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A participatory diagnostic study of the oil palm (*Elaeis guineensis*) seed system in Benin

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ABSTRACT

A participatory diagnostic study of the oil palm (*Elaeis guineensis* Jacq.) seed system (OPSS) was conducted along a gradient of rainfall and distance to the oil palm research centre across the oil palm growing belt of Benin. The objective was to identify, jointly with key actors, the constraints in the OPSS and to assess the performance of the OPSS from a farmers' perspective. The methodology included introductory community meetings, group discussions, individual in-depth interviews, field visits and a validation workshop with the key actors. Farmers indicated that the current OPSS does not perform well. Major constraints include the poor geographic distribution of authorized nurseries, poor genetic quality of the material on plantations, high cost of hybrid planting material, and poor seedling care in nurseries, leading to poor physiological quality. The poor physiological quality was specifically mentioned in relation to authorized nurseries in the east of our study area, whereas farmers in the west and centre were more concerned about the uncertain genetic quality of the planting material. The constraints indicate the need for further research to understand the historical context of OPSS development, joint experimentation to improve seedling management practices in authorized nurseries and joint identification of the (genetic) quality of oil palm seedlings, using morphological and molecular characteristics and tools. The study also identified potential opportunities for institutional intervention: redefinition of the procedure of establishing authorized oil palm nurseries, formalization of currently non-authorized nurseries, ISO certification of authorized nurseries and social communication.

1. Introduction

An initial exploratory study was carried out within the Convergence of Sciences for Strengthening Agricultural Innovation Systems programme (CoS-SIS, see the introduction to this issue and http://www.cos-sis.org/) in Benin in 2009 to obtain a general view of the major researchable socio-economic, institutional and technical constraints experienced by smallholder oil palm (*Elaeis guineensis* Jacq.) farmers and the existing opportunities to deal with such constraints [1]. Among the constraints mentioned by farmers was the functioning of the oil palm seed system (OPSS), mainly in relation to the genetic and physiological quality of the purchased planting material, indicating that neither the formal nor the informal seed system were performing adequately. The diagnostic study of the OPSS reported here was undertaken to deepen the initial constraints analysis.

Researchers have identified many instances of dysfunction in food crop seed systems for reasons that include inability to meet the annual demand for seeds; limitations of the regulatory frameworks [2]; high prices and inappropriateness of hybrid varieties [3]; the level of inputs needed to make use of improved varieties that many small farmers cannot afford [4]; and the release of only a few varieties that in turn fail to meet small farmers' needs [5]. No such studies seem to have been made on perennial crops. If seed systems are to benefit many farmers, these setbacks need to be adequately addressed [4], also for perennial crops. This requires

Abbreviations: OPSS, oil palm seed system; CoS-SIS, Convergence of Sciences for Strengthening Agricultural Innovation Systems; CRAPP, Centre de Recherche Agricole Plantes Pérennes; SNV NGO, Dutch Development Organization; CIRAD, Centre de Coopération Internationale en Recherche Agronomique pour le Développement; CeRPA, Centre Régionale de Promotion Agricole; FNPPH, Fédération Nationale des Planteurs de Palmier à Huile.

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a thorough understanding of the particularities of the seed system, even more so for seed systems of perennials where heavy investments are needed before the production of the first harvest.

In principle, oil palm farmers in our study area either can use the traditional and locally available oil palm seedlings of the so-called *dura* type or they can plant hybrid material of the *tenera* type [6]. *Tenera* produces higher yield than *dura* owing to the heterosis effect. A small percentage of oil palms is naturally of a different fruit type, the so-called *pisifera* palms. Since around 1970 [7], the oil palm research system in Benin has produced the more productive hybrid or *tenera*, obtained through a cross of *pisifera* (male) and *dura* (female) parents [6]. Breeding has further progressed by producing improved lines of both parents and crossing these. Farmers start any planting event, whether of hybrids or traditional *dura* palms, by using established seedlings because controlled germination of seed is a tedious and knowledge intensive step. Farmers are prepared to purchase seedlings, but only if they are hybrids, because hybrid seedlings are difficult to obtain otherwise and can be accessed only from the research system, either directly or through nurseries. *Dura* type seedlings are obtained without financial cost through uprooting volunteer seedlings in existing plantations or in wild groves.

The production of hybrid planting material requires many technical steps including the selection of parents, inflorescence isolation, checking the inflorescence at maturity and controlled pollination. The hybrid seeds that are harvested six months later then undergo a controlled germination process. These steps are normally conducted under the surveillance of a breeder in order to control quality. The germinated seeds are delivered to specially trained and authorized nurseries that raise the seedlings and sell them on to farmers.

The supply of hybrid planting material to farmers is arranged through a network of actors. A farmer who buys oil palm seedlings has no means to directly check the genetic quality of the material and may unwittingly buy non-hybrid material or a mix of non-hybrid and hybrid material. It is currently possible to distinguish hybrid oil palms from non-hybrids only through the dissection of their nuts, and the first of these are produced only when palms are around 3–4 years old. The economic impact on rural livelihoods of this delay is important. According to Ngoko et al. [8], the supply of non-hybrid material to farmers in Cameroon reduces production from 77% down to 59% of its potential. The seedling quality delivered in any country is closely linked to the way the seed system is organized and functions. Durand-Gasselin et al. [9] argue that the supply of hybrid oil palm planting material, especially to smallholders in developing countries, needs more attention but that the reform of existing systems should be carried out cautiously. Smallholder farmers who want to increase oil production on their farm through the use of improved material are, to a large extent, exposed to poor quality material from multiple sources. This paper analyses the relevance of earlier findings on the seed systems of annual crops and OPSS for the specific case of oil palm in Benin.

In this paper we use the definition of seed system as formulated by Maredia et al. [10]: "*The complex of organizations, institutions and individuals associated with the development, multiplication, processing, storage, distribution and marketing of seeds of any specific crop in a country*".

In this definition an organization is understood as any social unit of people that is structured and managed to reach a need or a set goal. Institutions are defined as the rules of the game, i.e., norms, values, regulations in which organizations are grounded [11]. A seed system may include an informal seed system, also known as a local [2,12] or farmers' seed system [5], and a formal seed system. All activities in an informal seed system that are connected to seed development and production are performed without any external control of seed quality. A formal seed system typically involves a number of formal organizations, each with specific tasks. Strict quality control protocols regulate the development of new varieties and production of the seeds that are released to farmers. The main difference between informal and formal seed systems lies in the formalization in the latter case of control over seed quality during development and production.

The formal seed system in this study refers to the oil palm research system where the control over the quality of seedlings from hybrid seeds is formally assured. Hybrid seeds are obtained from controlled pollination. The term *informal seed system* refers here to seedling production and distribution in which there is no formal control of the genetic quality. The term *authorized nursery* is used for nurseries that officially obtain germinated seeds from the research system and where the nursery holder has received formal training to ensure seedlings are of both genetically and physiologically high quality. The term, non-authorized nursery, applies to any other nursery that obtains seedlings unofficially from the research system or any other source, and where the nursery holder may not have received training on how to deliver quality seedlings. A special case is the planting by farmers of seedlings collected by uprooting volunteer seedlings from existing plantations or wild groves. We thus take the OPSS to include the various supply sources, the involved actors, their respective activities and the interrelations among the actors from seedling production to delivery to end users.

The study focuses on the following four questions: (1) what are the components of the OPSS?, (2) how can the OPSS be characterized?, (3) what are the major issues hindering smallholder farmers from getting quality planting material in a timely fashion?, and (4) what are actors' perspectives on the possibilities for improvement? Based on these four key questions, this study identifies the relevant actors involved in the OPSS and their respective roles, as well as research issues and key institutional factors constraining smallholder farmers from getting access to good quality planting material.

The next section outlines the importance of the oil palm crop and presents the study area. Data collection and data analysis methods and tools are described in the methodology. The results section presents the components, organizational arrangements and characteristics of the OPSS from the farmers' perspective, identifies the constraints, and explores farmers' knowledge and practices in the OPSS. The extent to which the OPSS fits farmers' goals and needs and the institutional level at which solutions to the major constraints might be found then are analysed and discussed. The paper concludes by indicating the way forward in terms of further research and possible institutional intervention to improve seeds system functioning.

2. Study context

Oil palm is an important crop for farmers in the southern part of Benin [6] and for the rural economy of this region [13]. It is a multifunctional crop well-embedded in everyday life of the local people. Its uses include food consumption (local dishes, palm wine), traditional soap making, customary ceremonial practices and organic fertilizer. Some of the main by-products obtained from milled processing, such as palm kernel and cattle cake, are valued as animal feed [14–16]. Palm oil is also used for industrial processing: to make cooking oil (known as whitened oil), for valuable compounds like the oleochemicals used in cosmetics, for energy (as a solid fuel and biofuel) and paper [17,18]. Kernel oil is used in margarine, and the cake and chocolate industries [17].

In the past, oil palm was a crop with a strong positive influence on the national economy [19]. It was the prime export cash crop until the early 1970s with an export value share of 73.9%

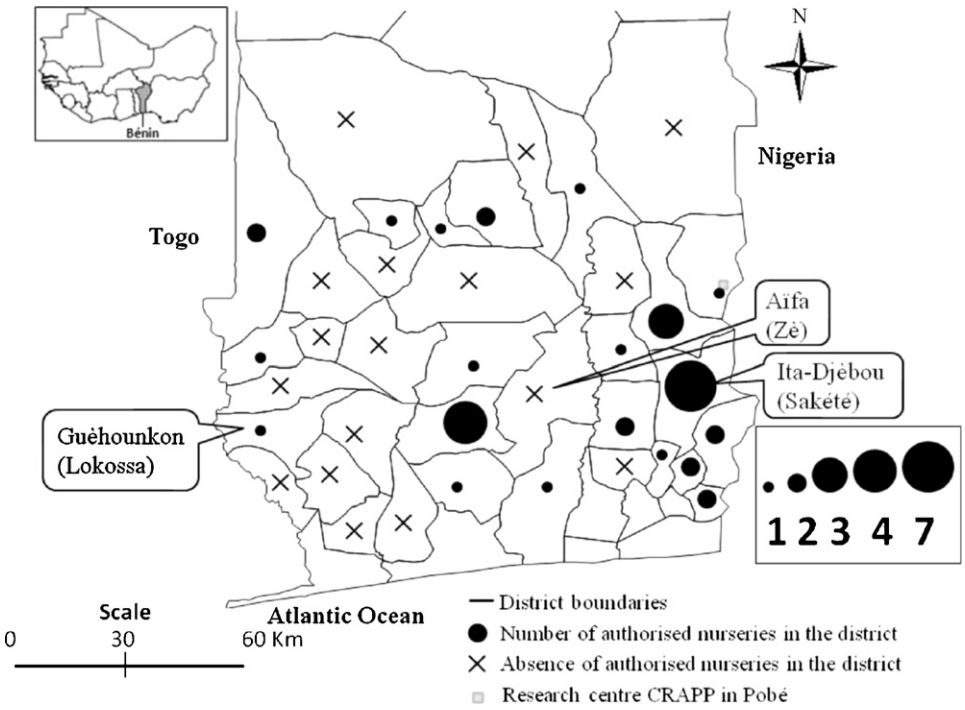

Fig. 1. Map of south Benin. The selected villages (districts) are indicated in balloons; the research station sites and the absence or numbers of authorized nurseries in each district are indicated by symbols as explained in the legend.

in 1965 [20]. By the mid-1990s oil palm represented more than 50% of the total production of vegetable oil in Benin [21] and covered 43% of the national demand for fats [6]. However, national production of palm oil (35,000 MT) today covers only about half of total domestic consumption (75,000 MT) [5,10,22–24]. A government programme initiated in 1995 for the development of the oil palm sector had little impact [5,23,24]. This initiative emphasized the development of smallholder oil palm plantations to improve smallholder livelihoods while also increasing national palm oil production for industrial purposes [13]. A good first step was made through the establishment of nurseries ran by trained nursery holders and that were provided with a foundation stock of good quality seedlings. In this way, planting material of assured quality became more readily available to farmers in the agro-ecological zones most suited for oil palm production.

Agro-ecological zones suitable for oil palm growing are located in the southern part of the country, between the coast (6° N) and inland (7° N). The climate is transitional equatorial with two rainy seasons, from March to July and from September to November, and two dry seasons, from August to September and from November through March. Annual rainfall decreases from 1400 mm in Sakété (east) to 950 mm in Grand-Popo (west) [25]. For oil palm to express its yield potential, an average annual rainfall of 1800 mm evenly distributed over the year is required (with a minimum of 1300 mm) [26]. The observed annual average temperature ranges from 23 °C to 32 °C [25,27] compared with the reported minimum of 18 °C and maximum between 28 °C and 34 °C [26].

The oil palm research centre (Centre de Recherche Agricole Plantes Pérennes: CRAPP) develops planting material of assured quality to meet farmers' needs. The CRAPP, located in the district of Pobè (Fig. 1), produces and sells hybrid seeds to both national and international buyers. At the country level, nursery holders, the extension service and oil palm farmer organizations are part of the seed supply system of the CRAPP. Both hybrid and non-hybrid types are used on farmers' plantations. Up to the early 2000s *dura* palm farms dominated; the current oil palm landscape indicates that planting of oil palms sold as hybrids has become common [13], implying that there has been a great change in the seed system, especially for farmers, and that a new effort to guarantee the quality of the planting material is needed.

Planting material constitutes the first input in the agricultural cycle [28] to improve farm outputs [29]. In the establishment of an oil palm plantation the genetic and physiological quality of the planting material is of crucial importance to farmers because it lasts in their plantations for more than 30 years [7]. Durand-Gasselin et al. [9] argue that the development of oil palm plantations is closely connected to a successful supply of hybrid planting material. Hybrid planting material ensures higher productivity and thereby secures planters' investment.

An exploratory study carried out within the CoS-SIS programme on the constraints to smallholder oil palm production suggested that the OPSS is not working adequately for farmers and constitutes a major bottleneck. Farmers complained mainly about the poor genetic and physiological quality of the planting material supplied to them [1]. The diagnostic study reported here was carried out to obtain further insight into the seed system and to identify appropriate remedial actions. The diagnostic study was conducted in three districts, Lokossa, Zè and Sakété (Fig. 1), selected along a transect from east to west of the southern oil palm growing belt, along a rainfall gradient and a gradient of distance from the oil palm research centre. The criteria for the selection of the three districts along the gradients included the importance of oil palm production in the district, the distance from the research centre, the main reasons for growing oil palm and the age of the plantations. The selection of the three districts was carried out with the help of the extension service because secondary data on oil palm are scarce.

In each district a village (Guèhounkon in Lokossa, Aïfa in Zè and Ita-Djèbou in Sakété) (Fig. 1) was jointly selected by using information gathered from key informants, together with representatives

Table 1
Characteristics of the selected villages. District names in parentheses.

Criteria	Ita-Djèbou (Sakété)	Aïfa (Zè)	Guèhounkon (Lokossa)
Dominant ethnic group	Nago	Aïzo	Kotafon
Main purpose of oil palm production	Palm oil	Palm oil	Alcohol and palm oil
Proximity to the research service (km)	30	150	200
Age of hybrid oil palm plantations (years)	More than 10	More than 10	Less than 10
Annual rainfall (mm)	1400	1200	1000

Source: The communal centres for the promotion of agriculture of Sakété, Zè and Lokossa.

of oil palm farmer organizations and the local extension service. Table 1 presents the characteristics of the selected villages. The main selection criterion was the presence of both hybrid and non-hybrid oil palm plantations.

3. Methodology

To assess the performance of the seed system across the study area data were gathered about the components of the OPSS, the characteristics of the OPSS based on farmers' perspectives, the major issues constraining farmers, and farmers' knowledge of and practices in the OPSS. Data were collected through introductory community meetings, group discussions, open and semi-structured interviews, field visits and a validation workshop with actors. For a list of all meetings and numbers of participants, see Table 2.

3.1. Introductory meetings

In each of the selected villages an introductory meeting was held. In addition to oil palm farmers the meetings brought together the representatives of the oil palm farmer organization at the village level, and a representative of the extension service who facilitated the introduction of the main researcher (and first author of this paper). The objective was to inform the oil palm farmers about the purpose of the study and to announce that the researcher was ready to work on the many constraints that had been documented related to the quality of oil palm planting material, jointly with all actors in order to find appropriate solutions. The farmers then were asked to confirm that working on the quality of the planting material was worthwhile. The participants approved the opportunity offered to discuss such a question that they qualified as being of high importance. Many of the participants talked about their experience of poor quality planting material.

3.2. Data gathering about the components of the OPSS

The study used snowball sampling to identify the actors playing a role in the OPSS [30]. The starting nodes were individual farmers. Each actor was asked who his or her partners were and how they related to each other in the system. Group discussions were used to collect further data about the components of the seed system and its internal organization. Key informant interviews provided further details about the issues discussed in the groups.

3.3. Data gathering on farmers' perceptions of OPSS characteristics, constraints, knowledge and practices

Methods were chosen to stimulate open discussion so as to reveal the actors' perceptions of the OPSS characteristics [31], the major constraints, and the endogenous knowledge and practices in the OPSS. The farmers first were sorted into three groups based on the type of oil palm material they were growing: (1) oil palm farmers growing only local material, (2) oil palm farmers growing only hybrid material, and (3) oil palm farmers growing both materials. The hypothesis behind this typology was that farmers in the different categories might have different strategies for accessing planting material. A group discussion was held with each category of oil palm farmers. The number of attendees varied from 6 to 12. The same issues that emerged in the group discussions were pursued in follow-up semi-structured interviews with the individual participants in order to obtain more specific information. Subsequently, field visits were conducted with one to four key informants to check in the field setting some of the issues raised such as the inappropriate genetic composition of palm stands, variation in the characteristics of local oil palm, less productive hybrid oil palms, and nurseries.

3.4. Validation workshop

A workshop was organized with 15 representatives of the oil palm farmers, nursery holders, oil palm farmer organizations, the extension service, and the research centre in order to discuss and validate the findings of the study and to identify the need for further research and possible institutional interventions. The workshop was held in the conference room of the municipality of Sakété. Two invited representatives of the authorized nursery holders did not attend for private reasons.

3.5. Data analysis

The identified constraints regarding the OPSS were prioritized by participatory ranking and weighting using a seven-point scale indicating little importance (1) to very great importance (7) [32]. The mean was calculated based on the total number of participants. With respect to the organizations (farmer organizations,

Table 2
Summary of tools used for data collection and number of participants.

Tools	Number of participants per selected village		
	Ita-Djèbou	Aïfa	Guèhounkon
Introductory community meetings	33	37	27
Group discussions with farmers	31	25	28
Open discussions with representatives of organizations	9	10	11
Semi-structured interviews with farmers	148	102	136
Field visits	1	4	2
Validation workshop with actors from the three villages		15	

extension service, SNV NGO, research service), the raised constraints were simply ranked by priority. Matrix tables were constructed on the constraints and the data across the three studied villages were compared to find similarities and specificities connected to a given study village. The constructed tables allowed reading through the different actors' perceptions of the constraints in the seed system. The participants' framing of the constraints and facts were reported. To characterize the target farmers' profile, percentages were also calculated based on the number of respondents who answered the questions. Local names of different local oil palm types were recorded and compared with their known botanical names.

The farmers' perspective is used in the analysis, as described by Weltzien and vom Brocke [31], because farmers are the end users of seedlings. From a farmers' perspective a seed system has a number of characteristics: (1) seed quality, (2) appropriateness of the variety traits, (3) timeliness of seed availability, and (4) conditions at which planting material can be obtained. Seed quality is closely connected to the health status of the seed. It is concerned with the capability of the seedling to tolerate various ecophysiological and biological stresses and to be vigorous. Weltzien and vom Brocke [31] named these aspects physical qualities but in this paper the term physiological qualities is preferred because the performance of parts or the whole seedling is concerned. The appropriateness of the varietal traits refers to the genetic purity and suitability of oil palm traits for local uses, and includes whether the sold seedlings are hybrids or non-hybrids and whether the available oil palm varieties allow farmers to make their own choice in order to fulfil their needs. The timeliness of seedling availability underlines the capacity of the supply system to meet farmers' demand at planting time. For this third characteristic, the phrase fine-tuning of supply and demand is used. The conditions at which seedlings are available refer to financial and physical accessibility, i.e., the price in the market as well as facilities (equipment, infrastructure, location). These characteristics are interdependent and analysis of them will help to develop a good understanding of the functioning of the whole seed system.

The hierarchical, multi-level framework of Geels [33] has also been used in the analyses in this paper. Innovation arises, according to Geels, from the interactions of distinctive processes at a range of levels: the niche level of localized change where institutional and socio-technical experiments can take place; the regime level, signifying relative stability in institutions across multiple locations, and the landscape level, signifying the larger institutional context that cannot be readily changed by niche experiments or regime-level 'rules of the game'. In this paper, a simplified two-level framework is used in order to classify constraints as either constraints at farm level, understood as issues that could be solved by innovations developed and carried out by local actors, including farmers, and constraints above the farm level, that need contributions from higher level actors to resolve.

4. Limitations to the study

The oil palm sector is very dynamic so that the identified constraints in this study may change slightly, some time later, for their order of priority or be phrased differently by the same interviewed people.

Besides the production phase, the oil palm value chain also includes processing and marketing. This study only looked at the production phase with focus on the quality of the seedling supplied to the farmers. In oil palm production in Bénin mainly men are involved. This justified the fact that most people interviewed during this study were men. Women are seen mainly at the processing and marketing phases.

5. Results

5.1. Components and organization of the OPSS

The two components of the OPSS (informal and formal seed systems) and their interrelations are presented.

5.1.1. Informal oil palm seed system

Two main supply sources were distinguished in the informal seed system: volunteer seedlings and non-authorized supply sources.

Farmers collected volunteer seedlings in both local oil palm plantations and existing hybrid oil palm plantations. The collection of seedlings did not involve any selection. Most farmers concerned acknowledged picking the planting material around a place with many seedlings. The collected seedlings were directly transplanted on the farm without first rearing them in pots.

Non-authorized supply sources are composed of:

1. *Non-authorized suppliers of germinated oil palm seeds*. The persons who were interviewed indicated they supplied germinated hybrid seeds to non-authorized nursery holders. The seed was allegedly collected from bunches that had been controlled pollinated and thus should lead to hybrid seedlings as indicated by the research centre workers from whom they obtained the seeds. We have not been able to trace these workers to further check the source. The material collected by the workers of the research service was delivered to their clients either by themselves or through intermediaries. These intermediaries were people who knew the research centre workers, or had an acquaintance at the research centre, or formerly worked at the research centre. The price of a germinated seed from a non-authorized source was 100 FCFA[1] against 150–250 FCFA in the formal system.
2. *Non-authorized nursery holders*. Non-authorized nurseries exist across the oil palm growing belt. They provide planting material allegedly raised from hybrid seeds to smallholder oil palm farmers. All non-authorized nursery holders interviewed during the study were males. The price of the germinated seed was as cited above. They raised the seedlings in the same way as the authorized nurseries did. The selling price of an alleged hybrid seedling varied from 200 to 600 FCFA. All non-authorized nursery holders interviewed expressed their willingness to operate in the formal seed system if there would be a possibility to acquire authorization from the CRAPP and obtain certified germinated hybrid seeds.
3. *Oil palm farmers relying on non-authorized nurseries*. Farmers used the informal channel to obtain hybrid oil palm planting material. They testified that their suppliers insured them that the material they were selling was from hybrid seeds they had obtained from the research centre. Farmers also acknowledged that they relied on the informal nursery as this was the one easily accessible to them. They reported that they bought the planting material for 200–600 FCFA per plant.

5.1.2. Formal oil palm seed system

The formal seed system included:

1. *Oil palm research centre*. Nationwide, the Centre de Recherche Agricole Plantes Pérennes (CRAPP), the oil palm research service, was the only organization that produces certified hybrid oil palm seeds. These were delivered to farmers via authorized nursery holders or directly to state co-operatives. CRAPP authorized

[1] The exchange rate during the study was fixed at 655 FCFA for 1 €.

the establishment of new authorized nurseries in collaboration with the extension service. It trained the extension agents and oil palm farmer organizations on growing practices. CRAPP provided technical support to authorized nurseries at their operating sites for them to raise good quality (well developed) pure hybrid planting material. Only when a farmer expressed the need for support, the researchers visited oil palm farms for technical intervention. CRAPP supplied the authorized nurseries with germinated seeds that were either tolerant or not tolerant to *Fusarium* wilt, a disease endemic to Africa that develops mostly during the replanting[2] phase. The certified material was produced by CRAPP in collaboration with the oil palm programme of CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement). To protect the material, many controls under a representative of CRAPP were organized to check on possible cheating (introduction of non-hybrid seedlings) by the nursery holders. A nursery holder who would be found to be cheating would be withdrawn from the list of authorized nursery holders and was no longer provided with germinated seeds from the research centre.

The research centre fought against the non-authorized nurseries as well. Any case of non-authorized nursery discovered across the oil palm growing belt was systematically destroyed with the help of the local security officers. The research service acknowledged that these actions were illegal as no formal regulation existed to give them the right to act in such a way.

2. *Authorized nursery holders*. Authorized nursery holders conducted their activities under the control of CRAPP. They raised the germinated seeds until the stage that plants were ready to be transplanted on the farm. They provided farmers with seedlings at planting time. Many of the nursery holders helped the less skilled farmers in planting techniques. The selling price of the planting material to farmers varied among nursery holders and depended on the agronomic characteristics of the material being sold. The price varied from 600 FCFA for material not tolerant to *Fusarium* wilt to 900 FCFA for material tolerant to *Fusarium* wilt. However, the official prices for the different hybrid seedlings were 600 and 700 FCFA, respectively.
3. *State co-operatives of oil palm*. State co-operatives were spread over the oil palm growing belt and owned large oil palm plantations that were all planted to hybrid *tenera*. The germinated seeds raised by state co-operatives were purchased directly from the research centre.

   Farmers reported that they bought planting material from representatives of state co-operatives. State co-operative representatives acknowledged that they sold the leftover of planting material to other co-operatives or private planters.
4. *Extension service*. The extension agents inform the farmers about authorized nursery holders for seedling purchase. The latter were not well known among most new planters of hybrid oil palm. When it was considered time to open a new nursery, they looked for new applicants who filled in an application form that was sent to CRAPP via the headquarters of the regional extension service. They also checked on the non-authorized nurseries to stop their activities. They sold specific inputs such as KCl fertilizer to farmers and nursery holders.
5. *Dutch development organization (SNV NGO)*. The SNV NGO supported farmer organizations, extension agents and CRAPP to preserve the quality of seedlings. It provided the research centre with financial support to train extension agents and representatives of oil palm farmer organization on growing practices. It played the role of broker that tried to gather the different actors for joint and co-ordinated actions. The SNV NGO initiated a memorandum of agreement in 2010, between itself (SNV NGO), CRAPP, the headquarters of the regional extension services (CeRPA: Centre Régionale de Promotion Agricole) and the oil palm farmer organization (FNPPH: Fédération Nationale des Planteurs de Palmier à Huile). The role of CRAPP in the memorandum focused entirely on arrangements that contributed to deliver quality hybrid planting material to farmers. The memorandum was valid until December 2011.
6. *Oil palm farmer organizations*. The oil palm farmer organizations guided farmers to the authorized nursery holders to avoid the purchase of non-hybrid seedlings. They helped their peers to get access to specific fertilizers by collecting their demands for grouped orders.
7. *Oil palm farmers*. Oil palm farmers are the 'end consumers' of the planting material. They helped their peers to buy hybrid planting material by indicating sources they trusted themselves.

It is essential to mention that the CRAPP had formal links only with authorized nursery holders and state co-operatives; there were no legally established or formalized links with any of the other actors in the OPSS that have been noted above.

5.1.3. Links between the formal and the informal seed systems

The study showed that the informal and the formal seed systems are interrelated. An example in this respect was the seedling flow. Hybrid oil palm seedlings were found in both seed systems. Actors operating in the informal seed system obtained hybrid seedlings from their peers in the formal system. Furthermore, many oil palm farmers operated in both systems through acquiring seedlings from the informal seed system in one year and from the formal seed system in another year.

Another way in which the informal and the formal seed systems could be considered to be complementary was the reliance of farmers on the informal seed system whenever the formal seed system was found to be deficient or not able to supply the required material. An illustration of the role of the informal seed system as the default option is provided by the case of Zè district, where authorized nurseries do not exist, obliging most farmers to rely on the non-authorized seedling suppliers. Moreover, farmers who failed to obtain enough planting material from the authorized nursery turned to the non-authorized nursery holders. In this way, the informal seed system could be said to be complementary to the formal seed system, even though the non-authorized nursery holders were pressed by local authorities, under the lead of CRAPP, to cease their activities.

5.2. Characteristics of the OPSS, based on farmers' understanding of a seed system

First, the four characteristics are presented of a seed system from the farmers' perspective (mentioned in the conceptual framework, i.e., physiological quality of the planting material, genetic quality and suitability of oil palm materials to local uses, fine-tuning of supply and demand and physical and financial accessibility of seedlings). Second, the extent to which the current OPSS fulfils these characteristics is highlighted.

5.2.1. Physiological quality of the planting material

Farmers in Ita-Djèbou stated that the care of the planting material in nurseries had to improve. Farmers assessed the physiological quality of the planting material by checking on seedling vigour, how disease free it was, and size of the collar diameter. The interviewed farmers in Ita-Djèbou, the study site closest to CRAPP, stated that when they compared the planting material from the authorized nursery holders with the planting material they bought

[2] Replanting is the replacement of an old plantation by a new one.

from the nursery of CRAPP, the seedlings they obtained from the authorized nurseries looked stunted. They presumed the seedling management practices to be the main cause. Farmers also noticed that the nursery holders did not sort out their planting material and obliged them to buy even the least vigorous plants. Finally, farmers acknowledged that they observed many cases of mortality after transplanting on the farm.

5.2.2. Genetic quality and suitability of oil palm materials to local uses

Farmers indicated that the genetic quality of the planting material was problematic. The purchased seedlings, all presumed to be *tenera*, included non-hybrid material. Unfortunately, determining the palm types of an oil palm plantation (*dura*, *tenera* or *pisifera*) is not possible until it starts producing seeds, i.e., at an age of 3–4 years.

All farmers interviewed across the three sites acknowledged that they did not have the possibility to choose within the available material the varieties that would suit their needs. Farmers reported for example that they did not have the opportunity to choose a hybrid variety that produces palm oil with a redder colour and good conservation traits. The palm oil from the local material, that was redder in colour than the oil from the hybrid material, was acknowledged to have better conservation traits.

Another issue raised by farmers was that the hybrid oil palm material did not fulfil many of the needs covered by the local material. An example of these needs raised by farmers was the use of the local material for wine tapping in the case of an urgent need for cash. Farmers also reported that bunch production of the local oil palm seemed to be better distributed over the year than that of the hybrid material. This allowed them to collect products from their oil palm farms over the whole year, creating financial flows that allowed them to solve their everyday problems.

5.2.3. Fine-tuning of supply and demand

Farmers attested that they lacked planting material at planting time. The authorized nursery holders in this regard reported that farmers failed to express their demand in time. Consequently, the amount of seedlings raised per planting season by the nursery men was often below the demand in order to avoid a seedling surplus. When farmers lacked planting material at planting time in a given year, they postponed planting to the following year.

5.2.4. Physical and financial accessibility of seedlings

Farmers reported that the planting material was not easily accessible, because the authorized nurseries were situated far away from their farms. Physical accessibility was described also in terms of road infrastructure, as the roads to some nursery sites were in a bad state and the nurseries were located in muddy areas. With respect to financial accessibility, farmers indicated that the purchase price (600–900 FCFA per plant) of the hybrid seedling was too high.

The next section presents the farmers' and other actors' framing of the constraints on the seed system. The analysis provides suggestions for follow-up research priorities and institutional interventions.

5.3. Perceptions and analysis of the constraints around the OPSS

The constraints were listed, prioritized and weighted (Table 3) by adding the weight scores provided by individual participants during group discussions. The mean was obtained by the ratio of the total weight and the number of the participants.

5.3.1. Oil palm farmers

Based on farmers' prioritization, the distance of the authorized nurseries to the farms, the poor genetic quality (pure *dura* or a mix of *dura*, *pisifera* and *tenera*), the high cost of the hybrid planting material, the high number of non-authorized nurseries, the poor physiological quality (the poor care) of seedlings and the palm oil colour and conservation appeared to be the major constraints of the OPSS (Table 3). The constraints identified were technical, socio-economic or institutional, or all at the same time.

The ranking of the constraints differed slightly between the farmers using hybrid material and the farmers growing both materials. For the latter, the less reddish colour of the hybrid material's palm oil was a more important issue than for the farmers growing only hybrid material. In contrast, the oil palm farmers growing only local material specifically pointed to the inappropriateness of hybrid oil palm for local uses.

The main difference between the selected sites was the absence of authorized nursery holders in the district of Zè. The genetic quality constraints appeared to be more important for farmers in the centre (Aïfa, Zè district) and the west (Guèhounkon) than for farmers from the east (Ita-Djèbou). For the distribution of the authorized nurseries over districts see Fig. 1. The west and the centre of the oil palm growing area appeared to be characterized by a low number of authorized nurseries.

5.3.2. Other actors

Table 4 shows the ranking and weighting of the constraints regarding the OPSS by farmer organizations, authorized nursery holders, non-authorized nursery holders, SNV NGO, the extension service and CRAPP. The high number of non-authorized nurseries, the lack of regulation and enforcement and the lack of specific fertilizers were the major constraints raised by most actors. For the non-authorized nurseries, the refusal of CRAPP to authorize the opening of more hybrid oil palm nurseries is the most important constraint. The genetic quality issue was a concern for farmer organizations across the sites. All identified constraints proved to be at least partially institutional. Because authorized nursery holders were shown to play a key role in the seed system, a cause–effect relationship analysis was conducted of the constraints leading to the poor seedling care in nurseries. The institutional constraints, particularly those related to the lack of specific inputs, seemed to be one of the roots of the technical constraint of poor seedling care.

When reading through the constraints from all actors' perspectives (Tables 3 and 4 pooled together), it appeared that farmers and their organizations were concerned about many constraints, with particular emphasis on the genetic quality of available seedlings and the poor distribution of the formal nurseries. The other actors, on the other hand, perceived few constraints in the seed system but were concerned about issues like the weak functioning of farmer organizations.

5.4. Farmers' knowledge and practices in the OPSS

5.4.1. Categorization of farmers, gender, age, education and growing purposes

At Ita-Djèbou a higher proportion of the interviewed farmers grew only hybrid oil palm (50.0%) than at Aïfa where the farmers combined both materials (59.8%) (Table 5). In contrast, the local oil palm material was the most used in Guèhounkon (74.2%). Oil palm farmers in this area relied mainly on the informal seed system.

The demographic characteristics used in the study to describe the profile of the target farmers were gender, age and education level. Most oil palm farmers interviewed across the study area were men (95.3, 92.2 and 88.2% in Ita-Djèbou, Aïfa and Guèhounkon,

Table 3
Farmers' weighting of the constraints on the oil palm seed system, based on criteria developed in group interviews with farmers growing local oil palm, hybrid oil palm or both.

Constraint	Local oil palm farmers			Hybrid oil palm farmers			Farmers using both materials		
	Ita-Djèbou (n = 8)	Aïfa (n = 6)	Guèhounkon (n = 12)	Ita-Djèbou (n = 11)	Aïfa (n = 9)	Guèhounkon (n = 8)	Ita-Djèbou (n = 12)	Aïfa (n = 10)	Guèhounkon (n = 8)
Poor seedling care by authorized nursery holders	.	.	.	5.7	.	.	4.4	.	.
Distribution of less productive oil palms (red leaf nerves)	.	.	.	2.3	.	.	2.3	.	.
Death of palms after planting	.	.	.	3.0	2.3	.	3.4	2.8	.
Poor genetic materials	.	.	.	4.7	5.9	5.9	5.4	6.1	5.6
Less reddish coloured and poor conservation of palm oil from hybrid material	4.0	4.3	4.5	4.5	3.4	5.0	4.9	4.7	5.8
Lack of a strong communication system for farmer orientation	.	.	.	.	.	4.9	.	.	.
Use of CRAPP name to provide non-hybrid material	.	.	.	.	.	4.3	.	.	3.9
Absence of authorized nurseries	.	.	.	.	7.0	.	.	7.0	.
High number of non-authorized nurseries	.	.	.		6.6	6.8	.	5.9	6.6
Refusal of CRAPP to establish authorized nurseries	.	.	.	.	4.3	.	.	4.5	.
Lack of regulation and enforcement	.	.	.	.	3.9	.	.	.	.
Location of authorized nursery far from farm/high transportation cost from nursery to farm	.	.	.	6.5	4.6	5.3	6.2	5.6	5.4
Existence of intermediary reselling planting material produced by CRAPP	.	.	.	2.2	.	.	.	.	.
Requirement of fertilizer use for hybrid oil palm	.	.	3.1	.	.	.	.	.	.
Former regulation that hybrid material is planted only by state co-operatives	.	.	3.3	.	.	.	.	.	.
Inappropriateness of hybrid oil palm for local uses (early wine tapping)	.	3.5	5.3	.	.	.	.	.	.
High cost of hybrid planting material	5.1	5.7	5.0	5.5	4.8	6.1	5.7	5.4	6.5
Lack of credit system to support farmers	3.1	2.3	2.8	1.8	1.4	2.6	2.0	2.7	2.4

Note: Figures in the table are averages of weights attributed by the indicated number of farmers in each village (n). The study used a seven-point scale, where higher values indicate a higher importance. Cell with 'dot' means no constraint. CRAPP, Centre de Recherche Agricole Plantes Pérennes.

Table 4
Ranking and weighting of the constraints on the oil palm seed system by representatives of farmer organizations, nursery holders, an NGO, the extension service and the research centre.

Constraint	Farmers' organizations			Holders of informal nurseries			Holders of formal nurseries			Local extension service representative			SNV NGO ($n=1$)	Research centre ($n=2$)
	Ita-Djèbou ($n=3$)	Aïfa ($n=2$)	Guèhounkon ($n=2$)	Ita-Djèbou ($n=1$)	Aïfa ($n=4$)	Guèhounkon ($n=3$)	Ita-Djèbou ($n=3$)	Aïfa ($n=2$)	Guèhounkon ($n=3$)	Ita-Djèbou ($n=2$)	Aïfa ($n=2$)	Guèhounkon ($n=3$)		
Lack of regulation and enforcement	3	5	3	.	.	.	.	.	.	2	3	3	4	2
Lack of specific inputs	5	8	4	.	.	.	5.3	4.5	5.7	4	5	4	.	.
Absence of authorized nurseries	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Poor genetic materials	2	3	2	.	.	.	.	.	.	.	.	.	.	.
Poor distribution of authorized nurseries by CRAPP	.	7	.	.	.	.	.	.	.	.	.	.	.	.
High number of non-authorized nurseries	1	2	1	.	.	.	6.3	7.0	7.0	1	1	1	1	1
Lack of credit system to support farmers	6	.	5	.	.	.	4.3	5.0	4.0	.	.	.	.	.
Refusal of CRAPP to establish authorized nursery	.	4	.	.	.	.	.	.	.	.	.	.	.	.
Lack of a good communication system for farmer orientation	4	6	.	.	.	.	.	.	.	3	4	2	3	.
Difficulties to get authorization	.	.	.	6.0	6.3	6.0	.	.	.	.	.	.	.	.
Lack of trust of the clients	.	.	.	.	4.0	4.7	.	.	.	.	.	.	.	.
Weak functioning of farmer organization	.	.	.	.	.	.	.	.	.	.	2	.	2	3

Source: Based on open discussions with representatives of organizations.
Note: Data without decimal are rankings within a column from most important (1) to least important (the highest number). Data with decimals are average weights on a seven-point scale as attributed by the indicated number of participants (n); the higher the value, the more important the constraint. n, number of participants. Cell with 'dot' means the indicated constraint was not mentioned. CRAPP, Centre de Recherche Agricole Plantes Pérennes.

respectively). Across the three sites, most oil palm farm owners interviewed (about 60% at least) were at least 40 years old. Farmers in the study area had a low education level (more than 60% of them were illiterate). In Ita-Djèbou and Aïfa, the oil palm growing purpose was entirely for their bunches, i.e., palm oil (100% of the interviewees). However, in Guèhounkon, where the local oil palm was still predominant, wine tapping was the main purpose of oil palm production for about 14% of the interviewees. All farmers who grew oil palm for wine tapping purpose were 'only local oil palm' farmers.

5.4.2. *Farmers' knowledge of the existing variation of the material in the OPSS*

Farmers growing hybrid oil palm, across the study sites, reported that they did not observe any variation in the material supplied to them. In contrast, the farmers relying on local oil palm or both materials recognized variation within the local material. They gave different names to the different materials and based the differentiation on the thickness of the shell of the nut and on nut colour. Table 6 compiles farmers' knowledge of the local oil palms. Farmers specified that apart from the natural *dura*, the other palm types they identified were rare in the natural oil palm populations (two to four per ha). When the farmers growing local oil palms were asked whether they linked the variation in the local material to different areas of the country, they answered that there was no clear relation that could be pointed out.

5.4.3. *Farmers' practices in seedling acquisition*

Across the study sites, oil palm farmers put forward three main considerations when acquiring hybrid planting material: trust, nursery proximity, and purchase price. For the farmers who were supplied by authorized nurseries, trust was the first consideration. Farmers tended to get planting material from the nursery nearest to their place of residence. Farmers supplied by non-authorized nurseries also cited the proximity of the nursery when choosing their source of seedling supply. According to the farmers, proximity helped to reduce the transportation hassle and saved time. The lower price of non-hybrid seedlings compared with the price of hybrid ones was the other criterion used by the farmers supplied by non-authorized nurseries.

6. Discussion

6.1. *Complementarity of the formal and informal oil palm seed systems*

The informal and formal OPSS appear to be evolving together across the oil palm growing belt, under the control of different categories of actors. The formal seed system, where the CRAPP has a monopoly on the production of certified material, provides a key role to authorized nursery holders, relying on them to deliver quality hybrid planting material to the farmers. The informal seed system, however, continues to operate as an important part of the OPSS. It delivers both hybrid and non-hybrid material to farmers. The informal seed system fills in many shortcomings of the formal seed system's material, namely, higher quality palm oil, a more even distribution of bunch production over the year and fitness for wine tapping, i.e., traits that effectively tally with smallholders' needs. With respect to bunch production of the hybrid oil palm, the peak month often produces 40% of the annual production, with less than 1% in the least productive months [34]. The complementarity of the two seed systems also relates to the failure of the formal seed system to supply the entire demand for seedlings.

Table 5
Profile of oil palm farmer respondents.

		Ita-Djèbou (n = 148)	Aïfa (n = 102)	Guèhounkon (n = 136)
Category of farmers[a]	Farmers growing only local material (%)	50.0	26.5	74.2
	Farmers growing only hybrid material (%)	17.6	13.7	11.8
	Farmers growing both materials (%)	32.4	59.8	14.0
Gender[a]	Male (%)	95.3	92.2	88.2
	Female (%)	4.7	7.8	11.8
Age[b]	29 years and younger (%)	4.2	12.5	11.9
	30–39 years (%)	11.2	29.1	18.6
	40–49 years (%)	20.8	25.0	30.5
	50–59 years (%)	31.9	16.7	25.4
	60 years and older (%)	31.9	16.7	13.6
Education[b]	Illiterate (%)	63.6	70.0	64.4
	Primary school (%)	13.0	28.0	22.0
	High school (%)	11.7	2.0	11.9
	Senior secondary school (%)	10.4	0.0	1.7
	University degree (%)	1.3	0.0	0.0
Growing[b] purposes	Palm oil (%)	100.0	100.0	86.4
	Wine tapping (%)	0.0	0.0	13.6

Source: Based on oil palm farmer interviews.
[a] Percentages in these rows were calculated with the total number of farmers registered per site.
[b] Percentages in these rows were calculated with the number of farmers who answered the question.

Table 6
Summary of farmers' knowledge on the variation in local oil palm.

Names of local oil palms in local languages			Corresponding botanical names	Uses	Endogenous criteria of recognition
Nago (Ita-Djèbou)	Aïzo (Aïfa)	Kotafon (Guèhounkon)			
Tchanka	*Houédé* or *Goudé*	*Bénindé*	Natural *dura* palms	Bunches, palm oil and wine tapping	Thick endocarp, high kernel number after processing
Okpèifa	*Fadé*	*Afadé*	*Idolatrica* palms	Traditional ceremonies in *Fâ* divinity	Leaflets packed together lifelong
Okpèimoko	*Sèdé*	*Sèdé*	*Virescens* palms	Treatment of illness, oil not good for consumption	Green fruits at early stage and yellow-orange at maturity
Ouma	*Dougbakoun* or *Dévotchi*	*Adéfotin*	Natural *pisifera* palms	Palm oil	Thin endocarp
Imofo	*Déhla*	–	Natural *tenera* palms	Palm oil	Small kernels with thin endocarp

Source: Based on interviews with oil palm farmers.

6.2. Identified constraints and the institutional levels at which solutions might be developed

The identified constraints indicate that the formal OPSS does not currently fulfil farmers' needs, as has been observed for other seed systems [31]. Farmers and other actors raised many constraints that affect the quality of the supplied planting material, with emphasis on the poor geographic distribution of the authorized nurseries, the observed poor genetic material on the plantations, the high number of non-authorized nurseries, the high cost of hybrid planting material, the poor seedling care in nurseries, the poor quality of hybrid palm oil and the lack of specific inputs.

The poor geographic distribution of the authorized nurseries provides space for the non-authorized nurseries to enter the market. In areas where authorized nurseries are lacking, non-authorized nursery holders are the sole source of supply of (allegedly) improved planting material for resource-limited farmers. The west and the centre of the study area are characterized by a low number of authorized nurseries and these are the areas where farmers are more concerned about the issues of genetic quality of planting material. The poor distribution of authorized oil palm nurseries clearly requires a redefinition of the process of authorizing nursery establishment. In terms of the multi-level perspective of Geels [33], this is an institutional issue that needs to be discussed by actors at a higher level than the farm (Table 7).

Table 7
Identified constraints in the oil palm seed system (OPSS), indicating the level at which institutional action could be taken to improve the working of the system.

Indicative level for action	
Farm level	Above the farm level
Poor quality of palm oil from hybrid *tenera*	Poor seedling care Poor quality of palm oil from hybrid *tenera*
High number of non-authorized nurseries	Poor geographic distribution of authorized nurseries across the oil palm growing belt High price of hybrid planting material Poor genetic materials in plantations High number of non-authorized nurseries Lack of regulation in OPSS

Source: Adapted from Geels [33].

The poor genetic quality of the planting material is primarily a matter of the mixture of oil palm materials, i.e., *dura*, *pisifera* and *tenera* found on the plantations. This suggests that some of the seedlings might have been collected from existing hybrid oil

palm plantations.[3] A common reasoning used by many of the nursery holders and farmers we interviewed is that seedlings collected from hybrid oil palm plantations do generate hybrid oil palms. This reasoning would be valid if the oil palm was a self-pollinating species [17,35], but the fact that oil palm is strictly cross-pollinating means that the collection of seedlings from hybrid plantations is a very unreliable approach to genetic improvement. Obviously, an improved understanding by the actors in the OPSS of what hybrid material is, is essential. The report by farmers that their plantations have a mixture of oil palm types makes clear the failure of the whole supply system. Genetic quality control so far has been the task of the CRAPP, which has tried to protect the quality of its own material by conducting periodic visits to the authorized nursery holders to provide technical support and check their trustworthiness. Despite this, non-hybrid material is still somehow sold to farmers as hybrid plants. The main question that remains is: where and how does the non-hybrid material enter the seed system. Further studies to assess the reliability of the current OPSS are needed to develop a better understanding. By establishing the extent of non-hybrid materials on smallholder plantations in relation to the seedling supply sources and practices, the performance of the seed system could be assessed more accurately.

Another question is whether the genetic quality control of planting material should still be the task of CRAPP. The involvement of other actors, such as forestry officers, might offer some advantages because forestry officers, unlike CRAPP, are represented in all districts across the country. They are closer to the operating sites of the nursery holders. Quality control might be more effective also if it were carried out jointly with the authorized nursery holders and representatives of farmer organizations, in a participatory way that allows joint learning across the system. Furthermore, since we found that most of the interviewed non-authorized nursery holders wished to operate in the formal seed system, a review of the procedures for the establishment of authorized nurseries might significantly reduce the flow of non-hybrid material to farmers. Additional steps for controlling genetic quality might include regulation and enforcement of standards, mass sensitization, and further research to find out which characteristics might allow early differentiation between hybrid and non-hybrid material. However, bringing these propositions into reality seems to be the task of actors above the farm level [33].

Farmers attested that the purchase price (600–900 FCFA) of the hybrid planting material was too high. The high prices of planting material in the formal seed systems hindered the resource-constrained farmers from using hybrid material, as in other seed systems [3,35–37]. Reducing the purchase price of oil palm planting material is an option that could materialize through government intervention. An alternative option would be to allow farmers to postpone payment until the farms become productive (up to five years) but this might create problems of collection of the final payment. Getting one or another option into reality obviously requires action from above the farm level [33,42].

The other issues relating to planting material quality were found to be the seedling care in the nurseries, hybrid palm oil colour and conservation. Good nursery management involves more attention but is one of the first prerequisites to guarantee a good plantation [38,39]. A closer analysis of practices in the authorized oil palm nurseries would be a promising field of research that could lead to an improvement in the physiological quality of seedlings. Further actions to ensure the physiological quality of seedlings could include the development of procedures for ISO certification of the authorized nurseries. With respect to the quality of the palm oil from the hybrid material, research results suggest that, apart from poor processing practices, options are available within the existing oil palm germplasm to improve palm oil quality in terms of the desired colour of the palm oil [40,41]. These issues could be solved by investing in research (by agricultural research institutes, universities, and NGOs operating in the research domain), i.e., by institutional developments above the farm level [33].

Our analysis shows that the OPSS displays many of the weaknesses already identified by research on other seed systems (e.g., [2]). Even though oil palm is a perennial crop, the OPSS is performing dysfunctionally in ways observed already in seed systems for annual staple foods [2]. The formal seed systems in many developing countries often fail to ensure seedling supply to farmers, especially smallholders [5,42]. Almekinders et al. [43] and Daniel and Adetumbi [44] advocate official support for the complementarity of the informal and the formal seed systems because one seed system alone cannot fulfil the different needs of users. They further consider it might be useless to treat the seed systems independently in policy as well as in seed supply studies. However, an important respect in which the oil palm seed system differs from that of annual crops is the near impracticability of breeding by farmers themselves, given the 20–30 year life cycle of the oil palm, and the necessity to sustain a direct link between the farmers and the formal breeding programme over this long period. Overall, our findings and analysis suggest that improving the productivity of oil palm for smallholder farmers, in such a constraining seed system environment, will be challenging without the effective support of actors from local to national level (e.g., policy makers) working together, as proposed also by Kessy and Laub [4].

6.3. *Farmers' knowledge of oil palm variation in relation to their seedling acquisition practices*

Farmers were found to have a good knowledge of their material. The main traits they use to characterize the diversity within their material are the thickness of the shell of the nut and nut colour, which are the same criteria used by research scientists. These shared reference points for varietal identification provide a good basis for co-operation between farmers and scientists to develop additional indicators.

Trust and nursery proximity were found to be important considerations used by farmers to select seedling suppliers. A trust factor used by farmers to select a nursery was how often their peers bought seedlings in that nursery. To some extent, this might be a misleading indicator because it does not avoid the purchase of non-hybrid material that is sold as hybrid, a problem that is complex given the long period of time that elapses between purchase and the evidence of actual performance of the material.

7. Conclusions and implications for further research

The present study indicates that the major issues constraining smallholder farmers in the OPSS were the poor geographic distribution of the authorized nurseries and related presence of non-authorized ones, the inability of most actors to check the genetic quality of material at purchase, the high price of hybrid planting material, the poor seedling care in nurseries, the poor

[3] A hybrid oil palm plantation consists of only *tenera* material [9,37]. Seedlings collected from a hybrid oil palm plantation will contain around 25% *dura*, 50% *tenera* and 25% *pisifera* due to the monogenic inheritance of shell thickness [17,38]. As the *pisifera* palms are female sterile (abortion of the female flower before the maturity of the bunch) the resulting plantation contains many sterile oil palms (about 25% of the total number of palms), a frequency far higher than in natural groves.

quality of hybrid palm oil and the low availability of specific inputs. Farmers in the west and centre of the study area (located far away from the research centre) were more concerned about the genetic quality of seedlings.

The study, based on farmers' perceptions of the seed system, provides insight into the degree to which the OPSS meets smallholder farmers' expectations. It shows that the OPSS includes a formal and an informal seed system that are interrelated and that the current OPSS is not performing adequately from a farmers' perspective, a finding shown also for seed systems in other developing countries. However, the particularities of the OPSS as a tree-based system also were shown to be consequential, i.e., the tedious seed germination process and cross-pollination necessary for seed development, obliges hybrid oil palm farmers to rely entirely on seedling suppliers (in contrast to seed development or improvement for most annual food grains, where the technical requirements can be more easily performed by farmers themselves).

This study provides baseline information that indicates that few of the identified constraints could be solved by institutional and technical developments at the farm level. The issues identified in this study that would seem to require action at higher levels, include a review of procedures of authorizing oil palm nursery establishment, regulation of the informal seed system, an improved mechanism for controlling the sale of quality hybrid seedlings, research on traits that would allow farmers to distinguish *tenera* seedlings from *dura* ones, and improvement of the circulation of information regarding seedling quality issues.

Follow-up research that seems indicated on the basis of this study includes:

1. The analysis of factors (seedling supply sources, distance to research centre and historical changes) affecting the genetic quality of the material in the smallholder oil palm plantations to check on the reliability of the OPSS so far.
2. A study of characteristics of quality (genetic) oil palm seedlings using morphological markers that could help in early and independent detection of any cheating in the OPSS.
3. Improvement of seedling management practices in the authorized nurseries and the optimization of the current protocols to improve the physiological quality of seedlings.

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