), the origin of the planting material and even the possible suppliers of planting material could well be sought implicitly by using the Mendelian inheritance principles based on the segregation of the oil palm shell thickness alleles Sh+ (D) /Sh- (P).

1. *Case of farms planted with 100% Dura*

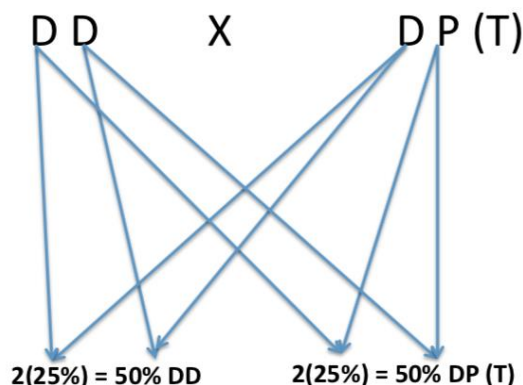
Farms having 100% Dura were planted with seeds obtained from natural groves under nearby Dura trees otherwise; they were collected from the seed farms of female genitors which contain only Dura trees. This is because 100% Dura can only be obtained from a self cross of Dura X Dura.



The possible suppliers of this type of planting materials to farmers are the pollinating agents of seed production units of the research centres (IRAD agent), who collect free pollinated fruits that fall under female genitors in the seed gardens used for the production of improved seeds thinking that these seeds will perform the same as those obtained in the artificial cross pollination of this female genitor with a compatible male pollen to produce the hybrid Tenera.

2. Case of farms with 50% Tenera and 50% Dura

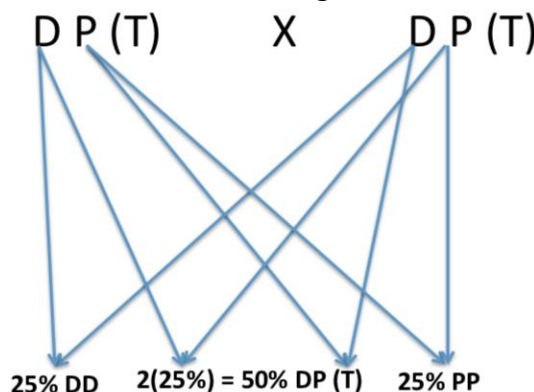
Farms having 50% Tenera and 50% Dura were planted with seeds obtained either from old smallholder plantations cultivated with a mixture of the different varieties. They might also have originated from research centres either from the experimental plots used for progeny tests or from parent plots used for seed production. In any of the above mentioned cases, Dura trees are planted nearby Tenera trees and this will normally lead to cross pollination (D X T) between them to produce 50% Dura and 50% Tenera.



The possible suppliers of these farms are either relatives of the farmers who have collected seeds from farms planted with bad quality material. Workers of research centres producing oil palm seeds may also disseminate such quality of planting material. These type of seeds can also be supplied by IRAD agents who collect seeds from progeny trial plots and raise nurseries.

3. Case of farms with 50% Tenera, 25% Dura and 25% Pisifera

These are seeds obtained from self-pollination of Tenera variety (T X T). Loose fruits that fall and later germinate under trees planted with 100% Tenera as is in the case of Industrial plantations must have served as seeds for cultivating such farms.



The possible suppliers of seeds for such farms are workers of agro industrial plantations such as the CDC, SOCAPALM, and SAFACAM. These workers are very ignorant of the hybrid nature of the Tenera variety of oil palm, which will always segregate in its F1 generation to produce its constituent parents, the Dura and Pisifera along side Tenera.

4. Case of farms with 100% Tenera

These seeds are acquired from the seed production centres of PAMOL Lobe and CEREPALH La Dibamba bought either directly or through honest intermediaries in the seed sector. All farmers supplied by the authorities of MINADER or some of their specialised programmes received improved planting material. Since all MINADER staff are aware of the differences between oil palm varieties, the complexity involved in the production of the Tenera hybrid and the losses that ensue as a result of planting material of doubtful origin. The stability and the usual close relationship that exist between them and their farmers might also have played greatly in this faithfulness. Most of the farmers (61%) are ignorant of the fact that only the seeds produced from research centre through artificial pollination can give the highly appreciated Tenera variety.

D. Conclusions

This study shows that the majority of smallholder farmers (65%) in the South Province of Cameroon cultivate bad quality material composed of a mixture of all the three varieties either obtained from natural groves or from precedent crops. No single farmer planted bad quality material intentionally; hence, their various suppliers only deceived them. Planting improved quality material will increase productivity, income and limit the unnecessary conversion of forests for new plantations. The major suppliers of this poor quality material are;

1. Private nursery entrepreneurs,
2. IRAD agents and
3. NGO's.

These suppliers must be very ignorant about the hybrid nature of Tenera and also they don't hold any liability or guarantee of the quality of material they sell to farmers. With the tight security that surrounds seed production processes and the manner with which data is computerized at all the stages, it becomes very difficult for an IRAD seed production agent to steal. Hence, they will only collect loose nuts from seed plots that are a consequent of free pollination and germinate them for their clients. Farmers supplied by government services especially the Ministry of Agriculture and Rural Development and some of its specialized development projects all received good quality material. This is because of their awareness of the existence of different varieties of oil palm that are indistinguishable at the seed stage. Also, their stability in their work place gives them the liability to supply good quality planting material. Thus, this is the only means now available which can assure the distribution of seeds produced in research centres since all of these centres (PAMOL and IRAD/CEREPAH La Dibamba) are enclaved.

E. Recommendations

The 2005 seed law should be reinforced which insists in the fact that individuals engaging in the seed and seedling distribution should be given licences and their nurseries frequently checked by experts from the research institutes and MINADER. If they are caught distributing bad quality seed, then they shall be tried in court and punished according to this law. CEREPAH and PAMOL should enter into agreement with other government agencies like the divisional delegations of MINADER, IRAD stations and other government projects to establish decentralized nurseries in their localities. Also, they can open up seed shops in the major towns of Douala, Yaoundé and Bamenda for smallholder farmers.

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