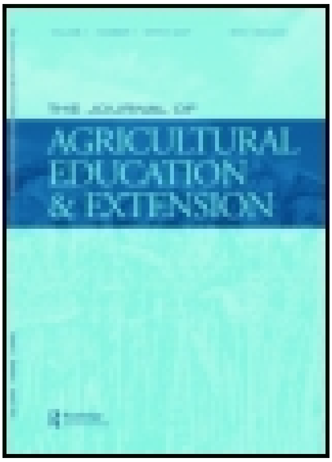

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Co-production of Knowledge in Multi-stakeholder Processes: Analyzing Joint Experimentation as Social Learning

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Co-production of Knowledge in Multi-stakeholder Processes: Analyzing Joint Experimentation as Social Learning

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ABSTRACT Purpose: *Changing research design and methodologies regarding how researchers articulate with end-users of technology is an important consideration in developing sustainable agricultural practices. This paper analyzes a joint experiment as a multi-stakeholder process and contributes to understand how the way of organizing social learning affects stakeholders' ownership of process outcomes.* Design/Methodology/Approach:*A learning group composed of the different stakeholders of the oil palm seed system in Benin was set around a joint experiment. We use a detailed account of the group dynamics to understand the social process.* Findings: *The way the process is designed and conducted has a great effect on the ownership by the participants. Methodological steps taken in this research process showed its efficacy to produce quick and positive feedback mechanisms. Stakeholders' perspectives on what constitutes a quality oil palm seedling varied widely. Participants, mainly nursery holders, learned new production practices. Representatives of the research center learned a mismatch of recommendations with users' contexts. Field observations further to the process indicate changes in practices among stakeholders that would be sustainable.* Practical Implications: *Beyond focusing on outcomes, initiatives in multi-stakeholder processes should also document and analyze social processes in order to better understand the mechanisms by which such processes foster socio-technical change, as well as identify potential institutional barriers to such processes.* Originality/Value: *Through a detailed analysis of group dynamics, this paper addresses an important knowledge gap in participatory agricultural development.*

KEYWORDS: Joint experimentation, Social learning, Co-production of knowledge, Innovation, Oil palm, Benin

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Introduction

The added value of multi-stakeholder collaboration in problem solving is increasingly well recognized (Douthwaite and Gummert 2010). As such, developing sustainable agricultural systems requires changing research methodologies in terms of how scientists and technologists articulate with end-users of technology (Defoer 2002). Trans-disciplinary research has the advantage of achieving remarkable impacts on society and delivers high quality research through involving different stakeholders with broader knowledge bases (Enengel et al. 2012). One of the main attributes of trans-disciplinary research is that it generates space for social learning and (hybrid) knowledge production (Raymond et al. 2010). Many studies acknowledge the importance of trans-disciplinary research in effectively addressing societal and environmental problems (e.g., Luyet et al. 2012). The significant contributions of non-academics in the development of sustainable agricultural practices and technologies have also been reported in many domains, including integrated pest management with Farmer Field Schools (Davis et al. 2012), soil conservation and fertility management practices (Dalton et al. 2011), development of new crop variety through participatory plant breeding (Almekinders 2011). While there are many projects that document how trans-disciplinary participatory work achieves applied outcomes (Muro and Jeffrey 2008), there has been relatively little analysis of the social encounter and learning dynamics within such projects; for an exception see (Almekinders 2011). Scholarly papers often focus on outcomes achieved through participation, but do not provide a full and more disaggregated explanation of social processes and group dynamics behind those outcomes. This paper aims to address some of the main gaps of the literature on co-production of knowledge in multi-stakeholder processes (Bell, Morse, and Shah 2012; Crane 2014). In particular a joint experiment on quality oil palm seedling production in Benin is analyzed as a social encounter between farmers, nursery holders, extensionists and technologists through which social learning contributes to changes in practices.

Through an earlier diagnostic study, Akpo et al. (2012) reported farmers' complaints about the low physiological quality of seedlings they buy from officially established nursery holders. In Benin, the organization of the oil palm seed system does not allow smallholder farmers to raise hybrid seedlings by themselves. Smallholder farmers are forced to rely on officially established nursery holders to purchase hybrid planting material. The Beninese national oil palm research center (OPRC) trains the official nursery holders and then provides them with hybrid germinated seeds that they raise and further sell to farmers. Rather than following the production technologies they learned during their training, nursery holders adapt the training package to their particular socio-economic conditions. While nursery holders' innovations make their seedling production enterprise more profitable, and have led to a diversification of production practices, not all of their practices ensure high quality of planting material.

The production of high quality oil palm seedlings for field planting is a job that involves many stakeholders with different roles: farmers are the end consumers of seedlings; nursery holders are local suppliers of hybrid seedlings; extension agents monitor nursery holders' activities; the OPRC supplies hybrid germinated seeds to nursery holders and is also in charge of quality control in officially established nurseries. All of these stakeholders, from their various perspectives, have their own particular ideas about what constitutes a good quality seedling.

In order to facilitate interaction and co-production of knowledge among stakeholders for sustainable agricultural practices, we engaged in a joint experiment with stakeholders so that they could share and evaluate their knowledge about seedling production practices. The ultimate aim was to identify seedling production practices that satisfied all stakeholders' interests and needs. The technical results of the experiment have been reported in a different paper (Akpo et al. 2014). In this article, we instead analyze the joint experiment as a social process of encounter by multiple stakeholders, wherein they all contribute to the knowledge production process, co-designing, co-implementing and co-analyzing the results. Furthermore, particular attention is given to how stakeholders work across their divergent positions and how their knowledge and practices evolve in response to the joint experiment. The study addressed the following three questions: (1) How do different stakeholders frame seedling quality? (2) What are stakeholders' views of the effects of different nursery practices on seedlings? (3) Does the way the social learning is organized significantly affect stakeholders' ownership of the process outcomes?

Theoretical Background

Different ways of organizing social learning and knowledge production with stakeholders will affect the outcomes of the process (Jakku and Thorburn 2010). The quality and nature of the end products of stakeholders' participation is closely connected to the kind of process that lead to them (Reed 2008; Crane 2009). A pipeline approach to technology production is unlikely to yield the same outcomes as a socially inclusive management regime. The way participants engage in participation significantly affects the outcomes of the process and it is important to use methods and tools that maintain a higher transparency of the process (Bell, Morse, and Shah 2012). Issues that need to be considered for a successful learning process include early integration of all stakeholders, fairness and equity for all stakeholders, their full involvement without barriers and the process facilitation (Luyet et al. 2012). The issue of language when communication takes place among social actors, for example, academics and non-academics is also important (Luks and Siebenhüner 2007). For example, in such a context scientists need to adapt their language to the audience they are collaborating with.

Besides the design and implementation of social learning process, the way to report on outcomes is important as well. We underscore the failure of researchers to fully account the group dynamics behind reported outcomes of trans-disciplinary works (Bell, Morse, and Shah 2012; Bos, Brown, and Farrelly 2013). The ability of stakeholders to interact and transcend their personal interests constitutes a key issue that affects outcomes. This paper analyzes these methodological steps, during both process design and implementation, as well as how it leads to outcomes, as defined by changing practices by participants.

The social learning literature shows a wide variety of definitions for the concept but generally admits that its meaning is context-related (Muro and Jeffrey 2008). In this study, we understand social learning as different stakeholders interacting to solve a problem, through which they acquire new skills (both technical and social), produce knowledge, and develop relationships (Muro and Jeffrey 2008). As such, it transcends a mere individual learning (Luks and Siebenhüner 2007). Social learning develops effectively through social spaces, which can take different forms. Experimentation is seen as an important means that enables social learning and knowledge production because it generates understanding and facilitates change in difficult socio-technical problems (Bos, Brown, and Farrelly 2013). The experiment implemented in this study was built upon the inputs from the main stakeholders of the oil palm seedling supply system in Benin.

Multi-stakeholder platforms are known as processes that bring together the main stakeholders to address an issue and to reach collective outcomes (GIZ 2011). It is a means to strengthen close cooperation between stakeholders. Multi-stakeholder processes also imply dealing with divergent views of different stakeholders about the same issue (Welch-Devine 2012). Through multi-stakeholder processes, different players collaborate, learn from each other and share knowledge (Triomphe et al. 2013). It has been argued that stakeholders' participation in a problem solution determines their ownership of ensuing outcomes (Ahmad, Kyratsis, and Holmes 2012), which has implications for sustainability (Vallejo and Hauselmann 2004). In the case presented here, the joint experiment served as a multi-stakeholder platform that aimed to bridge the social gaps between stakeholders in the oil palm seedling supply system in order to improve its material functioning. Such a process will enable an organization like OPRC research center to adjust their training package for nursery holders through received feedbacks. In this research, we called the stakeholder platform the learning group.

Research Design

Research Agenda Setting and Implementation

The joint experiment described here was part of a collaborative research project involving stakeholders of the oil palm seed system in Benin. The first step consisted of a diagnostic study that highlights the major constraints hindering the oil palm seed system and that limited smallholders' access to high quality seedlings (Akpo et al. 2012). In line with the underlying approach of the Convergence of Sciences project within which the current research was conducted (for further details see: www.cos-sis.org), we involved the different stakeholders to solve the problem of physiological quality of seedlings that farmers were facing.

Prior to the joint experiment, the lead author of this paper conducted an introductory field visit to explore seedling production technologies in use in the officially established nurseries as well as stakeholders' various experiences and perceptions about the quality of seedlings currently produced. Subsequent to that visit, he gathered stakeholders to share findings and discuss possible ways of addressing identified weaknesses in seedling production. Through consensus, participants reached agreements about the production practices to be tested in the joint experiment. Group members arranged to collectively monitor and evaluate the effects of tested practices on seedling growth. In addition to measuring the biophysical effects of the treatments on oil palm seedlings, the lead author observed and recorded stakeholders' observations, contributions and interactions to analyze the issues shared or perceived in different ways, the way they appreciate effects of different production practices on seedling growth and the overall social dynamics of the joint experiment. We subsequently conducted field observations and interviews to look at changes in stakeholders' practices further to the joint experiment (Figure 1).

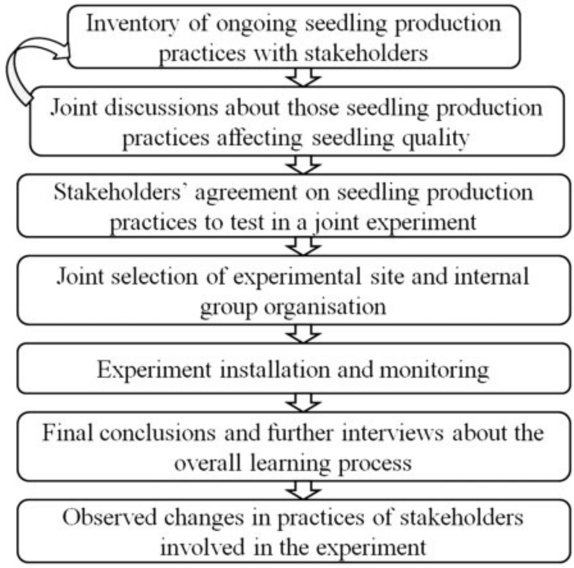

Figure 1. Research design.

Learning Group Establishment and Composition

Provenance of involved stakeholders. Fifteen participants took part in the joint experiment, including six nursery holders, six farmers, one representative of research centre, one extensionist, and the lead author of this paper. Each participant was a delegate representing an organization or peers. All six official nursery holders supplying seedlings to farmers in the region of Sakété were involved in the experiment. The six farmers involved were selected by their peers at a group meeting and included one woman. The representative of OPRC who took part in the experiment held the position of the head of breeding department of the oil palm research center. The extension agent was the head of the local extension service of Sakété. The lead author of this paper is a former employee of OPRC, but was engaged in this process as a PhD researcher.

Roles of involved stakeholders. Participating stakeholders played specific roles in the course of the joint experiment. During the introductory discussions, farmers initially offered to provide a site for the experiment. However, to avoid the risk of seedling robbery before the end of the experiment, and to solve the problem of water availability, the learning group ultimately and by consensus decided to locate the experiment in one of the nursery holders' sites. Farmers further offered to take care of the cleaning of the experiment site. The representative of the oil palm research center offered to get seedlings that were used in the experiment from OPRC. In addition to documentation and analysis of both social and biophysical data, the lead author of this paper also facilitated the learning process.

Facilitation of the joint experiment. Aware of the importance of the facilitation for the outcomes of the whole process, we made sure that all participants expressed their opinions on the ongoing activities. We intervened in such way that the process was democratic and not dominated by any single stakeholder. We encouraged all participants, particularly illiterate farmers, to speak out their mind to let the group know their thinking of the main directions that were given to the ongoing activities. We made sure that the minutes of different meetings are produced and its contents shared with all group members for eventual corrections. We paid particular attention to the language issues and made sure that enough time was taken to share different ideas and gain mutual understanding. Participants were encouraged to use the local language (Nagot) instead of French, as it is the one all participants understood. The language issue was also concerned with the way participants understand and express the objects being tested. No scientific concept or term was preferred over vernacular words and expressions.

Joint Experiment Set-up and Monitoring

Selection of the experiment site. When the learning group agreed that one official nursery place would serve for the experiment site, we registered three candidate sites. The group then unanimously decided to visit the proposed plots together to choose the one that was more suitable for the experiment. The group graded the visited sites for their characteristics, whether it is a plateau or with a large slope, easily accessible by either foot or bike, ready availability of water. Together, the learning group assessed the three sites and chose the farm Gbemanwonmede, which is on a plateau, is easily accessible and has water readily available. Though all candidates were eager to host the experiment, the site selection process was transparent and there were no complaints from the non-selected candidates.

Identification of tested nursery practices. Rather than testing research-recommended seedling production practices, the joint experiment tested actual production practices being used by different official nursery holders, which varied from official OPRC recommendations in several ways. Based on our survey of nursery holders' actual practices, we investigated the effect of six treatments (using participants' language) on seedling growth: (1) pot sizes, (2) soil substrates, (3) ways of fertilizer supply (4) planting ages, (5) transplanting densities and (6) watering regimes.

Drawings of nursery practices: challenging communication issues. Developing effective communication among participants is an important aspect of trans-disciplinary research (Roux et al. 2010). One out of six nursery holders and four out of six farmers who participated in the experiment were illiterate. At the outset, the learning group had to address the question of how to label the various treatments being tested to improve communication among group members. A farmer suggested that drawings could best represent each nursery practice, an idea that was endorsed by the whole group. Figure 2 shows some of the representations that were used.

Co-construction of variables for participatory monitoring of nursery practices. Having identified the treatment variables to test, the next step was to identify variables by which the outcomes would be assessed. Participants listed a variety of different variables through which to measure the effects of each nursery practice. In keeping with their own professional perspectives, representatives of extension and OPRC initially suggested the use of seven variables to assess treatment performance: seedling height, collar diameter, number of leaves, light interception, length of most developed leaf, width of most

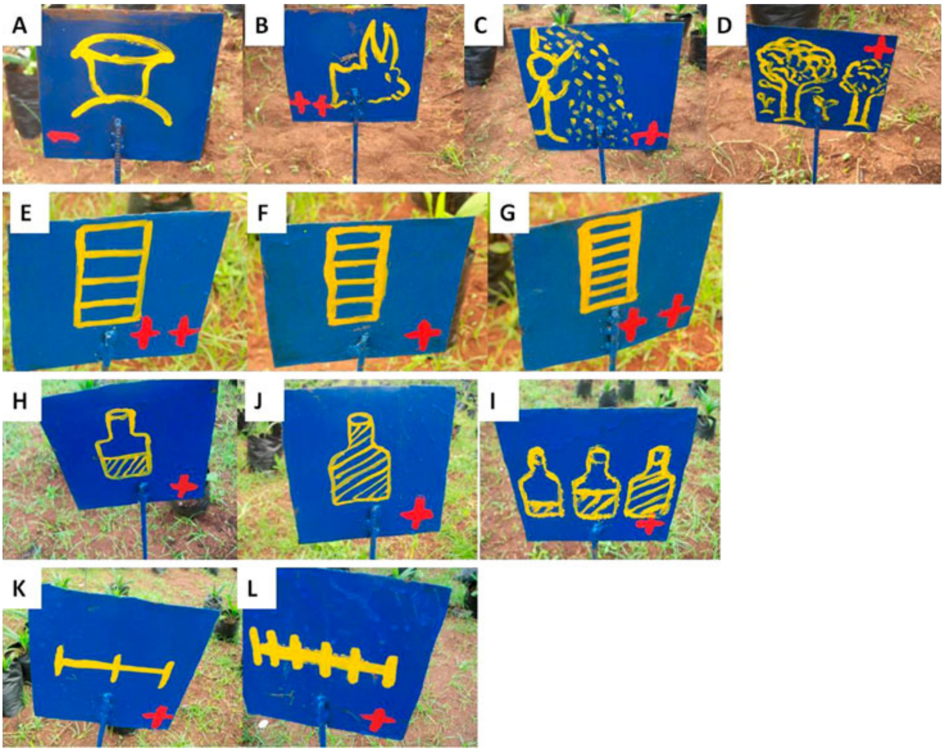

Figure 2. Examples of nursery practice drawings for the understanding of non-literate group members.

Note: Drawings A, B, C and D indicate nursery place arable soil, mixture arable soil and animal manure, household waste and forest soil substrates, respectively. Drawings E, F and G represent seedlings transplanted after four, five and six months old, respectively. Drawings H, I and J are half liter, one liter and progressive watering increase from quarter to one liter. Drawings K and L indicate single and double seedling densities, respectively. The symbol –, +, + + indicates that seedlings receive no fertilizer, split dose and full dose fertilizer. As types of pots can be distinguished visually, it was not represented by drawings.

Source: Group meeting with stakeholders

developed leaf, biomass production. Nursery holders thought height, collar diameter and number of leaves are enough to measure treatment effects. Farmers on the other hand suggested that they only look at seedling height, collar diameter and the greenness of leaves to assess the physiological quality of seedlings. The discussion among group members concluded that because farmers are the ones who purchase seedlings their criteria are the most important ones. The group members collectively decided to use the farmers' suggested evaluation criteria.

Next, the learning group discussed the way to measure the three variables. Representatives of extension and research centers and the nursery holders suggested that we use scientific instruments to measure height and collar diameter, though they added that they don't know how to measure the leaf greenness. Farmers pointed out that they do not use any device to measure seedlings before buying; they only appreciate visually. Farmers then suggested the appreciation of treatment on two points scale: good performing and less performing treatments. The facilitator and lead author of this paper suggested that the group assesses treatment performance through assigning points to treatments on a 5-point (Likert) scale, with the best performing treatment having the highest number of points (Crano and Brewer 2002). This suggestion was adopted and the learning group assessed each of the three variables on the following scale: (1) very poor performance (not desirable); (2) poor performance (less desirable); (3) acceptable performance (desirable enough); (4) good performance (desirable); (5) best performance (most desirable).

Internal organization of the learning group. The learning group elected a president who was in charge of the implementation of the learning group activities. A farmer and the OPRC researcher both suggested two candidates because nobody volunteered: one among nursery holders and the other among farmers. By consensus, the group finally agreed that the suggested candidate among farmers be the leader of the learning group. The selected president was the one in charge of reminding group members of the periodic meetings. The president was also the spokesman of the learning group in case external visitors come to the experiment site to learn about the ongoing experiment. Besides the president of the learning group, a nursery holder was chosen as secretary to take notes on the main points of each meeting. The participants agreed to gather at the experiment site on the last Thursday of each month and held a total of 17 meetings.

Experiment monitoring. At the beginning of each meeting, the secretary reminded the group of main issues debated during previous meeting and main decisions that were made. Other members provided additional comments if important information was missing. Further to the summary, the president distributed group members into sub-groups of two or three people to jointly assess the effects of each treatment on seedlings. Participant distribution in sub-group did not follow any criteria. In each meeting, a plenary presentation and discussion followed assessment activities. Each time, we made feedback on previous meetings to see whether the observed trends per treatment remained unchanged or whether new things emerged. In this way, the group conducted the analysis, evaluation and discussions of the experiment on an iterative basis. The meetings usually lasted approximately two hours.

Methods and Tools for Data Collection and Analysis

In order to develop a detailed account of the discussions and group dynamics within the learning group, we used a multi-method approach for data collection. We used focus group discussions to document stakeholders' framing of quality seedlings. Meeting minutes and participant observations allowed reporting on stakeholders' views of the performance of the different nursery practices. We used interviews of participants and nursery visits to document stakeholders' appreciations and ownership of the process outcomes. Altogether, these permitted a multi-faceted analysis of the social dynamics in the joint experiment process.

Focus Group Discussions

We used focus group discussions to collect stakeholders' framing of quality seedlings. For each category of stakeholders (i.e. farmers, nursery holders, representatives of research and extension services), we asked to state what a good quality seedling is like and what could be the determinants. We conducted three focus group discussions: one with farmers, one with nursery holders and one with representatives of research and extension services.

Meeting Minutes

The meeting minutes allowed us to keep track of the main issues discussed in each meeting throughout the joint experiment. The discussions revolved around the effect of nursery practices on seedling growth over time, i.e. the better and worse performing nursery practices. The secretary recorded the perceptions of each stakeholder of the different nursery practices being tested. These records facilitated the flow of information among participants in the course of the joint experiment process.

Participant Observations

The first author of this paper took part in the different activities of the learning group. This allowed us to minimize our distance from group members (Johnson, Lilja, and Ashby 2003) and enabled us get useful information out of the collaborative work. The researcher used participant observations to collect information related to the way the different stakeholders interacted and communicate among themselves; the terms that participants used to define the different nursery practices and their effects; the way consensus was reached among participants. In the end, participant observation permitted direct evidence of individual experience including the meaning they make of those experience (Elliott 2005), but also allowed the researcher to get further insights into the subject (Iacono, Brown, and Holtham 2009) and avoid most of the pitfalls arising in collaborative research (El Ansari 2005).

Interviews and Nursery Visits

We used semi-structured interviews to collect participants' perceptions and evaluation of the joint experiment. For example, the farmers, nursery holders and representatives of OPRC and extension service were asked to state the way they perceive a physiologically sound seedling. They scored effects of different nursery practices from their views. Through informal and semi-structured interviews, participants also provided their views about the way the process was conducted and expressed what they had learned and changed through their participation in the joint experiment. Nursery visits allowed verification of the changes in practices.

Data Analysis

Through recording the different stakeholders' perceptions of physiologically acceptable seedlings, we synthesized the different views to draw the most important issues that farmers, nursery holders representative of extension and researcher services use to define good quality seedlings. We examined stakeholders' evaluation of the performance of tested nursery practices focusing on the differences of their appreciations. The report of the details of the discussions showed the way stakeholders start from divergent views to reach consensus. To show the observed changes in practices, we compared stakeholder's seedling production practices before and after the experiment. We synthesized and reported farmers' narratives of the improvement of their relationships with other stakeholders. The ranking permitted us to understand the importance of the variables or issues for different stakeholders and allowed comparison across stakeholders.

Results

Framing of Physiologically Sound Seedlings by Different Stakeholders

Farmers, nursery holders, the extension agent and the OPRC representative did not have the same criteria for what a physiologically sound seedling looks like. Stakeholders defined good quality seedlings based on the type of connections and uses they make of oil palm seedlings. According to farmers who participated in the experiment, a good quality seedling should be disease free and survive pest attacks after planting. It should have a large collar diameter, verdant leaves and be high enough. It should grow steadily in the first vegetative phase even without additional fertilizer supply.

Nursery holders, on the other hand, mentioned that a physiologically sound seedling should be strong enough and should not wave after a light wind passes. They mentioned that the seedling quality depends on the cost of inputs needed for seedling production. Nursery holders underlined the high cost increase of nursery materials that was not followed by an increase in the price of seedlings, which was fixed almost two decades ago by the Government of Benin. To secure a return on the seedling production enterprise, nursery holders acknowledged using alternative practices that do not always sustain optimal seedling quality. Ultimately, they said that seedling quality is a compromise between production costs and recommended standards.

For the participating extension agent and OPRC representative, a physiologically sound seedling has good plant architecture. They highlighted the characteristics of poor seedlings that are not good for field planting: slender, short and leafy, with short leaflets that look close to each other.

Stakeholders' Evaluation of Tested Nursery Practices: From Divergent Views to Consensus

Stakeholders' evaluation of the performance of the different nursery practices varied with the use they make of planting material. This section presents stakeholders' evaluation of treatment performance and provides detailed account of the way the discussions went between stakeholders before consensus is reached.

Stakeholders' evaluation of effects of pot size on seedling growth. All participants observed that the best seedling growth (seedling height, collar diameter, and greenness of leaves) was registered on seedlings raised in the large pot size (40 cm × 40 cm) (Table 1), though seedlings raised in medium pot size (31 cm × 31 cm) showed physiologically acceptable growth for the three variables. Seedlings raised on small pot size (25 cm × 30 cm), on the other hand, were of lower quality in comparison to medium and large pot size. They looked short, presented narrow collar diameter and their leaves looked yellow. Even though the largest pot size had the best seedling growth, farmers (who are first consumers of seedlings) expressed that they preferred seedlings raised in medium pot size because they are easier and cheaper to transport. Small pot size was not favorable enough to seedling growth and it was not preferred by farmers. Nursery holders also prefer medium pot size because they lower seedling production costs in comparison to large pot size. One nursery holder supported the use of small pots as being good enough for seedling production and further reducing transportation and production costs for both farmers and nursery holders. The majority of participants, however, agreed that the medium pot size favors both farmers and nursery holders. This agreement reached by the learning group directly contradicts the OPRC's recommendation to use a large pot size for oil palm seedling production.

Stakeholders' evaluation of effects of soil substrates on seedling growth. Participants observed that seedlings transplanted into arable soil mixed with animal manure produced the largest collar diameter, greenest leaves and largest seedling height, across the whole seedling vegetative period (Table 1). Seedlings grown on household waste substrate came in second in performance. Arable soil and forest soil, according to participants produced similar and poorer seedling growth. Nursery holders observed, however, that household waste substrate released its nutrients faster than arable soil with animal manure and if after four months additional fertilizers are not supplied, seedlings suffer of lack of

Table 1. Stakeholders' joint assessment of tested nursery practices on different variables on a 5-point scale.

Stakeholders' name of nursery practices	Seedling height	Collar diameter	Leaf greenness
Pot size			
Small pot size	2	1	1
Medium pot size	3	3	3
Large pot size	5	5	5
Type of soil substrates			
Arable soil	3	3	3
Mixture arable soil and animal manure	5	5	5
Household waste	4	4	3
Forest soil	3	3	3
Fertilizer supply			
No fertilizer supply	2	2	2
Split dose fertilizer supply	4	4	4
Full dose fertilizer supply	5	5	5
Seedling transplanting ages			
Four-month-old seedlings	5	5	5
Five-month-old seedlings	4	4	4
Six-month-old seedlings	2	2	3
Seedling density			
Single density	4	5	5
Double density	5	4	5

Note: 1: very poor performance (not desirable); 2: poor performance (less desirable); 3: acceptable performance (desirable enough); 4: good performance (desirable); 5: best performance (most desirable).

nutrients. Farmers, claiming that few nursery holders apply fertilizer on regular basis, suggested that they use arable soil mixed with animal manure because it maintains seedling quality even without additional fertilizer supply. The researcher from OPRC outlined the importance of avoiding places where oil palm had been planted before for arable soil collection, as it may lead to the introduction of pests and disease. Nursery holders, however, argued against using forest substrate, citing increasing land pressure in south Benin, where forests are increasingly scarce. Finally the learning group suggested that nursery holders preferentially use arable soil mixed with animal waste as it maintains seedling quality even in the absence of additional fertilizer supply. They added that arable soil should be collected carefully away from oil palm stands. The learning group's conclusion is again at odds with the OPRC official recommendation to use forest soil for oil palm seedling production.

Stakeholders' evaluation of effects of ways of fertilizer supply on seedling growth. The participants observed that the three fertilizer treatments tested did not produce the same seedling growth (Table 1). Seedlings amended with split dose and full dose fertilizer produced physiologically sound quality seedlings. Seedlings raised without fertilizer supply showed the weakest seedling growth: yellow foliage, erected seedling stand, and narrow collar diameter. Leaflets on seedlings raised without fertilizers presented more leaf insect holes in comparison to fertilized seedlings. Farmers underlined the importance of fertilizing seedlings during the nursery phase as they hardly supply fertilizer after field planting. Nursery holders emphasized the labor constraint of supplying fertilizer twice a month in split doses. The participants finally came to the conclusion that fertilizer supply to seedlings in nursery phase maintains green seedling foliage with good plant stand. As split and full dose fertilizer produce similar seedling growth, most participants agreed that fertilizer could be supplied once monthly in full dose instead of twice in split dose. The researcher from OPRC, however, highlighted that the supply of full dose fertilizer is counter-productive in periods of abundant rainfalls, when much of the fertilizer will wash out.

Stakeholders' evaluation of effects of transplanting ages on seedling growth. Bag seedlings transplanted after four months of pre-nursery were evaluated as showing the best seedling growth, followed closely by seedlings that spent five months in pre-nursery, which showed similar growth for height, collar diameter and leaf greenness (Table 1). However, when seedlings spend six months in pre-nursery before transplanting to full nursery, they grow more slowly in comparison to those of five months and four months old. The researcher from OPRC mentioned that the earlier seedlings are transplanted, the better they grow. Nursery holders argued, however, that the delay of seedling transplanting in the nursery reduces production costs, even though they recognized that a longer delay also reduces seedling vigor. Farmers advocated for earlier seedling transplanting for plantation success. Even though the official research recommendation is to transplant seedlings at four months old, participants showed some flexibility and suggested nursery holders to transplant seedlings to full nursery at no later than five months old, representing a compromise between physiological and economic factors.

Stakeholders' evaluation of effects of density on seedling growth. Farmers observed that the higher seedling density increased height but decreased collar diameter. Nursery holders argued that raising seedlings at double the recommended density did not compromise seedling vigor, but rather saved space and reduced production cost. They also proposed that the double density helped to fight against weeds and thus reduced labor, adding that seedling density could even be increased to further reduce weed infestations. The researcher from OPRC drew the participants' attention on the negative effects of higher density on seedling vigor if the time seedlings spent in the nursery gets longer, for example in case the nursery holder fails to sell all seedlings in a given year. Finally, the participants agreed that raising seedlings at 'double density' is a good option, though it would be risky to further increase seedling density.

Stakeholders' evaluation of effects of watering doses on seedling growth. The participants agreed that the three watering regimes did not show any perceptible difference in growth (Table 1). The representative of research center drew the participants' attention on the seedlings' increasing water demand as they mature. The participants concluded that one liter per seedling three times a week was best in case of lower rainfalls.

Knowledge Acquisition, Appreciation of the Joint Experiment and Observed Changes in Practices

All participants reported that they had never taken part in a joint experimentation before. Their appreciation on a 5-point scale of the originality of the learning process (Table 2) showed higher scores (a minimum of 4.4 over 5 points). Nursery holders gave the highest rank on the originality of the learning experiment. All participants thought that their expectations were met because they acquired new knowledge of oil palm seedling production. After the experiment, participating farmers reported that they have a full knowledge of the technical package of seedling production, and better appreciated the

Table 2. Acquired knowledge and participants' perceptions of the learning, as expressed on a 5-point scale.

Stakeholders (*n*)	Appreciation of the originality of the initiative on a 5-point scale	Acquired knowledge
Farmers (5)	4.4[a]	• Technical package of oil palm seedling production • Labor requirement of nursery activities
Nursery holders (5)	4.6[a]	• New seedling production practices (value of animal waste) • Risk of using soil substrates from oil palm stand to raise seedlings
Extension Agent (1)	4.5	• Seedling behavior on different nursery practice • Intense workload of nursery activities
OPRC researcher (1)	4.5	• Mismatch of research recommendations with field context regarding pot size • Need the update nursery holders' training package

Notes: The originality appreciation scale varied from not new to very original. *n* is the number of respondents.
[a]Average over number of respondents.

difficulties that nurseries holders face. Nursery holders likewise reported that they had learned new production practices from their peers. Furthermore, the representative of the oil palm research center came to appreciate how the logic behind current research recommendations is not well matched with the contextual logics of nursery holders' and farmers' pressures and preferences. Participants also appreciated the free exchange of opinions and insights during the experiment. The democratic environment in which participants took part was valued by all group members. Even though participants rarely came to meetings precisely on time, their participation in scheduled activities was high, ranging from 60 to 93%.

Observed changes in production practices. Following on the joint experiment, nursery holders who had used production practices that were identified as undermining seedling quality have changed those practices. Specifically, two of the nursery holders who were using small pot size have shifted to the medium size pots. During a field visit after the experiment, we no longer observed small pot size in those nurseries. Nursery holders, who participated in the experiment, also used animal manure in combination with soil from eucalyptus forest and also arable soil.

Nursery holders who moved from small to medium pots acknowledged that the move seems to induce additional production costs, but that these are offset through more timely sale of seedlings. These nursery holders reported that farmers delay sometimes seedling purchase when the seedling growth is not optimal.

The OPRC participant in the joint experiment is the head of the breeding department of the oil palm research center. In response to his participation, he instituted new ways of overseeing of official nurseries, increasing the number of field visits from one per year (and even none in some years) to two or three visits. He also reported that he carried additional field visits himself to official nurseries. The OPRC has also adjusted the nursery holders' training curriculum to recommend the medium pot size instead of the large pot size, representing a systemic change emerging from social learning in the joint experiment. This change has been incorporated into the 2012 training material.

Farmers who took part in the experiment expressed that they have learned about nursery management practices. They reported that the knowledge they acquired on the oil palm nursery improved their appreciation of to what extent which nursery holders used good practices to raise seedlings. Farmers reported that, if they have the choice, they will no longer purchase seedlings that nursery holders fail to raise appropriately. Furthermore, they reported that if nursery holders offer poor quality seedlings to them, they will not hesitate to bargain for reduced price.

Improvement of social network. Most participants reported that they improved their social network through participation in the joint experiment. Farmers witnessed that this joint experiment has improved their connection with nursery holders, reducing the need for third parties to purchase seedlings. Farmers also reported that the joint experiment has facilitated their contact with the OPRC, as they have henceforth got closer to one of the key staff members. The nursery holders also indicated that their experience in the joint experiment has given them easier access to extension agents and services. They reported looking for more input from local extension agents about pesticides and diseases during the nursery phase.

Discussion

Stakeholders' Perceptions of Quality Seedlings and Their Appreciation of Treatment Performance as Dependent on the Use They Make of Planting Material

Even though all stakeholders were gathered around the same planting material, they did not have the same viewpoint of physiologically sound seedlings. While farmers put forward seedling vigor while describing quality seedlings, nursery holders highlighted the involved costs and reported that seedlings' quality is a compromise with costs. If farmers put seedling vigor first to define quality seedlings, it is certainly due to their position as end-users and planters of seedlings. Farmers are the only ones to bear consequences of failure of poor quality seedlings. If nursery holders integrate the cost dimensions into quality of seedlings, it is because they put first the gain they make from their seedling production enterprise. It appears that stakeholders' perceptions of seedling quality varied with the use they make of planting material (Couix and Hazard 2013; Pohl et al. 2010).

During the experiment, evaluation of the treatments' effects on seedlings varied substantially according to the stakeholders' social position vis-à-vis oil palm (Crane 2010). For example, when most participants found the small pot size not sustaining seedling growth, a nursery holder remarked that it is fine. When the farmers, extension agent and researcher found that seedling delay in pre-nursery inappropriate for seedling growth, nursery holders found it useful technique to cut production costs. Ultimately, the use stakeholders make of seedlings played an important role in their appreciation of treatment performance. In trans-disciplinary research, where multiple stakeholders are involved, it is understandable that sometimes they share different views (Welch-Devine 2012). During the different exchanges, farmers often find internal agreement among themselves and, later on, share with the group members. This also applies to nursery holders who sometimes talk to each other to get their colleagues' view that is further shared with group members. This way of sub-group communication per category of stakeholders showed implicitly their different stakes in quality of seedlings. However, through the social learning process, all participants eventually came to appreciate others' positions in relation to seedlings, leading to compromise, consensus and mutual understanding around recommended nursery practices.

Significance of Observed Changes in Practices

It is noteworthy that at the end of the joint experiment, the learning group recommended several practices (regarding pot size, substrate and planting density) that directly contradicted official recommendations from the OPRC as well as some nursery holders' practices. Where official recommendations are often based on controlled on-station conditions and narrow biophysical criteria, the learning group's recommendations emerging from this joint experiment represent a balanced appreciation of all stakeholders' interests and evaluation criteria, both biophysical and social. The fact that the OPRC has systemically changed its pot size recommendation in its training curriculum in response to this experience is a strong indication that they are giving stronger consideration to stakeholders' various positions and constraints.

In addition to the OPRC's change in recommended pot size, field visits showed that participating nursery holders had incorporated some of the tested nursery management practices in their nurseries. The observed changes in practices on the different participants could be explained by their full involvement in the research from the problem identification to the experiment implementation, monitoring and evaluation. The transparency of the process, the way participants challenged communication-related issues, and ultimately the whole research path have a great deal to play in the observed rapid change in practices (Luks and Siebenhüner 2007; Luyet et al. 2012).

Research Design on Joint Experimentation as Means to Facilitate Social Learning and Knowledge Production

The purpose of joint multi-stakeholder collaboration is to enable social learning and co-production of knowledge that is robust for all actors involved. The joint experiment described in this paper was grounded in nursery holders' existing practices rather than newly introduced or officially recommended practices. Rather than taking a researcher-guided participatory approach (Schwilch et al. 2012), the study took the path of a joint and free collaboration of stakeholders with a simple purpose of improving seedling production in way that is both empirically-grounded as well as appropriate to the stakeholders' practical considerations. Through gathering the different parties involved in the oil palm seedling supply system, the process provided space for stakeholders to exchange insights and develop ways to improve the quality of seedling production, contributing to new articulations between stakeholders in the seed system (Offei et al. 2010). Existing knowledge of the various stakeholders has been put together, implemented and monitored jointly with them and new knowledge emerged for participants (Steyaert et al. 2007). Even though, nursery holders are working in the same area and had received the same guidelines from the research center, there was variation in production practices. Individually, nursery holders combined their available resources for seedling production in different ways to make the seedling production enterprise more profitable. Those practices were not known by their peers, who took the opportunity to learn from each other and from farmers, while still receiving useful insights from scientific expertise. In this respect, this study argues that participatory technology production is an effective way to contribute substantially to system innovations.

A learning experiment in agriculture is a space where technologies are tested and their fitness in the local conditions is evaluated but also new knowledge and ties are formed. Such process significantly contributed to bridge the gap between the different players though generating knowledge partnership (Berkes 2009). Before the implementation of the current learning experiment, there were few opportunities for nursery holders in the same community to discuss and exchange their production difficulties and learn from their peers. The implemented learning experiment provided means for them to meet and share concerns and knowledge to improve their practices. From this experience of learning, nursery holders who participated in the experiment reported that they would henceforth continue to exchange about seedling production practices that are both effective and economical.

Conclusion and Implications for Multi-actor Processes

Each stakeholder, based on the use they make of oil palm seedlings, has particular values about what constitutes sound seedlings. While farmers put forward seedling vigor to frame quality seedlings, nursery holders highlighted production costs. Stakeholders' appreciations of nursery practices' performance also varied across them as well. The mismatch between research-recommended practices and the user contexts has been identified on a number of issues, including pot size, substrate type, fertilizer supply, seedling transplanting ages and seedling density. Participants, mainly nursery holders, applied new production practices in response to their learned appreciation for other stakeholders' approaches to evaluating seedling quality. Field observations further to the process showed changes in practices among stakeholders that would be sustainable.

For the sake of multi-actor processes, a joint experimentation is a challenging process and key methodological steps are to be considered. Above all, a total integration of the local context into the design is prerequisite. The process requires more skills and management if we are to incorporate people from different backgrounds, from research professionals to illiterate farmers. The process allows social learning and shows the richness of integrating the insights and evaluations from different stakeholders. To succeed in such a process, some skills of facilitation are needed; otherwise, the process may be hijacked by some of the participating stakeholders (Wiggins 2004). For different participants to arrive at a common agreement on main issues, some efforts are needed to reach a common language for mutual understanding. This requires some time for negotiations among stakeholders. Consensus building is sometimes difficult and requires a commitment to work across differences toward a shared objective. In the end, for such a process, the successful management of each phase—joint problem definition with stakeholders, co-design of research, co-implementation and co-analysis with all parties involved—is critical. This needs some iterations to revisit issues discussed during former phases of the process for adjustments.

Involvement of all participants and their active participation at the very beginning is important. This lays the way for the stakeholders' ownership of the outcomes (Ahmad, Kyratsis, and Holmes 2012). Technology uptake by end-users would get easier if the process is more transparent and collaborative from the start to the end, wherein consumers of technologies are also explicit co-producers of it. Social spaces are useful to share knowledge and experiences. Learning takes place each time people exchange and reflect on a common problem that requires a timely and appropriate solution. The way the process is designed and conducted has a great effect on the ownership by the participants. In this article, we have analyzed the joint experiment as a social process of encounter by multiple stakeholders, wherein they all contribute to the knowledge production process, co-designing, co-implementing, co-analyzing and co-evaluating the results. Beyond focusing on outcomes, we recommend that initiatives in multi-stakeholder processes should also document and analyze social processes in order to better understand the mechanisms by which such processes foster socio-technical change, as well as identify potential institutional barriers to such processes.

Supporting many other authors, our research findings suggest that the full and balanced integration of multiple stakeholders' knowledge and contexts into the process of agricultural technology development increases the uptake and ownership of agricultural technologies. Furthermore, the co-learning approach to experimentation also leads to greater mutual understanding between stakeholders, providing a stronger foundation for effective future collaboration. Building on this, policies regarding agricultural research strategies and rural development priorities can capitalize on these observations by placing greater emphasis on trans-disciplinary co-production of agricultural technologies and sustainable natural resource practices.

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