STRENGTHENING RICE SEED SYSTEMS AND AGRO-BIODIVERSITY CONSERVATION IN WEST AFRICA:

A socio-technical focus on farmers' practices of rice seed development and diversity conservation in Susu cross border lands of Guinea and Sierra Leone

Florent Okry

Thesis committee

Thesis supervisors
Prof. dr. P. Richards
Professor of Technology and Agrarian Development
Wageningen University

Prof. dr. ir. P.C. Struik
Professor of Crop Physiology
Wageningen University

Thesis co-supervisors
Dr. ir. E. Nuijten
Researcher, Technology and Agrarian Development group
Wageningen University

Dr. ir. P. Van Mele
Formerly Program Leader Learning and Innovation Systems
Africa Rice Center, Cotonou, Benin
Currently Director Agro-Insight, Belgium

Other members
Prof. dr. ir. C. Leeuwis, Wageningen University
Prof. dr. ir. J.C.M. van Trijp, Wageningen University
Dr. M.P. Temudo, Tropical Research Institute, Lisboa, Portugal
Dr. ir. L. Visser, Centre for Genetic Resources, Wageningen

This research was conducted under the auspices of Wageningen School of Social Sciences (WASS).

STRENGTHENING RICE SEED SYSTEMS

AND AGRO-BIODIVERSITY CONSERVATION

IN WEST AFRICA:

A socio-technical focus on farmers' practices of

rice seed development and diversity conservation in

Susu cross border lands of Guinea and Sierra Leone

Florent Okry

Thesis
submitted in fulfilment of the requirements for the degree of Doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. dr. M.J. Kropff,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Wednesday 21 December 2011
at 1.30 p.m in the Aula.

Florent Okry
Strengthening rice seed systems and agro-biodiversity conservation in West Africa: A socio-technical focus on farmers' practices of rice seed development and diversity conservation in Susu cross border lands of Guinea and Sierra Leone

208 pages

Thesis, Wageningen University, Wageningen, NL (2011)
With references, with summaries in English and Dutch

ISBN 978-94-6173-111-1

Abstract

Okry, F. (2011) Strengthening rice seed systems and agro-biodiversity conservation in West Africa. A socio-technical focus on farmers' practices of rice seed development and diversity conservation in Susu cross border lands of Guinea and Sierra Leone." PhD thesis, Wageningen University, Wageningen, The Netherlands, 208 p.

Some decades ago it became clear that formal agricultural research institutions - and hence formal interventions in agriculture - were somehow missing their targets for African farmers, mainly because their proposed solutions, and the ways these solutions were developed and introduced to African farming communities, did not match the realities of peasant life. It was recommended that the formal research should consider the wider contexts within which farmers operated to formulate better solutions. These solutions are essential for low-resource farmers facing many (socio-economic and cultural) constraints and having to cope with uncertainties (climate change, market variations, soil degradation, political and social unrest). The research presented in this thesis analyses the functioning of West African rice seed systems with regards to this recommendation. It starts with a regional focus (seven West African coastal countries) and then focuses on specific in-depth field studies undertaken in Guinea (with some comparison from neighbouring Sierra Leone). The study is based on an interdisciplinary approach combining methods from social and natural sciences.

Findings show that despite efforts from governments, policy makers and formal agricultural research, the informal seed system still predominates, largely because it is the seed system closest to low-resource farmers. The objective of replacing the informal seed system by a formal seed system exclusively promoting improved varieties is a distant prospect. The research shows that local varieties are, to a large extent, superior to improved varieties in the sub-optimal conditions facing most farmers. It is also shown that even when improved varieties suit farmers' conditions they are often channeled through inappropriate institutional arrangements that block access by low-resource farmers. Formal seed projects often lack follow-up to sustain actions. Innovations are lost between research planning, donor requirements to demonstrate adoption and the realities of peasant coping strategies. It is argued that success indicators in the formal seed system need to be redefined based on a clear conceptual divide between variety dissemination and bulk seed supply. The formal seed system merges these two activities whereas the informal seed system pursues a different path and addresses different procedural constraints. We suggest seed projects should concentrate on variety dissemination and leave bulk seed supply to local seed dealers. The thesis demonstrates that local dealers are effective and more closely in tune with farmer needs.

The major finding of this thesis is that the informal seed system is closer to farmers, and works well, because it reflects (and is integrated with) local ideas about food security and social solidarity. This social dimension is missing in the formal system, designed and funded by experts who neither live by planting rice nor share in the local sets of assumptions about social reciprocity and obligation. Guinea may be undermining its long-term food security if it continues to seek to replace a social seed system with one driven solely by abstract ideas of economic rationality. The better option, supported by the weight of evidence in this thesis, is to seek complementarity and synergy between the two systems.

Keywords: *Oryza sativa*, *Oryza glaberrima*, food security, formal seed system, informal seed system, varietal diversity, sub-optimal agriculture, small-scale farmers, farmers' practices, Guinea, Sierra Leone, West Africa.

Acknowledgements

At the end of this PhD process, I finally have the opportunity to express my gratitude to the persons and institutions that make it a reality. Mentioning everybody is impossible. I will therefore list a number of them as an indication.

I would like to express my gratitude to The Netherlands Organization for International Cooperation in Higher Education (NUFFIC) that funded this research. The Africa Rice Center (AfricaRice) provided additional funds for field activities. The Institut de Recherche Agronomique de Guinée (IRAG) and the Association pour la Promotion Economique de Kindia (APEK) assisted in practical organisation of the field activities.

My sincere thanks go to the brave farmers of Guinea and Sierra Leone. This work would have not been possible without their enthusiasm and willingness to spend their valuable time to answer my endless questions.

This work would have not been completed without the constant support of my wife Vicentia and my daughters Foumilayo, Omonlola and Marotan. I left you alone for months and months. You found ways to cope with my absence and gave me the necessary support to continue this PhD research. Please see this piece of work as an expression of my love.

My deep gratitude goes to Paul Richards, Paul C. Struik, Edwin Nuijten, Paul Van Mele and Roch L. Mongbo who guided my steps throughout this process. I enjoyed working with you. The large and rich supervision team you composed because of your diverse backgrounds has been my chance in this ambitious adventure of combining the natural and the social sciences in a single piece of work. I highly appreciated your invaluable inputs and the offered learning opportunities. At an advanced stage of this work, I had the difficult task to drop one member of the supervision team because of administrative reasons. Roch Mongbo kindly understood the situation and accepted to leave the team. I would like to say a big thank you to you for your understanding.

My thanks go also to Harro Maat. You first introduced me to TAO group and to Paul Richards in 2003; I was then a Master student. Paul Richards accepted me in the group after his reading of my rejected PhD proposal submitted to ZEF (Born) a year earlier. Since then it has been an enjoyable experience with the TAO group and its staff.

My gratitude goes to Dominique Hounkonnou. I remember our chats months before I started this work. You said a lot to me and shaped my carrier by offering me "Jonathan Livingston le goeland". Please see this work as a first trial.

Ramon Sarró and Marina Temudo gave me the first insights into the Guinean culture and agriculture. I still remember your hospitality when I visited you in Lisboa at the beginning of this work. Sincere thanks for your constant support and critical comments.

Special heartfelt thanks go to my mother Thérèse Somadjè Okambawa. Please see these pages as a result of your sacrifice and commitment to the education of your kids.

My best thoughts go to my late father Placide. I was about to start this work when you passed on. I still remember the last chat we had about me embarking on a PhD work. This is the result.

I extend my sincere thanks to Victorin Adjakou, Victor Akoto, my brothers and sisters, my sisters and brothers in-law, Patrice and Roseline Dangbemey and my extended family. I cannot list you all. You have been very supportive; many thanks!

My appreciation goes to the TAO staff and students for the scientific environment offered and the scientific discussions during the Lunch Seminars and other informal gatherings. I have appreciated being part of you. I owe special thanks to Conny Almekinders for inspiring scientific discussions and support and to Inge Ruisch for her invaluable help. Inge, without you my stay in Wageningen would have not been as enjoyable as it was.

I would like also to say a big thank you to A. Mokuwa and B. Teeken for the good moments we shared as members of the research team on African rice (TAO group, Wageningen University) and also during informal get together. I will remember you. My gratitude goes also to my PhD colleagues A. Amele, Chen R., Sabarmattee, Jacintha V., A. Barraza, Sen D., A. Castellanos N., Doreen M. and all the rest for the friendly working atmosphere we created and the scientific discussions we had. Long life to the PhD support group!

I also sincerely thank A. Boccalon, F. Honfo-Zannou, L. Idrissou, Y. Madodé, E. Dannon, A. Kouévi, L. Glin, A. Singbo, D. Arinloyé, S. Adékambi, G. Zoundji, J. Wanvoeke, S. N'cho, G. Maboudou, H. Hounhouigan, O. Hounkpatin and many others for social and emotional support during my stay in Wageningen.

Special thanks go to B. Cissé for his support and assistance to my family during the long period I spent abroad.

I owe much gratitude to N'Famoussa Camara, Foromo Kolié, Baldé Thyerno, N'Djalakoro, N'Famoussa Camara (Father) and many other persons for their direct involvement in data collection either as surveyors, translators or field assistants.

My sincere thanks to people of IRAG and APEK. I name only a few: Louis Béavogui, Sékou Béavogui, Famoi Béavogui, Billo Barry, Sékou Diawara, Malick Soumah, Late Babady Camara, Rouma Barry, Donzo Moustapha, Nestor Bourouno for their guidance at initial stages of my fieldwork and insights they gave me in Guinean agriculture.

I thank A. Saka, Félicité, B. Bancolé, Djénabou Barry, M. Fofana and K. Azoma for their assistance in data collection and data entering; Cesar Andres Ospina N., R. Glele, E. Dannon, S. Kpenavoun and A. Amele for discussions related to statistical tools and methods.

I thank my friends and colleagues. I name, amongst others, at Foulaya and Kindia (Guinea): D. Foncéca, M. Sangaré and family Donzo, A. Béavogui and family Béavogui; at Bo (Sierra Leone) family Mokuwa; at Cotonou (AfricaRice): A. Sinzogan, Y. Moukoumbi, E. Zossou, P. Kouamé, N. Yao, D. Montcho, S. Mounir, G. Djedatin., A. Kabouré, A&M. Niang and the Staff of the Africa Rice Center. I cannot list you all; you have been very supportive.

My sincere thanks and appreciation go to all I have not listed. I am endlessly grateful to you all; you have been as important as the ones I listed.

Florent Okry

December 2011

Wageningen, The Netherlands

To Vicentia, Foumilayo, Omonlola and Marotan

Table of contents

CHAPTER 1

GENERAL INTRODUCTION

Florent Okry

1.1 OVERVIEW

Rice is an important crop for the global food security. Although its importance varies across regions rice is staple for 50% of the world's population (FAO 1995). Most rice is grown in Eastern and Southern Asia, less in Africa and America (Maat and Glover 2011). Even so, rice is grown in about 40 sub-Saharan African (SSA) countries by more than 20 million farmers (WARDA 2006) of which the great majority (80%) are small-scale producers. Notwithstanding a growth in production of 4% per annum between 1985 and 2003 a quadrupling of total production between 1961 and 2003, demand for rice in Africa far outstrips supply, and 44% of the rice consumed is annually imported. African countries spend about 1.4 billion USD per year on rice import, counting for 19% of the continent's total grain import bill (WARDA 2006, WARDA 2007, Obilana and Okumu 2005).

In the continent, rice is more produced in West Africa. From 2000 to 2009, West Africa, accounted for 41% of the total African rice production followed by North Africa (32%) and East Africa (24%). There is less production in Central and Southern Africa (FAO 2011) where other cereals predominate. In upper West Africa, (from Cote d'Ivoire to Senegal) rice is not only important in terms of volume of production but also as a prestige crop with ceremonial relevance. As a staple cultivated for perhaps three millennia in the region (Portères 1962) rice is deeply rooted in the social life of the people. In Guinea, the focus of this study, rice occupies 40% of the total cultivated area and annum per capita consumption had reached 69 kg in 2004 (WARDA 2007). Several authors have reported on the cultural embedness of rice in various countries of West Africa: Ghana (Brydon 1981), Sierra Leone (Richards 1986), Senegal (Linares 2002), Guinea (Sarró 2009, Okry et al. forthcoming), Guinea Bissau (Temudo 2011) and Togo (Teeken et al. 2010). About Avatime in eastern Ghana Brydon writes: "*Rituals for the cultivation of rice are the only regular occasion on which 'all- Avatime' is involved. No one can begin to plant, harvest or eat rice until the relevant rituals have been performed*" (Brydon 1981 p. 662).

In addition to cultural relevance, rice also occupies an important place in the economy of many West African countries. But about 37% of rice consumed in the region is now imported (FAO 2004). So the development and promotion of the local rice economy is an important mission for governments and national and international agencies in the region. This focus on rice reflects a strong political and institutional willingness to reduce the region's dependency on rice importation in order to strengthen food security and food sovereignty, and in so doing, to conserve important socio-cultural values attached to rice cultivation. Such development assumes, among other aspects, the establishment of an effective and efficient seed sector to meet farmers' needs for seed of desired varieties suited to their agro-ecological conditions and socio-economic contexts.

Considerable efforts have thus been made to achieve the objective of seed development. In most African countries, an emphasis has been placed from the 1960s on introduction and promotion of improved varieties merely based on their yield superiority under optimal conditions (Amanor 2011). This strategy assumes that optimal conditions can be found over a wide area, or that environments can be readily modified in the direction of optimality. In effect, this has meant that non yield-related characteristics of varieties of importance to farmers because environmental constraints or socio-economic and cultural requirements were overlooked. More recently, it has begun to be realised that the promoted improved varieties did not meet small-scale farmers' needs because they were not well adapted to sub-optimal farming conditions (Sall et al. 1998). In addition, farmers give higher assessments than at first realised to characteristics other than yield. African small-scale farmers may be poor in terms of material conditions but their social lives are rich and complex, and food quality and preference plays an important part in social life (Douglas 1966). Upland (or rain-fed) rice cultivation is perhaps the most striking instance of non-adoption of improved varieties released for yield optimality. In rain-fed conditions farmers rarely cultivate improved varieties because they are inferior to local ones on characteristics not related to yield (Dalton 2004). A further problem is that even when improved varieties suit farmer agro-ecologies they are channelled down dissemination pathways that are disconnected from rural realities and embedded in "formal" institutional arrangements hampering access by small-scale farmers (Okry et al. 2011a). Last but not least, seed projects lack follow-up action to assure sustainability.

Two rice species are grown in West Africa. The indigenous *Oryza glaberrima* is presumed to have been first cultivated about 3-4000 years ago in the inland delta of the river Niger (Portères 1962). Asian rice (*Oryza sativa)* was introduced to West Africa within the last one thousand years, either by contact with the Nile valley or via the coast through Portuguese sea-borne trade (Alvares d'Almada 1594, Portères 1962, 1976). Asian rice is well appreciated for high yield, flavour and (in some areas) the whiteness of some varieties (Nuijten 2005, Teeken et al. 2010). Its varieties, however, seem to be more susceptible to local stresses (WARDA 2006) when compared to varieties of *O. glaberrima* (Dingkuhn et al. 1998, 1999). In some agro-ecologies in West Africa (mainly in upland farming) *O. glaberrima* is still grown, though generally on a relatively small area in farmers' fields (see Jusu 1999 for Sierra Leone, Linares 2002 for Senegal, and Nuijten 2005 for The Gambia). Farmers continue to cultivate some *O. glaberrima* because it has a number of desirable traits, such as grain colour, long dormancy, and the ability to grow on poor soil. In some specific agro-ecologies, such as Lower Guinea (Guinea), Guinea Bissau and the Togo Hills of Ghana and Togo, *O. glaberrima* is cultivated more widely, and enjoys a prestigious relevance. There, farmers cultivate it on relatively larger scale, apparently because of medicinal properties, religious purposes, resistance to stresses (drought and diseases) and culinary properties: seemingly, it digests much more slowly and thus provides energy over a longer period, and this is a desirable characteristic for many peasant farmers working long hours, especially during the pre-harvest "hungry season" (Teeken et al. 2010, Temudo 2011, Okry et al. forthcoming). It is especially welcomed by work gangs performing labour intensive activities such as clearing bush and planting (Richards 1986, 1989, Okry et al. forthcoming). Long-dismissed by many rice researchers as having limited potential for improvement, *O. glaberrima* now attracts increasing attention because it is assumed to embody several adaptive mechanisms for resisting or tolerating major (a)biotic stresses such as drought, soil iron toxicity, soil acidity, weed competition, blast, viruses and diseases (Jones et al. 1997a, Audebert et al. 1998, Dingkuhn et al. 1998, Johnson et al. 1998, Dingkuhn et al. 1999), and also because it possesses good grain quality, making it a preferred type by many farmers, and even in some cases a luxury crop compared to the local standard (Semon 2003). There is now a new interest in the idea of improving *O. glaberrima* (Mohapatra 2010). But it should be added that this earlier neglect by crop scientists (Richards 2006) means that all varieties of *O. glaberrima* currently in cultivation are entirely the products of farmer agency.

In local practice, *O. glaberrima* coexists with *O. sativa* in neighbouring pure stands or in mixtures (Jusu 1999, Teeken et al. 2010, Okry et al. forthcoming, F. Okry et al. unpublished). Recent studies have shown that as a result of this latter condition, varieties with an interspecific background (as the products of spontaneous crosses between *O. glaberrima* and *O. sativa*) have developed in farmers' fields (Barry et al. 2007, Nuijten et al. 2009). Technological advances have also made interspecific crosses possible under laboratory conditions, resulting in the "New Rice for Africa" (Nerica). It is shown that rice varieties with an interspecific background, whether of farmer origin, or Nerica, can be very productive and well-adapted to poor cropping conditions (Jones et al. 1997a, 1997b, Nuijten et al. 2009). Farmer hybrids identified in Sierra Leone, Guinea, Senegal and Guinea Bissau by Nuijten et al. (2009) are incorporated into the local varietal portfolio, and exchanged among farmers within the informal seed system. Nerica varieties, on the other hand, are disseminated through formal interventions such as the African Rice Initiative (ARI) which is implemented by Africa Rice Center (AfricaRice, formerly known as WARDA).

Since the early days of independence from colonial rule in the 1960s, governments of West African countries have been developing formal rice seed dissemination systems linked closely with research and extension services, with (latterly) the involvement of NGO networks, to disseminate improved varieties, i.e. research outputs. The same political will across a range of countries has provided impetus and direction to seed system development to date. Improved or modern varieties are considered superior to local varieties as an act of ideological faith, and as such continue to receive the full attention and energy of the formal system. However, adoption studies reveal generally low adoption rates for improved varieties in many sub-Saharan Africa countries (Dalton 2004, Diagne 2006, Amanor 2011). There is some suggestion that this is mainly because farmers only have access to them through the formal seed sector covering only a limited part of the production areas and a restricted range of farmers' seed needs (8% in the case of Guinea, SNPRV 2001). Farmers mostly rely on local varieties and on-farm-saved seed (Okry et al. 2011a) because it is cheap, readily available, and close at hand, and because these varieties are often particularly suitable to local agro-ecologies (Dalton 2004, Okry et al. 2011a). But quite what lies behind this problem is not well known, and is the subject of investigation in this thesis. Given evidence on low adoption rates for new varieties in the West African rice region, it is not at all clear that further research outputs (improved varieties), will prove any more popular, despite their high potential performance, if low adoption reflects socio-technical, socio-economic, socio-political and cultural constraints unrelated to specific varietal attributes, or not yet addressed by researchers. These other variables have often received scant attention from the formal research system. Hence the importance of studying these aspects - a challenge explored in this thesis.

1.2 PROBLEM STATEMENT

1.2.1 The need to investigate the informal seed system

The current seed system (world-wide) is dominated by the informal seed system (Tripp 2001, Almekinders and Louwaars 2002). Depending on the region and crop, 60-100% of seed is locally produced and exchanged (Almekinders et al. 1994, Okry 2005, Almekinders et al. 2007, Duijndam et al. 2007). The dominance of farmer-saved seed is perhaps greatest in sub-Saharan Africa, and extends to uptake of improved varieties (Okry et al. 2011a, Okry et al. forthcoming). Yao (1996) reports in Ethiopia that the adoption rate of improved bean varieties does not exceed 10%. Almost the same rate has been reported for rice in Guinea (SNPRV 2001). Hence farmers largely depend on local seed sources. According to some authors (e.g. Seboka and Deressa 2000), farmers rely on the informal seed sector and indigenous social networks to acquire seeds because seeds of newly developed varieties are not available in adequate quantities, mainly due to a lack of seed multipliers and inefficient seed distribution channels. Moreover, the formal seed system covers mostly the demands of urbanised regions, and its dependency on a formal extension system limits the number of farmers reached; in Cote d'Ivoire for example only 11% of farmers have contact with extension services and research organisations (see Diagne 2006). In marginal areas (distant regions or regions with poor infrastructures), the formal seed system is expensive due to excessive transaction costs. In addition, costs attached to information gathering on seed from the formal seed system appear to be high (Almekinders et al. 2007).

It is believed that the formal seed sector better guarantees seed purity and quality than the informal sector, but evidence is lacking, and the challenges of maintaining seed quality seem to be not limited to the local seed sector alone. Moreover, local seed may at times be better in quality than improved seed (Janssen et al. 1992, Rubyogo et al. 2009). In some cases, seed purity, as defined by the formal sector, may be disadvantageous for farmers' strategies of risk mitigation in fragile ecosystems. Jusu (1999) and F. Okry et al. (unpublished) describe some traditional farming practices that lead to purposive seed/variety mixtures in Sierra Leone and Guinea. Varietal mixtures, however, are an important cause of quality reduction in milled rice. Therefore it is important to take into account the objectives of production when defining weaknesses of seed systems. Despite the positive attributes of the informal seed system, scholars almost unanimously agree on the need to improve it, in order to reinforce the role it plays in attaining and maintaining food security. The approach should be improvement not replacement.

To respond to the rapid increase of rice consumption in West Africa, and given the alleged deficiencies of the informal seed system, efforts at seed development have been directed, for decades, towards the development of a formal seed system based on a “western” model. Consequently, the traditional rice seed system has been neglected, both from a research and development perspective. The same observation has been made for other crops. Furthermore, projects claiming to work with the principles of the informal seed system apparently act on an ideological basis, rather than on principles derived from careful study of functionality (Thiele 1999). So the overall purpose of this thesis is to study the functioning of an informal rice seed system, in order to deduce sound principles of operation, with the eventual aim of supporting a more efficient rice seed system.

1.2.2 Towards an intermediate seed system

The documented failure of the formal seed system to provide seed for small-scale farmers (Wiggins and Cromwell 1995, Seboka and Deressa 2000, Tripp 2001, Almekinders and Louwaars 2002) and the need properly to cover farmers’ demands and capture local energy (as manifest in farmer seed development (F. Okry et al. unpublished)) have recently raised the option of combining positive attributes of both formal and informal seed systems. How to bridge the two seed systems remains a domain of investigation in which there has been little scientific effort so far.

Among the exceptions is a study by Seboka and Deressa (2000) suggesting a redefinition of the role of extension services. These authors believe, the challenge of the improvement of the seed supply requires involvement of the extension services in mobilising/organising farmers, to enhance *in situ* genetic conservation and ensure institutional (formal and informal) linkage. This recommendation seems, however, too general and theoretical to an extent.

Almekinders and Louwaars (2002) go further in the adventure to integrate formal and informal seed systems. They suggest strategic points where the formal and informal seed systems could link up to support a more efficient seed system. But still, a methodical approach to reaching such linkage seems absent.

Another attempt of linking the formal and informal seed system is that of AfricaRice, which in the late 1990s came up with the Community-Based Seed System (CBSS) approach, an attempt to combine scientific principles of seed development and traditional practices of seed production, conservation and distribution (Bèye et al. 2005). This new approach was tested in Guinea from 1999 to 2003. At this point of time, the CBSS remains a candidate approach, and application in several other sub-Saharan African countries needs to be studied in order to assess the extent to which the approach can be rolled out or redesigned.

A recent study by AfricaRice and FAO (Food and Agriculture Organization of the United Nations) in nine African countries has documented the evolution and challenges of local seed entrepreneurs, many of whom actually or potentially provide links between the formal and informal seed systems (Van Mele et al. 2011, Okry et al. 2011b). The present thesis explores local seed system dynamics and processes with a view to throwing light on further options for linking informal and formal seed systems.

1.2.3 Impacts on local varietal portfolios

The development of a seed system (production, multiplication and dissemination) impacts upon agro-biodiversity. While the formal seed system is thought to threaten varietal diversity (Thiele 1999), the traditional seed system is portrayed as preventing depletion of agricultural diversity (Almekinders and Louwaars 2002). This is because in many low-input farming systems farmers hold a large range of varieties (Clawson 1985, Richards 1986). This large diversity helps mitigate risk, e.g. by buffering against total crop failure, keeping yields stable, by matching seed types to a wide range of ecologies (soil quality, soil condition, rainfall regime) (Richards 1986, Brouwer et al. 1993, Almekinders et al.

1995, Nuijten 2005), and keeps future options open; including adaptation to changing conditions of labour supply and consumption patterns and market demands (Bellon 1996, Almekinders and Louwaars 2002, Almekinders et al. 2007). The informal seed system and agro-biodiversity conservation are thus coupled, forming an integrated system of crop development through varietal creation and/or selection, and variety conservation and exchange. A plausible hypothesis, therefore, is that a change in the traditional seed system might affect local varietal diversity. But to assess this hypothesis we need further information. In regard to rice in West Africa as a case study, we can ask a range of questions. These include:

- Is the varietal diversity exchanged through the informal seed system different from that exchanged in the formal seed system?
- Is it true that improved varieties hardly flow within the networks of the informal seed system?
- Is the persistence of *O. glaberrima* in the farming system related to the large dominance of the informal seed system?
- Would cultivation of local varieties especially *O. glaberrima* be threatened if the linkages between the formal and informal seed systems are strengthened?

In addition to these research questions, the thesis also asks questions about the type of varieties famished cherish within the informal system. Cultivation of a large varietal diversity is often presented as a risk mitigation strategy including prevention of total crop failure (see Richards 1986 for one influential elaboration of this thesis pertaining to rice in Sierra Leone). This means that farmers in setting their objectives look primarily for varieties that if cultivated in sub-optimal environments (uncertain rainfall, variable soil texture and fertility, pests and diseases pressure) help guarantee them a minimum yield. The widespread cultivation of local varieties in sub-optimum conditions may imply local varieties are robust (provide a minimum yield) and adapt to a large spectrum of environments. This thesis also seeks to test whether typical West African farmer rice varieties have these characteristics.

1.3 THESIS OBJECTIVES AND RESEARCH QUESTIONS

The research reported in these pages contributes to a better understanding of farmer seed systems. Overall, it aims to study the functioning of an informal rice seed system, in order to deduce sound principles of operation, with the eventual aim of supporting a more effective and efficient rice seed system in West Africa. The research starts with a regional focus (seven coastal West African countries) on farmers' varietal diversity and then zooms in on specific (field work based) case studies of Guinea and Sierra Leone, in order to understand how seed systems manage this diversity.

The research specifically aims to:

1. Explore farmers' varietal diversity across coastal West Africa in order to depict the diversity represented by farmers' varieties in the region;
2. Analyse the phenological behaviour of typical farmer varieties under different sub-optimal conditions across West Africa in order to evaluate their robustness and coping strategies;
3. Analyse processes of establishment, development and organisation of the rice seed systems in Guinea in order to depict actors' roles and perceptions, and institutional arrangements favouring or hindering seed supply to small-scale farmers;
4. Explore informal seed system dynamics with a view to throwing light on further options for linking informal and formal seed systems.

The research questions addressed in this thesis are as follows:

1. What diversity exists in farmers' fields in coastal West Africa? Is the varietal diversity created and exchanged through the informal seed system used in the formal crop development system?

2. How do farmer varieties perform across a wide range of environments? What are the implications of the robustness of farmer varieties for the formal system of crop development?
3. How is rice seed produced in West Africa?
   - How do farmers produce seed?
   - How closely related are seed production and seed distribution networks?
4. How do farmers obtain rice seed?
   - What are the different modes of seed acquisition? What purposes do they serve?
   - Who are the main actors involved? How do they emerge? What are the main characteristics of these actors? What are their institutional linkages? and how do they perceive other relevant actors?
   - Through which networks is rice seed distributed within farming communities in Guinea? How do they operate? How do they relate to each other? What varietal diversity do they distribute? Is it true that improved varieties hardly flow within the networks of the informal seed system? Is the persistence of *O. glaberrima* in the farming system related to the large dominance of the informal seed system? And, would cultivation of local varieties especially *O. glaberrima* be threatened if the linkages between the formal and informal seed systems are strengthened?
5. How does the informal seed system adapt to changes in the agrarian system?
6. What are the strengths and weaknesses of the seed systems?

1.4 CONCEPTUAL FRAMEWORK

1.4.1 Research design

This research examines existing seed systems and agro-biodiversity conservation practices. It is thus, above all, evaluation research.

Seeds and varieties are technological facts. They have both social dimensions (e.g. the social norms, rules and regulations developed around seed exchange and planting) and technical (biological, agronomic) dimensions. Taken together, these social and biological facts comprise a socio-technical system. Therefore, in this study we consider the formal seed system, the informal seed system, the Community-Based Seed System (CBSS) and related institutions or practices of variety development and conservation as socio-technical programmes. Each of these programmes has its own mode of operation, regulations, and aims. Within each programme individuals and institutions interplay, disagreements emerge and power games shape the relationships through which a level of achievement of initial goals is reached. In the specific cases examined below the objective of these programmes is to supply seed of suitable and desirable varieties to small-scale rice farmers.

A number of different research designs have been proposed as suitable for evaluation research. Here, use is made of the framework of Realistic Evaluation, as proposed by Pawson and Tilley (1997). Philosophically, this approach rests on realist (as opposed to idealist) assumptions - that there is a world out there, to be accessed through research. Reasons for adopting the realistic perspective are outlined by Pawson and Tilley (1997) as follows:

- The embedded nature of all human action within a wider range of social processes and the stratified nature of social reality; a chain of action occurs because of the accepted place of these actions in the whole.
- Social interventions only and always work through the action of mechanisms, in which resources and reasoning are woven together. Social mechanisms are thus about actors' choices and the capacities actors derive from group membership.

- Social programmes are always introduced into pre-existing social contexts (with prevailing social conditions) which are of crucial importance when it comes to explaining successes and failures. This implies that a crucial task of evaluation is to include investigation of the extent to which the pre-existing structures (existing sets of social relationships) 'enable' or 'disable' the intended or proposed mechanism of change.
- The objective of realist inquiry is to explain social outcomes and patterns.
- All social systems change and all social analysis (including evaluation research) involves a mastery of change.

As opposed to classic positivist forms of evaluation (e.g. economic cost-benefit analysis) a realist evaluation does not have a judgemental view. It rather attempts to point out the best of programmes under evaluation. To reach this end three guiding themes underpin a realist research strategy:

1- Increase specificity of understanding of mechanisms through which a programme accomplishes change. In the case of the present research this implies mechanisms through which different seed systems meet farmers' needs for access to seeds and varieties.

2- Increase specificity of understanding of the contextual conditions necessary for triggering programme mechanisms.

3- Increase specificity of outcome pattern predictions according to context and mechanism triggered (Op. cit, p. 114).

Deriving from the above, the design of this research invokes the recurrent question "what works for whom and in what circumstances?". This leads into the analysis of the context-mechanism-outcome configuration (CMOC) suggested by Pawson and Tilley as the analytical focus of evaluation research.

The rationale sustaining the CMOC is that, for any social programme, mechanisms act in particular contexts to cause specific outcomes. A realist evaluation is therefore continuously looking for mechanisms that are particular to contexts and specific to outcomes. One should, however, note that the balance of contexts-mechanisms-outcomes is prone to a perpetual and self-generated reshaping (Op cit, p. 86). Thus for instance if the coupling of context and mechanism changes (if, for example, farmers suddenly experienced climatic shocks or new pests) then an old seed system thought to work well might now have new and unexpected outcome failures. This is why realist evaluation is careful about judgements, at least until a CMOC is thoroughly well understood in dynamic terms.

1.4.2 An interdisciplinary approach

Seeds and varieties primarily enter the agricultural production system as technological inputs. Acquisition, management and reproduction of seeds quickly gain an embedded economic relevance, and entail a range of actors with potentially conflicting interests and strategies coming into interaction, thus leading to the establishment of sets of norms and values, modes of management, and micro-politics, etc. which confer a definite social life to what might have hitherto been regarded as purely technical artefacts. The distinction between seed (a technology *per se*) and the social relations involved in acquiring and planting that seed is a fine line, and therefore difficult to make: a technology implies social relations (Anderson 1997). Investigating such a socio-technical system (hybrid per essence) requires a range of tools that only a methodologically plural or interdisciplinary approach could provide. The present research thus combines agronomic and anthropological perspectives and methods of investigation to provide a holistic description and analysis of rice seed systems and related varietal diversity.

Seed systems have been investigated by both natural scientists (agronomists) and social scientists (anthropologists) drawing on various paradigms. Table 1.1 attempts to grasp (normatively) how seed systems could be perceived and studied via two distinct conceptual paradigms. Conceptions or perspectives presented in this table should not be seen as strictly conflicting. They are better regarded as different approaches to conceptualising the complexity of seed systems. The present research opts to develop and test its hypotheses within the second of these paradigms. It is then open to eventual debate whether different conclusions would be drawn from the same data framed according to the first paradigm.

Table 1.1: Some conceptions of seed systems according to a reductionist-positivist paradigm and a holistic paradigm

Reductionist- positivist paradigm	**Holistic paradigm**
Seed is a biological entity from which crops develop	Seed is part of social life of people and reflects social and cultural practices.
Seed is an agricultural input. It is exchangeable in way that any traded commodity is exchanged from a comparative advantage point of view: New high yielding varieties should replace the old varieties.	Social processes give meaning to seed and varieties. A good new variety may encounter difficulties to be exchanged depending on actors and cultural values involved.
Agricultural production means food production: farmers are looking for good seeds and varieties. Wherever they find them, they will use them.	Agricultural production is intertwined with the socio-economic system: variety adoption and seed exchange follow and reflect social relationships, power, and social status
High yielding varieties should be adopted. Farmers should use pure seed.	Yield increase is not the prime objective of small-scale farmers: a ‘secure’ stable yield is preferred, different varieties are grown for different objectives, and farmers often work with seed mixtures.

1.5 METHODOLOGY

1.5.1 Research area, units of analysis and sampling

The study was first conducted as part of a larger research project on farmer rice varieties in coastal West Africa from Senegal to Togo. The data sets in this larger project were drawn from seven countries: The Gambia, Ghana, Guinea, Guinea Bissau, Senegal, Sierra Leone and Togo (Figure 1.1). During a second stage of in-depth investigations the study zoomed in to collect data in Guinea and Sierra Leone, specifically among a single cross border group of Susu-speakers of Kindia region (Lower Guinea or Guinea Maritime) and Kambia District (North-western Sierra Leone). This is hereafter referred to as the study area. The Susu group has a long tradition in rice production. References stretch back to Portuguese and Cape Verdean visitors in the 16th century (Alvares d’Almada 1594). By deciding to investigate a group with some degree of cultural and linguistic uniformity it is implicitly assumed that much of the variation in practices of seed production and strategies of seed distribution or acquisition to be described is due to variation in national context, agro-ecology of seed usage, or farmers’ knowledge, options and strategies. The main research site was Kindia region (Guinea). Investigations in Kambia District (Sierra Leone) aimed at providing a comparative ground to analyse seed strategies and management of varieties and gene flow. Moreover, Kambia provided a context to investigate local strategies of seed recovering in a post-conflict situation. Kambia is only 50 km away from the Guinea border and approximately 200 km from Kindia.

The Guinean government (and partners), in an effort to develop a formal rice seed sector, created in the 1980s four seed centres specialised in seed production. These are located in Bordo, Kilissi (Kindia), Koba and Sérédou. The selection of Kindia as a research site offered the opportunity to collaborate with one of the seed centres. Some seed projects (e.g. CBSS, Participatory Varietal Selection (PVS)) started in Kindia, with successful components replicated in others regions. Investigations in Kindia therefore provided in-depth insight into the success/failure of seed projects and formal initiatives for seed. The details on the selection of villages studied are presented in the methodology section of each chapter.

The prime units of analysis were rice growing households and local seed dealers. These are the major actors in manipulating (producing, reproducing and exchanging) planting material. Other units of analysis were researchers, extension workers, NGO-staff and seed companies intervening in seed development in the study area. Again, the sample size and sampling techniques are presented in the methodology section of each chapter.

Figure 1.1: Geographic overview of the West African study area. Pushpins indicate study areas. (Extracted from Nuijten et al. 2009)

1.5.2 Research methods, tools of data collection and analysis

A detailed account of methods of data collection and analysis is provided in the methodology section of each chapter. Preliminary interviews helped to understand the general context of the research. The in-depth investigations used:

Methods from natural sciences:

- Field trials: Experiments (five) on adaptive plasticity/robustness of farmer rice varieties
- Molecular analysis: AFLPs were used to characterise farmer rice varieties collected across seven West African countries
- Other measurements: germination, seed rate and evaluation of rate of seed mixture

Methods from social science:

- Participant observation: used to gain close understanding of the reality under study; “to become, to a certain extent, an insider” (Theis and Grad 1991 p. 33). We used participant observation to understand strategies of seed acquisition, seed exchange among farmers, and transactions between farmers and seed dealers. Here participant observation (coupled with informal interviews) helped to unravel the unspoken relationships (e.g. power relationships) and intentions hidden behind spontaneous seed gifts, etc.

- Interviews: used to further explore views, situations and events that participant observation could not properly address. Interviews included questionnaires[1], check-lists (e.g. during focus group discussions) and informal interviews. Informal interviews were conducted with individual farmers, often in neutral settings.
- Story telling: in-depth interviews in which narratives were recorded to reconstruct farmer life histories, from which information was extracted to further explain an issue at hand. New aspects to be investigated also arose from life histories. Life histories were used to explain farmer behaviour or decision making processes.

Secondary data were collected through literature review, archive searches and interviews (personal communication) with resource persons and key informants. Discourse and content analysis helped to process information at this stage.

1.6 THESIS OUTLINE AND OVERVIEW OF ARGUMENTS

This thesis is organised in eight chapters. Chapter 1 (the current one) presents the research context and objectives, the research design and the general methodological orientation. It also introduces the case studies of Guinea and Sierra Leone.

Chapter 2 characterises and compares 315 rice varieties collected in seven countries across the West African coastal region. It explores the molecular diversity of the collected varieties. Chapter 2 contributes to the research objective 1 and research questions 1.

Chapter 3 analyses the phenological behaviour of 24 farmer varieties of two rice species (*O. sativa* and *O. glaberrima*) selected from the large sample characterised in Chapter 2 and put in trials across five different locations (in five countries). Responses of the varieties in terms of canopy development, yield components and yield were studied and compared across the five different environments to better understand underlying mechanisms for adaptive plasticity of these two rice species. Chapter 3 contributes to the research objective 2 and research questions 2.

Chapter 4 analyses the organisation of the rice seed sector in Guinea. It reviews the formal interventions that took place in the seed sector and confronts these with recent dynamics observed in the informal seed system. It explores how stakeholders perceive the functioning of the current seed sector, maps out their respective roles, analyses the institutional linkages and highlights seed distribution initiatives within the informal seed sector. Chapter 4 contributes to research objectives 3 and research questions 4 and 6.

Chapter 5 presents the local seed trade as a response of the informal seed system to challenges emerging from recent changes in rice cultivation in Guinea. It explores the roles of local seed dealers in disseminating improved varieties. Through a scenario mapping exercise, it explores dealers' willingness to get involved in formal seed distribution projects. Chapter 5 contributes to research objective 4 and research questions 4 and 5.

Chapter 6 characterises a range of seed producers and dealers. It re-constructs dealers' trajectories of seed enterprise development and analyses their market and network development strategies. Through a thorough description, Chapter 6 shows that viable small seed enterprises developed and operate in a sustainable manner in Africa contrary to the well spread idea that seed enterprises should always bear an "industrial format". Chapter 6 contributes to the research objectives 3 and 4 and research questions 4, 5 and 6.

[1] Questionnaires and check-lists are available and can be accessed upon request.

Chapter 7 describes seed production and selection in the research area (Guinea and Sierra Leone), analyses the contexts within which farmers select and produce seed, discusses strengths and weaknesses, and suggests improvements. Chapter 7 contributes to research objective 4 and questions 3, 4, 5 and 6.

Chapter 8 summarises key findings of the research, underlines some mechanisms behind certain farmer behavioural patterns within the context established earlier in the thesis, suggests institutional arrangements to improve the impact of the formal seed system on rural livelihoods, and discusses possibilities and ways of linking the formal and informal seed systems better to service the seed needs of small-scale farmers.

REFERENCES

Almekinders, C.J.M. and N.P. Louwaars (2002). The importance of the farmers' seed systems in a functional national seed sector. Journal of News Seeds 4: 15-33.

Almekinders, C.J.M., G. Thiele and D.L. Danial (2007). Can cultivars from participatory plant breeding improve seed provision to small-scale farmers? Euphytica 153: 363-372.

Almekinders, C.J.M., L.O. Fresco and P.C. Struik (1995). The need to study variation in agroecosystems. Netherlands Journal of Agricultural Science 43: 127-142.

Almekinders, C.J.M., N.P. Louwaars and G.H. de Bruijn (1994). Local seed systems and their importance for an improved seed supply in developing countries. Euphytica 78 : 207-216.

Alvares d'Almada, A. fl. (1594). Brief treatise on the rivers of Guinea. Translated Paul Hair, Department of History, University of Liverpool, 1984.

Amanor, S.K. (2011). From farmer participation to pro-poor seed markets: The political economy of commercial cereal seed networks in Ghana. IDS Bulletin 42 (4): 48-58.

Anderson, B. (1997). Work, ethnography and system design. The Encyclopedia of Microcomputers 20: 159-183.

Audebert, A., M. Dingkuhn, M.P. Jones and D.E. Johnson (1998). Physiological mechanisms for vegetative vigor of interspecific upland rices. Implications for weed competitiveness. Japanese Journal of Crop Science 67 (2): 358–59.

Barry, M.B., J-L Pham, J.L. Noyer, C. Billot, B. Courtois and N. Ahmadi (2007). Genetic diversity of the two cultivated rice species (*O. sativa* & *O. glaberrima*) in Maritime Guinea. Evidence for interspecific recombination. Euphytica 154: 127-137.

Bellon, M.R. (1996). The dynamics of crop intraspecific diversity: a conceptual framework at the farmers level. Economic Botany 50 (1): 26-39.

Bèye, A.M., M.P. Jones and B.M. Simpson (2005). Système semencier communautaire: Cas de la riziculture traditionnelle. Guide du technicien. Collection ADRAO Formation. ADRAO, Bouake, 68p.

Brouwer, J., L.K. Fussell and L. Herrmann (1993). Soil and crop growth micro-variability in the West African semi-arid tropics: a possible risk-reducing factor for subsistence farmers. Agriculture, Ecosystems and Environment 45: 229-238.

Brydon, L. (1981). Rice, yams and chiefs in Avatime: speculations on the development of a social order. Africa 51 (2): 659–677.

Clawson, D.L. (1985). Harvest security and intra-specific diversity in traditional tropical agriculture. Economic Botany 39: 56-67.

Dalton, T.J. (2004). A household hedonic model of rice traits: economic values from farmers in West Africa. Agricultural Economics 31: 149-159.

Diagne, A. (2006). Diffusion and adoption of Nerica rice varieties in Cote d'Ivoire. The Developing Economies XLIV-2: 208-31

Dingkuhn, M., D.E. Johnson, A. Sow and A.Y. Audebert (1999). Relationships between Upland Rice Canopy Characteristics and Weed Competitiveness. Field Crops Research 61 (1): 79–95.

Dingkuhn, M., M.P. Jones, D.E. Johnson and A. Sow (1998). Growth and yield potential of *Oryza sativa* and *O. glaberrima* upland rice cultivars and their interspecific progenies. Field Crops Research 57 (1): 57–69.

Douglas, M. (1966). Purity and danger: An analysis of concepts of pollution and taboo. London: Routledge.

Duijndam, F.P., C.J. Evenhuis and J.E. Parlevliet (2007). Production and use of maize seed for sowing in Bolovia, Ecuador. Euphytica 153: 343-351.

FAO (Food and Agriculture Organization of the United Nations) (1995). Dimensions of need. An atlas of food and agriculture. http://www.fao.org/docrep/u8480e/U8480E07.htm#The sources of food [visited 1 September 2011].

FAO (Food and Agriculture Organization of the United Nations) (2004). http://faostat.fao.org/faostat [visited on March 2006].

FAO (Food and Agriculture Organization of the United Nations) (2011).http://faostat.fao.org/faostat) [visited on 1 September 2011].

Janssen, W., C.A. Luna and M.C. Duque (1992). Small farmer behavior towards bean seed: Evidence from Colombia. Journal of Applied Seed Production 10: 43-51.

Johnson, D.E., M. Dingkuhn, M.P. Jones and M.C. Mahamane (1998). The influence of rice plant type on the effect of weed competition on *Oryza sativa* and *Oryza glaberrima*. Weed Research 38 (3): 207–216.

Jones, M.P., M. Dingkuhn, D.E. Johnson and S.O. Fagade (1997b). Interspecific hybridization: Progress and prospect. Proceedings of the workshop: Africa/Asia joint research, interspecific hybridization between African and Asian rice species ed. (*Oryza glaberrima* and *Oryza sativa*). Bouaké: WARDA.

Jones, M.P., M. Dingkuhn, G.K. Aluko and M. Semon (1997a). Inter-specific *O. sativa* L. x *O. glaberrima* Steud: progenies in upland rice improvement. Euphytica 92: 237-246.

Jusu, M.S. (1999). Management of genetic variability in rice (*Oryza sativa* L. and *O. glaberrima* Steud.) by breeders and farmers in Sierra Leone. Published PhD thesis, Wageningen University, Wageningen, The Netherlands, 198p.

Linares, O.F. (2002). African rice (*Oryza glaberrima*): History and future potential. Proceedings National Academy of Sciences 99 (25): 16360-16365.

Maat, H. and D. Glover (2011). Introduction. East Asian Science, Technology and Society: An International Journal 5: 127-134.

Mohapatra, S. (2010). Pockets of gold: Scientists find a treasure trove of information in Africa's indegenous rice that could help breed better varieties for tomorrow's generation. Rice Today April-June 32-33.

Nuijten, E. (2005). Farmer management of gene flow: The impact of gender and breeding system on genetic diversity and crop improvement in the Gambia. Published PhD Thesis, Wageningen University, Wageningen, The Netherlands, 271 p.

Nuijten, E., R. van Treuren, P.C. Struik, A. Mokuwa, F. Okry, B. Teeken and P. Richards (2009). Evidence for the emergence of new rice types of interspecific hybrid origin in West-African farmer fields. PLoS ONE 4 (10): e7335. doi:10.1371/journal.pone.0007335.

Obilana, A.B. and B.N. Okumu (2005). INT/00/922 Africa-Asia Joint Research: Interspecific hybridization between African and Asian rice species. Evaluation study report, UNDP SU/SSC and WARDA, Cotonou, 84 p.

Okry, F. (2005). A socio-technical development of a seed (planting material) system: The case of yam in the Republic of Benin. Master thesis, Wageningen University, Wageningen, The Netherlands, 94 p.

Okry, F. et al. (Unpublished). Rice seed production among the Susu in Guinea and Sierra Leone: Local knowledge and farmers' practices.

Okry, F., D.N. Dalohoun, S. Diawara, M.B. Barry and P. Van Mele (2011b). Guinea: Networks that work. In: Van Mele, P., J.W. Bentley and R.G. Guéi (Eds.) African seed enterprises: Sowing the seeds of food security. CABI Publishing, UK, pp. 89-108.

Okry, F., E. Nuijten, P. Van Mele, P.C. Struik and P. Richards (forthcoming). Adaptation of the informal seed system to agrarian changes: The emergence of market oriented local seed dealers within the informal seed sector of rice in Guinea. Journal of Agrarian Change Submitted.

Okry, F., P. Van Mele, E. Nuijten, P.C. Struik and R.L. Mongbo (2011a). Organizational analysis of the seed sector of rice in Guinea: Stakeholders, perception and institutional linkages. Experimental Agriculture 47 (1): 137-157.

Pawson, R. and N. Tilley (1997). Realistic evaluation. London, Sage Publications.

Portères, R. (1962). Berceaux agricoles primaires sur le continent African. Journal of African History 3 (2): 195-210.

Portères, R. (1976). African cereals. In Harlan, J. et al (Eds.) The origin of African plants domestication. The Hague: Mouton.

Richards, P. (1986). Coping with hunger: Hazard and experiment in an African rice-farming system. London, Allen & Unwin.

Richards, P. (1989). Agriculture as a Performance. In: Chambers, R., A. Pacey and L. A. Thrupp (Eds.) Farmer first: Farmer innovation and agricultural research. London: Intermediate Technology Publications.

Richards, P. (2006). The history and future of African Rice: Food security and survival in a West African war zone. Afrika Spectrum 41 (1): 77-93.

Rubyogo, J.C., M. Dickinson, S. Mayes and T. Assefa (2009). Seed-health assessment of different bean seed grades and sources from Ethiopia using molecular tools. Journal of New Seeds 10: 293-310.

Sall, S., D. Norman and A.M. Featherstone (1998). Adaptability of improved rice varieties in Senegal. Agricultural Systems 57(1): 101-114.
Sarró, R. (2009). The politics of religious change on the Upper Guinea Coast: Iconoclasm done and undone. Edinburgh, Edinburgh University Press Ltd.
Seboka, B. and A. Deressa (2000). Validating the farmers' indigenous social networks for local seed supply in central Rift valley of Ethiopia. The Journal of Agricultural Education and Extension 6 (4): 245-254.
Semon, M. (2003). Analysis of evolutionary history, population structure and genetic diversity of Oryza glaberrima Steud Bases on microsatellite markers. Published PhD dissertation, Cornell University, United States of America, 142 p.
Semon, M., R. Nielsen, M.P. Jones and S.R. McCouch (2005). The population structure of African cultivated rice Oryza glaberrima (steud.): Evidence for elevated levels of linkage disequilibrium caused by admixture with O. sativa and ecological adaptation. Genetics 169: 1639-1647.
SNPRV (2001). Multiplication and diffusion of community- based seeds of Nerica rice developed by WARDA. Project document, 43 p.
Teeken, B., E. Nuijten, F. Okry, A. Mokuwa, M. Temudo, P.C. Struik and P. Richards (2010). Advocating the integration of socio-cultural factors in models for variety dissemination. Paper presented at the 28th International Rice Research Conference, 8-12 November 2010, Hanoi, Vietnam.
Temudo, M. (2011). Planting knowledge, harvesting agro-biodiversity: A case study of southern Guinea-Bissau rice farming. Human Ecology DOI 10.1007/s10745-011-9404-0.
Theis, J. and H. Grad (1991). Participatory rapid appraisal. London: IIED.
Thiele, G. (1999). Informal potato seed systems in the Andes: Why are they important and what should we do with them? World Development 27 (1): 83- 99.
Tripp, R. (2001). Seed provision and agricultural development. ODI/James Currey, Oxford.
Van Mele, P., J.W. Bentley and R.G. Guéi (Eds.) (2011). African seed enterprises: Sowing the seeds of food security. CABI Publishing, UK.
WARDA (2006). Rice is life for Africans: Poster available at http://www.warda.org/warda/posters/AGM7.html [visited on 24 December 2006].
WARDA (2007). Africa rice trends: Overview of recent developments in the Sub-Saharan African rice sector. Cotonou: Africa Rice Center.
Wiggins, S. and E. Comwell (1995). NGOs and seed provision to smallholders in developing countries. World Development 23 (3): 413-422.
Yao, S. (1996). The determinants of cereal crop productivity of the peasant farm sector in Ethiopia, 1981-87. Journal of International Development 8 (1): 69-82.

EVIDENCE FOR THE EMERGENCE OF NEW RICE TYPES OF INTERSPECIFIC HYBRID ORIGIN IN WEST AFRICAN FARMERS' FIELDS

Published as: Nuijten, E., R. Van Treuren, P.C. Struik, A. Mokuwa, F. Okry, B. Teeken and P. Richards (2009). Evidence for the emergence of new rice types of interspecific hybrid origin in West-African farmers' fields. *PLoS ONE* 4:e7335. doi:10.1371/journal.pone.0007335.

Abstract

In West Africa two rice species (*Oryza glaberrima* Steud. and *Oryza sativa* L.) co-exist. Although originally it was thought that interspecific hybridization is impossible without biotechnological methods, progenies of hybridization appear to occur in farmer fields. AFLP analysis was used to assess genetic diversity in West Africa (including the countries The Gambia, Senegal, Guinea Bissau, Guinea Conakry, Sierra Leone, Ghana and Togo) using 315 rice samples morphologically classified prior to analysis. We show evidence for farmer interspecific hybrids of African and Asian rice, resulting in a group of novel genotypes, and identify possible mechanisms for in-field hybridization. Spontaneous back-crossing events play a crucial role, resulting in different groups of genetic diversity in different regions developed by natural and cultural selection, often under adverse conditions. These new groups of genotypes may have potential relevance for exploitation by plant breeders. Future advances in crop development could be achieved through co-operation between scientists and marginalized farmer groups in order to address challenges of rapid adaptation in a world of increasing socio-political and climatic uncertainty.

2.1 INTRODUCTION

Rice (*Oryza* spp.) is one of the two most important grain crops worldwide. Its genetic diversity is a factor in securing local and global food security. West Africa is important for genetic diversity of rice, because, uniquely, two species – African rice (*Oryza glaberrima* Steud.) and Asian rice (*Oryza sativa* L.) – co-exist within the region. African rice was presumably first cultivated in Mali, Senegal and Guinea Conakry, ± 3500 years ago [1,2]. The history of Asian rice in West Africa is still uncertain, with introduction possible via Arab and/or Portuguese trading networks, ± 500–800 years ago. Asian rice has more recently tended to replace African rice, but African rice has persisted or made a modest come-back in some areas, including parts of coastal West Africa.

Several reports claimed that *O. sativa* is completely isolated from *O. glaberrima* by an F1 sterility barrier [3,4]. Hence, the development of the Nericas (New Rice for Africa) based on the hybridisation of *O. sativa* and *O. glaberrima* was considered a technological breakthrough [5,6]. However, some scientists suggested that introgression between the two rice species occurs in the field [7,8]. Based on experiments, Sano [9] argued that pollen flow occurs mainly from *O. sativa* to *O. glaberrima*. Other experimental studies showed that introgression from *O. glaberrima* to *O. sativa* is possible, although at a low frequency [10-13]. Artificial backcrosses produced fertile progenies which resembled the parental phenotypes, indicating that under natural conditions it will be difficult to detect hybrid derivatives [9,14]. This means that, for example, plants belonging to *O. glaberrima* can incorporate *O. sativa* genetic material but remain typically *O. glaberrima* to the eye.

Recent evidence suggests that interspecific hybridization does occur in farmers' fields resulting in new varieties [15-18]. Our paper shows that West African farmers have generated their own rices of interspecific background - genetically different from and independent of the scientific initiative leading to Nerica - and suggests possible mechanisms for in-field hybridization behind this major local genetic development, with spontaneous backcrossing playing a crucial role. Our results strongly suggest that interspecific hybridization in West Africa farmers' fields is a recurrent and continuing process, resulting in different groups of genetic diversity in different rice growing areas stimulated by (cultural) differences in selection. Our findings support the hypothesis by Sano et al. [14] that hybridisation followed by backcrossing between *O. sativa* and *O. glaberrima* might lead to the development 'of new variants not belonging to either of the two species'. These findings might have important implications for understanding crop development and human adaptation. For some time, it has been argued that small-scale farmers in the poorest countries should be consulted about crop improvement, to ensure a better fit between scientific innovation and local food security needs [19]. Now, molecular information is available on the importance of farmer agency during the domestication of rice [20]. We suggest that the current relationship between science and African farmers needs change. Our evidence shows that African farmers are active agents in plant improvement and we suggest that their agency may be taken as a starting point for scientific technology development. New lateral forms of cooperation are required to exploit fully the available genetic diversity of rice.

2.2 MATERIALS AND METHODS

We sampled the coastal West African rice belt, including Senegal, The Gambia, Guinea Bissau, Guinea Conakry and Sierra Leone, and the Togo hills rice cultivation outlier in Ghana and Togo (Figure 1.1). For demarcation of the upland rice ecology we followed local farmers' definitions. Per country, three or four villages/village clusters were selected, based on ecological and/or cultural contrasts. Per village, as full a set as possible of locally available dryland rice varieties was assembled. Per rice sample, 100–200 panicles were taken at random from the harvest as representative of a variety. Based on farmers' descriptions of the morphological identity of varieties, each rice sample was cleaned carefully. Thus farmer variety samples were morphologically as uniform as formal (released) varieties in the study.

Molecular analysis with AFLP markers, using the *Eco*RI primer E13 in combination with each of the *Mse*I primers M49 or M51, basically followed the procedures described in Nuijten and Van Treuren [16]. AFLP data from 231 collected samples were combined with those of 84 rice samples analysed previously by Nuijten and Van Treuren [16]. A total number of 176 bands was scored, of which 161 were found to be polymorphic. The programme 'SplitsTree' was used to visualize phylogenetic relationships between the samples [21] and version 2.2 of the software package 'Structure' was used to analyze genetic population structure and to assign samples to populations [22, 23]. To quantify gene variation within groups of samples, Nei's gene diversity (H_e) was calculated [24].

Information about trait and variety preferences, and the origin and spread of varieties, was obtained through quantitative and qualitative interviews with farmers from whom the rice samples were collected (in countries listed above).

Information on morphological features was collected in a field trial carried out in Sierra Leone to characterise morphologically the majority of the materials. The trial design and measurement of the traits followed the procedures described in Nuijten and Van Treuren [16]

Definitions

Interspecific hybrids: varieties which result from hybridization between *O. sativa* and *O. glaberrima.*

Nerica: improved varieties released by the African Rice Center (formerly WARDA) that result from artificial hybridization between *O. sativa* and *O. glaberrima* followed by two backcrosses to the *O. sativa* parent.

Farmer hybrid: variety which results from spontaneous hybridization between *O. sativa* and *O. glaberrima* followed by backcrossing in farmers' fields and subsequent self-pollination.

Off-type: rice plant with a phenotype distinctive from the sown variety and unknown as a variety (including non-cultivated and 'lost' varieties). Off-types can result from mixture, genetic mutation or spontaneous hybridization.

Mixture: a rice stand consisting of various genetically different varieties caused by intentional or unintentional mixing.

2.3 RESULTS

An unrooted phylogenetic network of the 315 rice samples is presented in Figure 2.1. As could be expected, *Oryza sativa* ssp. *indica*, *O. sativa* ssp. *japonica* and *O. glaberrima* form three distinct clusters. Nerica varieties of interspecific origin align along the *japonica* axis, with Nerica 1 and 2 facing the *O. glaberrima* branch. In addition to these three clusters, a fourth distinct cluster, consisting of two sub-clusters, was observed, at the junction of the *O. glaberrima-indica-japonica* axes.

Analyses with the software 'Structure' showed that the major structure in the data was captured when four populations were assumed. Three of these populations corresponded with *Oryza sativa* ssp. *indica, O. sativa* ssp. *japonica* and *O. glaberrima*, respectively, while the fourth population corresponded with cluster 4 in Figure 2.1 Of the 315 materials 285 samples were assigned to a cluster with more than 91% probability. All materials in cluster 4 in Figure 2.1 were assigned to cluster 4 with more than 81% probability in Structure, except two varieties from Senegal that were assigned to cluster 4 with 59% and 46% probability.

Prior to the molecular analysis, all varieties collected from farmers were classified as *O. sativa*, *O. glaberrima*, hybrid or unclear. None of the materials assigned to the two *O. sativa* clusters with more than 81% probability were classified as *O. glaberrima* and vice versa (Table 2.1). The single sample classified as *O. sativa* that was assigned to *O. glaberrima,* and the single sample classified as *O. glaberrima* that was assigned to *O. sativa,* were most likely caused by interchanging of materials during the experiment.

Cluster 4 comprised two subclusters (Figure 2.1). All varieties in sub-cluster 4-2 had been taxonomically determined as *O. sativa* prior to the molecular study, while cluster 4-1 consisted of samples that had been determined either as *O. sativa*, *O. glaberrima*, hybrid or unclear (Table 2.2). The main distinctive features between these two sub-clusters were panicle stature at maturity and pericarp (or seed) colour. Sub-cluster 4-1 consisted of varieties with an erect panicle, typical for *O. glaberrima* (Figure 2.2), or a semi-erect or slightly drooping panicle, and a red pericarp, except for a single variety from Senegal which had a brown pericarp. Farmers classify particularly the varieties with an erect panicle as *O. glaberrima*, because of the similarity in panicle stature. Farmers do not recognise the varieties of cluster 4 as a separate group. They divide all varieties into two types: those that resemble *O. sativa* and those that resemble *O. glaberrima*. Farmers are not specifically interested in varieties of interspecific origin, but in varieties that perform best under their conditions.

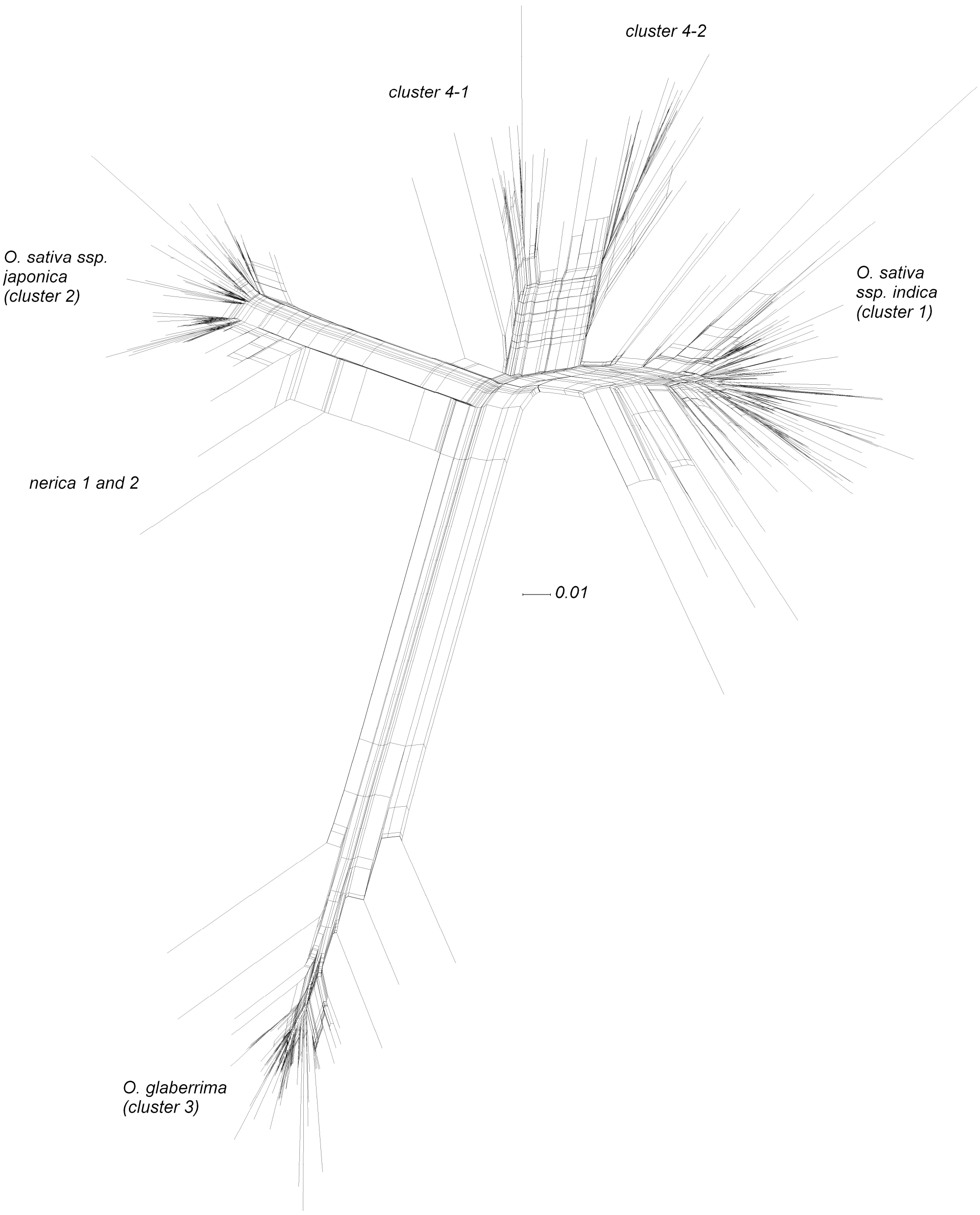


Figure 2.1: Phylogenetic relationships among the 315 samples studied

Table 2.1: Presumed taxonomic origin of the 289 farmer varieties in relation to the assignment probabilities to the four observed clusters

		O. glaberrima	Hybrid	Unclear	*O. sativa*
P (Gla)*	0.91 - 1.00	56		6	1
	0.81 - 0.90	2			
	0.71 - 0.80				
	0.61 - 0.70				
	0.51 - 0.60				
	0.41 - 0.50				
	0.31 - 0.40				
	0.21 - 0.30				
	0.11 - 0.20		3		
	0.00 - 0.10	8	16	18	179
P (Ind)	0.91 - 1.00	1	2	6	71
	0.81 - 0.90			1	3
	0.71 - 0.80		1		1
	0.61 - 0.70	1	1		2
	0.51 - 0.60			1	2
	0.41 - 0.50				2
	0.31 - 0.40				
	0.21 - 0.30				
	0.11 - 0.20	1	1		
	0.00 - 0.10	63	14	16	99
P (Jap)	0.91 - 1.00		5	5	70
	0.81 - 0.90		2		3
	0.71 - 0.80		1		
	0.61 - 0.70				
	0.51 - 0.60				
	0.41 - 0.50				1
	0.31 - 0.40				
	0.21 - 0.30				
	0.11 - 0.20	1	1		1
	0.00 - 0.10	65	10	19	105
P (Cl4)	0.91 - 1.00	6	6	5	23
	0.81 - 0.90		1		2
	0.71 - 0.80				
	0.61 - 0.70				
	0.51 - 0.60				1
	0.41 - 0.50				2
	0.31 - 0.40			1	2
	0.21 - 0.30	1	1		1
	0.11 - 0.20			1	2
	0.00 - 0.10	59	11	17	147

* Probabilities of the materials assigned to *O. glaberrima* (Gla), *O. sativa* ssp. *indica* (Ind), *O. sativa* ssp. *japonica* (Jap) and the fourth cluster (Cl4).

Table 2.2: Presumed taxonomic origin of the farmer hybrid varieties observed in sub-clusters 4-1 and 4-2 in Figure 2.1

Presumed taxonomic origin	Sub-cluster 4-1	Sub-cluster 4-2
O. sativa	3	24
O. glaberrima	6	0
Hybrid	7	0
Unclear	5	0
Total	21	24

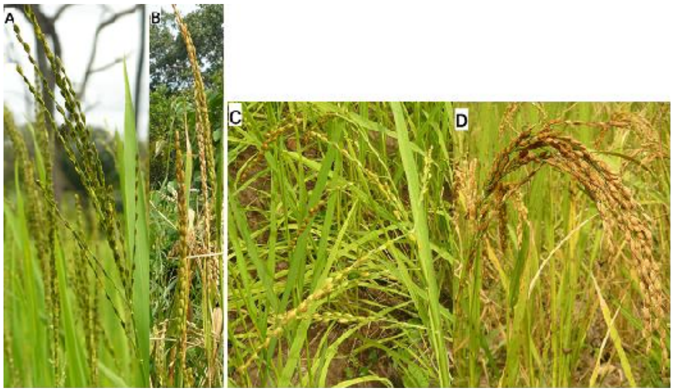


Figure 2.2: Main panicle types found in this study. Panicle stature of *O. glaberrima* (A), interspecific hybrids from sub-cluster 4-1 with erect (B) and intermediate (C) panicles respectively, and *O. sativa* and interspecific hybrids from sub-cluster 4-2 (D)

The three varieties in sub-cluster 4-1 that were classified as *O. sativa* had semi-droopy panicles which made them less distinctive from *O. sativa*. Sub-cluster 4-2 consisted of varieties in which panicles were predominantly strongly drooping, similar to *O. sativa*, and in which the pericarp colour varied from white to brown (90% of the varieties had a brown pericarp colour). Except for pericarp colour, the varieties in sub-cluster 4-2 did not have any clearly distinctive morphological features from *O. sativa* varieties (Table 2.3). Detailed morphological analysis of some varieties belonging to sub-cluster 4-2 in 2002 showed that when characteristics were aggregated in a Principal Component Analysis these farmer varieties were different from *O. sativa* ssp. *indica* and *O. sativa* ssp. *japonica* [16].

Table 2.3: Main distinctive morphological features of 12 varieties from cluster 4*

Variety name	Country	Sub-cluster	Panicle attitude	Ligule shape	Pericarp colour	Days to 80% flowering
Tebeleh	Sierra Leone	4-1	erect	pointed, long	red	105.8
Pa DC	Sierra Leone	4-1	erect	pointed, long	red	103.8
Pa Trimont	Sierra Leone	4-1	semi-droopy	pointed, long	red	92.5
Wonyonwonyon yi	Guinea Conakry	4-1	semi-droopy	pointed, long	red	96.3
Untufa	Guinea Bissau	4-1	erect	pointed, long	red	98.0
Dissi	Guinea Bissau	4-1	erect	pointed, long	red	104.0
Mani Konsunkuto	Guinea Bissau	4-2	strongly droopy	pointed, long	brown	87.5
Kolosar, Mani Wulendingo	Guinea Bissau	4-2	strongly droopy	pointed, long	white	91.8
Mani Wulengo	Gambia	4-2	strongly droopy	pointed, long	brown	88.0
Binta Sambou**	Gambia	4-2	strongly droopy	pointed, long	light brown	103.3
Ablie Mano	Senegal	4-2	droopy	pointed, long	brown	89.5
Madina Wulengo	Senegal	4-2	strongly droopy	pointed, long	brown	90.8

* Varieties of *O. glaberrima* included in this study had erect panicle, round short ligule and red pericarp colour. Varieties of *O. sativa* ssp. included in this study had strongly droopy panicle, pointed medium to long ligule, and white or red pericarp colour.

** In The Gambia Binta Sambou flowers only a few days later than Ablie Mano.

Genetic diversity within groups (H_e) was calculated for each of the four clusters. For this purpose an assignment probability of 91% was used as cut-off point to define the four clusters. The H_e value for cluster 4 was highest (0.098; n = 40) followed closely by the H_e value for the *O. sativa* ssp. *indica* group (0.089; n = 92). Relatively low values were observed for the *O. sativa* ssp. *japonica* group (0.045; n = 87) and the *O. glaberrima* group (0.034, n= 66).

Varieties in sub-cluster 4-1 not only displayed characteristics typical of *O. glaberrima*, such as the easily observable erect panicle stature (Figure 2.2), but also characteristics of *O. sativa*, such as the long, pointed ligule typical of *O. sativa* (Figure 2.3), a less conspicuous feature. The only explanation for this new morphotype is interspecific hybridization between *O. sativa* and *O. glaberrima*. This was supported by the molecular data, separating cluster 4 from *O. sativa* ssp. and *O. glaberrima,* and showing large within-group diversity.

Cluster 4 consisted of a considerable number of different farmer interspecific hybrids originating from the Upper West African coastal rice belt (Table 2.4). None of the modern varieties and none of the samples collected in Ghana and Togo were found in cluster 4 in Figure 2.1, nor were any of these samples assigned to cluster 4 in Table 2.4 with more than 40% probability. Thirty samples - originating from almost all countries, and including two modern varieties - were assigned with less than 91% probability to one cluster. No samples from Togo were assigned with less than 91% probability to one cluster. Although no samples from Ghana were assigned to cluster 4, five samples were assigned with high probabilities to two clusters. These samples may require further study to know whether they have an interspecific background. But we cannot assume that all such materials have an interspecific nature since one variety from IRRI was assigned to the *O. sativa* ssp. *indica* group with 76% probability (Table 2.S1). Likewise, existence of samples with a very high assignment percentage probability does not rule out an interspecific origin. For example, WAB 450-I-B-P-105-HB, a Nerica that was never officially released was assigned with 100% probability to the *O. sativa* ssp. *japonica* group.

To a certain extent, the sub-clusters relate to the countries of collection and local seed colour preferences. The varieties in sub-cluster 4-1 originate from Guinea Bissau (4), Guinea Conakry (2), Senegal (1) and Sierra Leone (14), while the varieties in sub-cluster 4-2 are from The Gambia (9), Guinea Bissau (6) and Senegal (9). Whereas in Guinea Conakry and Sierra Leone farmers commonly cultivate red rice (both African and Asian rice), farmers in The Gambia, Senegal and northern Guinea Bissau predominantly cultivate white rice. Southern Guinea Bissau occupies an intermediate position, as red rice is still cultivated but farmers strongly prefer white rice.

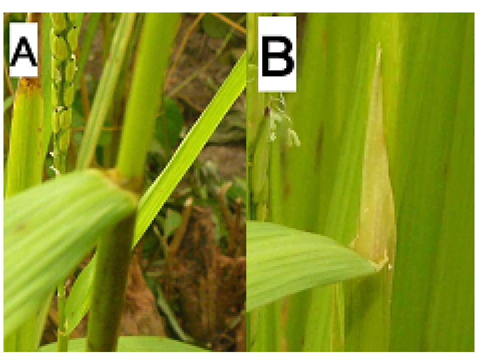


Figure 2.3: Main ligule shapes found in this study. Ligule shape of *O. glaberrima* (A: small, rounded) and *O. sativa* and interspecific hybrids from cluster 4 (B: long, pointed)

Table 2.4: Number of farmer varieties, modern varieties and (semi-) wild relatives assigned by the software 'Structure' to the four observed clusters. Data for the farmer varieties are presented separately per country of origin.

		Gambia	Senegal	Guinea Bissau	Guinea	Sierra Leone	Ghana	Togo	Modern	(Semi) wild	Total
P (Gla)*	0.91 - 1.00	4	3	4	25	8	10	9		3	66
	0.81 - 0.90		1	1						1	3
	0.71 - 0.80									1	1
	0.61 - 0.70										
	0.51 - 0.60										
	0.41 - 0.50										
	0.31 - 0.40										
	0.21 - 0.30										
	0.11 - 0.20	2					1				3
	0.00 - 0.10	53	18	36	21	52	35	6	21		242
P (Ind)	0.91 - 1.00	23	7	5	14	8	20	3	12		92
	0.81 - 0.90	1			1	1	1				4
	0.71 - 0.80		1				1		1		3
	0.61 - 0.70	2			1		1				4
	0.51 - 0.60		1	1			1				3
	0.41 - 0.50		1				1				2
	0.31 - 0.40										
	0.21 - 0.30										
	0.11 - 0.20		1		1					1	3
	0.00 - 0.10	33	11	35	29	51	21	12	8	4	204
P (Jap)	0.91 - 1.00	18		18	2	29	10	3	7		87
	0.81 - 0.90	1		2	1		1				5
	0.71 - 0.80	1							1		2
	0.61 - 0.70										
	0.51 - 0.60										
	0.41 - 0.50						1				1
	0.31 - 0.40										
	0.21 - 0.30										
	0.11 - 0.20	1	1	1							3
	0.00 - 0.10	38	21	20	43	31	34	12	13	5	217
P (Cl4)	0.91 - 1.00	8	7	10	2	13					40
	0.81 - 0.90	1	1			1					3
	0.71 - 0.80										
	0.61 - 0.70										
	0.51 - 0.60		1								1
	0.41 - 0.50		1	1							2
	0.31 - 0.40	1					2				3
	0.21 - 0.30		1		1		1		1		4
	0.11 - 0.20	1				1	1		1		4
	0.00 - 0.10	48	11	30	43	45	42	15	19	5	258

* Probabilities of the materials assigned to *O. glaberrima* (Gla), *O. sativa* ssp. *indica* (Ind), *O. sativa* ssp. *japonica* (Jap) and the fourth cluster (Cl4).

2.4 DISCUSSION

2.4.1 Development of interspecific hybrid varieties

The molecular data showed that cluster 4 is more closely related to *O. sativa* than to *O. glaberrima.* This can be explained by the following scenario for the development of interspecific hybrids in farmer fields. The progeny of an F1-hybrid between *O. sativa* and *O. glaberrima* can maintain itself in the gene pool only through backcrossing to either species (*O. sativa* or *O. glaberrima*), because of a high level of sterility of the F1-hybrid. Farmers do not harvest the panicles of an F1-hybrid because (almost) all grains are empty. Hybrids as such are not maintained in a plant population. The event of a flower being pollinated by pollen of the other rice species is not observable. A panicle that carries one seed which is the result of pollination by the other species (and 200 by self-pollination) looks normal. If that panicle is selected for sowing seed, the seed that is produced by the flower pollinated by the other species is sown in the rice field, germinates and produces a hybrid plant. Only after grain filling (usually at harvesting time) can a farmer recognize this plant as an interspecific hybrid because it does not carry any seed and therefore he/she will not harvest it. Backcrossing is the only way for the genes of a hybrid to be incorporated into a new genotype. From this point two sub-scenarios are possible. The first sub-scenario is that a hybrid plant is pollinated by surrounding normal plants and the few seeds produced by the hybrid remain in the field, germinating next season, then to be pollinated by surrounding normal plants, after which fertility is restored and the offspring may be harvested by farmers. This scenario was also suggested by Sano et al. [14]. For this scenario to be possible a farmer needs to crop the same field to rice for at least three consecutive growing seasons, as sometimes happens where land is initially fertile and where abandoned plots are then cleared for re-use by members of a household with low labour capacity, such as widows. Work on Nerica [5] and speciation in rice [14] suggests that two backcrosses are sufficient to obtain 'offspring' with good fertility. The second sub-scenario is that during flowering the F1-hybrid may pollinate the surrounding normal plants. A panicle of a normal plant in which one flower is pollinated by the hybrid looks normal and may be included in the seed for next season. Two such backcrossing events to *O. sativa* or *O. glaberrima*, and subsequent replanting of the progeny by farmers should also lead to fertile offspring, given enough time and opportunities. Subsequently, off-types of interspecific origin showing potential may be selected by farmers to be tested, multiplied and grown as new varieties. If other farmers show an interest in such a new variety, it may spread over a wider region. The whole process of the development of interspecific hybrid varieties is a combination of a random process of cross-pollination and backcrossing, followed by a selection process of those off-types that show most potential as new varieties by farmers.

Field studies suggested that introgression can occur in both directions (from *O. glaberrima* to *O. sativa* and vice versa) [7,8], although some experimental studies have indicated that introgression from *O. sativa* to *O. glaberrima* occurs more often than introgression in the opposite direction [11,12], as confirmed by field observations in 2002 by Nuijten [25]. Artificial backcrosses produced fertile progenies which resembled the parental phenotypes, indicating that under natural conditions it is difficult to detect hybrid derivatives [9,14]. Given that the hybrid group (cluster 4) is closer to *O. sativa* than to *O. glaberrima*, successful backcrossing events in the field to *O. sativa* might be more likely than to *O. glaberrima*. According to Sano [9] the combination of nuclear DNA of *O. glaberrima* with cytoplasmic DNA of *O. sativa* always results in cytoplasmic male sterility. This suggests that the farmer hybrids may be the result of backcrossing to *O. sativa* and carry a combination of cytoplasmic DNA of *O. glaberrima* with nuclear DNA mainly from *O. sativa.* Chloroplast DNA analysis may give more conclusive information on whether the farmer hybrids result from *O. glaberrima* × *O. sativa* hybrids or *O. sativa* × *O. glaberrima* hybrids [26,27]. These results may also clarify which scenario of backcrossing in farmer fields led to the development of the farmer hybrids. But it should also be noted that in both species varieties may exist that are able to overcome the sterility system - so-called Wide Compatibility Varieties [11].

Rice hybridization in farmer's fields may occur when *O. glaberrima* and *O. sativa* flower side by side. There are various scenarios to explain this co-occurrence at field level. The first possibility is the deliberate sowing of mixtures, which has been reported for several localities in the upper West African coastal zone [15,21,28]. The second, perhaps more common, possibility is the non-deliberate mixing of *O. glaberrima* within *O. sativa* seed stocks.

Roguing off-types requires skill and effort, and is sometimes neglected due to pressure to harvest the crop quickly, resulting in contamination of *O. sativa* seed batches with *O. glaberrima* seeds. Seed contamination can also reflect indebtedness, since farmers harvesting seed intended for loaning to poorer farmers rarely bother to rogue the material [29]. Because the separation of seed types after threshing is a much harder task than panicle roguing at harvest, contamination of *O. sativa* seed batches with *O. glaberrima* may be as high as 30%. These figures boost chances of spontaneous interspecific hybridization on the farms where seed has been loaned.

Another non-intentional factor is the presence of weedy rice types intermediate between wild African rice (*O. barthii*) and *O. glaberrima* in farmers' fields. Gene flow between weedy types and cultivated Asian rice may also result in some in-field interspecific hybridization. Weedy rice types like "ngewobei" and "ngafabei" (as named by Mende-speaking farmers in central Sierra Leone) may be the result of interspecific hybridization between *O. barthii* and *O. sativa* (Table 2.S1). Such weedy types may provide a bridge between wild and cultivated species for breeders to transfer useful characteristics from wild to cultivated rice.

2.4.2 Time depth of farmer hybrid-derived rices – historical evidence

Given the release of hybrid-derived interspecific rice varieties in the Nerica series from WARDA (Africa Rice Center) in the late 1990s it is appropriate to provide evidence that the farmer intermediate types analysed in this paper pre-date the Nerica releases. Rice varieties with the name elements "three month" and "disi" (also written as "DC") and the same morphological features as the collected varieties with the same name elements belonging to cluster 4-1 were collected by Richards [30] and Jusu [15] in Sierra Leone in 1987-88 and 1995-96, respectively.

Farmers from Guinea Bissau provided the following information in the present study. The interspecific farmer hybrids belonging to cluster 4-1 collected in northern Guinea Bissau were reportedly cultivated before 1940. How much earlier they were cultivated is not clear, since precise data from before 1940 are largely absent. Some farmers considered them to have always been there. This gains some support from some of the names. In northern Guinea Bissau farmers referred to these varieties by names also used for *O. glaberrima,* such as "jangjango", "untufa", and "wansarang". "Jangjango" specifically refers to the upright panicle typical of *O. glaberrima*. The meaning of the variety name "untufa" is 'rice from here' because it is considered ancient, implying farmers think it is *O. glaberrima*, the rice originally domesticated in West Africa.

The origin of many varieties from cluster 4-2, such as "mani wulengo", "mani wulendingo", "mani konsonkuto", "ablie mano", collected in The Gambia, Senegal and Guinea Bissau can be traced back to northern Guinea Bissau. One variety in The Gambia, "binta sambou", was developed from an off-type found in a field of "ablie mano" around 1990. Except for the variety "binta sambou" farmers could not pinpoint place or time of origin. In one village, Pantufa, in northern Guinea Bissau farmers indicated that varieties such as "mani wulengo", "mani konsonkuto", "mani wulendingo" and "ablie mano" were cultivated before 1940.

The information available so far suggests the countries where the interspecific farmer varieties were first cultivated were Sierra Leone and Guinea Bissau. No precise dates of origin can be specified, but the aforementioned data suggest that some existed for more than half a century, and thus long before the first release of Nerica varieties.

2.4.3 Spread of interspecific farmer hybrids

Adversity such as war and drought appear to have favoured the selection and spread of spontaneous interspecific rice hybrids among West African farmers. War has forced some farmers into intensively farmed pockets of land without access to fertilizers. Farmer hybrids appear to share the adaptation to poor soils of the *O. glaberrima* parent. Parts of the war zone in Sierra Leone, cut off from aid assistance over several years, appeared to be mainly growing interspecific hybrid varieties (or pure *glaberrimas*) in the period immediately after fighting ceased [31]. Farmers noted that war reduced the amount of time available for clearing of forest, weeding and careful harvesting new fields, since civilians were reluctant to linger for fear of encountering fighters. In other cases (e.g. as a result of war in Guinea-Bissau and southern Senegal) they fled across borders, taking their hardy varieties with them. Farmer hybrids are particularly frequent in our samples from southern Senegal, Guinea-Bissau and Sierra Leone (Table 2.4) − all regions affected by recent episodes of armed conflict.

In Senegal and The Gambia the farmer hybrids have probably helped farmers to cope with climatic fluctuation. The farmer hybrids (belonging to sub-cluster 4-2) collected in these two countries tend to flower about one week earlier than the farmer hybrids (belonging to sub-cluster 4-1) collected in Sierra Leone (Table 2.3). Senegal and The Gambia have been badly affected by drought in recent times. In addition, both countries have faced increased demographic pressure, exacerbated by armed conflict in southern Senegal and Guinea Bissau. Farmer hybrids may embody considerable adaptive plasticity to suboptimal farming conditions associated with such difficulties.

An important reason why in Senegal and The Gambia farmers mainly grow farmer hybrids belonging to sub-cluster 4-2 is that in these two countries farmers do not like a red pericarp colour (the variety belonging to sub-cluster 4-1 and cultivated in Senegal does not have a red pericarp). In addition, some farmers mentioned they do not like an erect panicle when mature. In Sierra Leone and Guinea Conakry the farmer hybrids found belonged to sub-cluster 4-1. In these two countries farmers prefer a red pericarp colour because they claim it is related to slow digestion. Also they do not consider an erect panicle a negative trait. These two traits are the main traits that differentiate sub-clusters 4-1 and 4-2. Both can be considered polygenic traits which may explain why farmer selection practices have resulted in large genetic differences between the two sub-clusters, as is shown by the molecular data. Given the different ecological and climatic conditions in the region, the outcome of farmer selection for traits such as panicle length, tillering, plant height, yield, taste, swelling, and ease of threshing may possibly have contributed to the genetic differences between sub-clusters 4-1 and 4-2.

2.4.4 Why are interspecific farmer hybrids absent or rare in Ghana and Togo?

Farmer interspecific hybrids are less frequent or absent in our samples from Ghana and Togo (Togo Hills), an important region of co-occurrence of *O. glaberrima* and *O. sativa.* Conditions in the Togo Hills may be less favourable to in-field interspecific hybridization due to cultural and geographical factors. The cultural significance of African rice seems to limit the amount of farmer hybridization on the Ghana side of the Togo Hills. Rice cultivators in eastern Ghana grow *O. sativa* mainly as a commercial crop under relatively favourable conditions. These farmers maintain a strong interest in African rice, but for cultural reasons. African rice is prominent in traditional ceremonies and as an ethnic marker [32]. In such circumstances, a hybrid would be less suited because of its blurred morphology. Farmers in Togo (the Danyi plateau) grow African rice at higher altitudes, while *O. sativa* is planted at lower altitudes. This imposes a geographical barrier to interspecific hybridization.

2.5 CONCLUDING REMARKS

Our results strongly suggest that interspecific hybridization in West African farmers' fields is a recurrent and continuing process, with spontaneous back-crossing events playing a crucial role, resulting in different groups of genetic diversity in different rice growing areas stimulated by differences in selection criteria and selection environments. This clear evidence for the emergence of farmer hybrids of African and Asian rice in West Africa has important implications for understanding crop development and human adaptation. Whether and how such hybridisation and backcrossing events have occurred for other crops may be a useful question to pursue, to achieve a better understanding of crop development and diversity. For example, it may help to identify the most plausible scenario for the development of maize (*Zea mays* L.). Our findings also suggest that adversity, such as dislocation by armed conflict and climatic change, has not hindered, and may have accelerated the rate at which interspecific hybrid rice varieties have spread [31]. Farmer interspecific hybrids of rice may complement those recently developed by formal scientific research. This points to potential value in linking science and local technology development by marginalized groups, better to address challenges of rapid adaptation in a world of increased socio-political and climatic uncertainty.

ACKNOWLEDGEMENTS

The late Dr Malcolm Sellu Jusu of Rokupr Rice Research Station, Sierra Leone, is recognised for proposing research on farmer interspecific rices during the 1980s. The assistance of Dr. Marina Temudo in the fieldwork in Guinea Bissau is much appreciated. We thank two anonymous reviewers for critical comments that helped improve the manuscript.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: EN RvT PS AM FO BT PR. Performed the experiments: EN RvT AM FO BT. Analyzed the data: EN RvT. Contributed reagents/materials/analysis tools: EN RvT AM FO BT. Wrote the paper: EN RvT PS AM FO BT PR.

REFERENCES

1. Harlan JR (1971) Agricultural origins: centers and noncenters. Science 174, 468−474.
2. Portères R (1962) Berceaux agricoles primaires sur le continent africain. Journal of African History 3(2): 195-210.
3. Chu Y-E, Oka HI (1969) Introgression across isolating barriers in wild and cultivated Oryza species. Evolution 24: 344-355.
4. Spillane C, Gepts P (2001) Evolutionary and genetic perspectives on the dynamics of crop genepools. In Broadening the genetic base of crop, 25-70 (Eds D. Cooper, C. Spillane and T. Hodgkin). Oxon: Cabi Publishing.
5. Jones MP, Dingkuhn M, Aluko GK, Semon M (1997) Interspecific Oryza sativa L.× O. glaberrima Steud. progenies in upland rice improvement. Euphytica 94: 237-246.
6. Jones M (2004) NERICA fighting Africa's war against poverty and hunger. Paper presented at the International Year of Rice & World Food Prize Celebration October 14–15 2004, Des Moines, Iowa, USA.
7. Chang T-T (1976) The origin, evolution, cultivation, dissemination, and diversification of Asian and African rices. Euphytica 25: 425-441.
8. Second G (1982) Origin of the genic diversity of cultivated rice (Oryza spp.): Study of the polymorphism scored at 40 isozyme loci. Japanese Journal of Genetics 57: 25-57.
9. Sano Y (1989) The direction of pollen flow between two co-occurring rice species, *Oryza sativa* and *O. glaberrima*. Heredity 63: 353-357.
10. Bouharmont J, Olivier M, Dumont de Chassart M (1985) Cytological observations in some hybrids between the rice species *Oryza sativa* L. and *O. glaberrima* Steud. Euphytica 34: 75-81.
11. Pham JL, Bougerol B (1993) Abnormal segregations in crosses between two cultivated rice species. Heredity 70: 466-471.
12. Pham JL, Bougerol B (1996) Variation in fertility and morphological traits in progenies of crosses between the two cultivated rice species. Hereditas 124: 179-183.
13. Yabuno T (1977) Genetic studies on the interspecific cytoplasm substition lines of japonica varieties of *Oryza sativa* L. and *O. glaberrima* Stued. Euphytica 26: 451-463.
14. Sano Y, Chu YE, Oka HI (1980) Genetic studies of speciation in cultivated rice. 2. Character variations in backcross derivatives between *Oryza sativa* and *O. glaberrima*: M-V linkage and key characters. Japanese Journal of Genetics 55: 19-39.
15. Jusu MS (1999) Management of genetic variability in rice (*Oryza sativa* L. and *O. glaberrima* Steud.) by breeders and farmers in Sierra Leone. PhD-thesis Wageningen University, The Netherlands, 198 p.
16. Nuijten E, Van Treuren R (2007) Spatial and temporal dynamics in genetic diversity in upland rice and late millet in The Gambia. Genetic Resources and Crop Evolution 54, 989−1009.
17. Barry MB, Pham JL, Noyer JL, Billot C, Courtois B et al. (2007) Genetic diversity of the two cultivated rice species (*O. sativa* & *O. glaberrima*) in Maritime Guinea. Evidence for interspecific recombination. Euphytica 154, 127–137.
18. Semon M, Nielsen R, Jones MP, McCouch SR (2005) The population structure of African cultivated rice *Oryza glaberrima* (Steud.): evidence for elevated levels of linkage disequilibrium caused by admixture with *O. sativa* and ecological adaptation. Genetics 169, 1639–1647.

19. Richards P, De Bruin-Hoekzema M, Hughes SG, Kudadjie-Freeman C, Offei SM, et al. (2009) Seed systems for African food security: linking molecular genetic analysis and cultivator knowledge in West Africa. International Journal of Technology Management 45, 196-214.
20. Sweeney MT, Thomson MJ, Cho YG, Park YJ, Williamson SH, et al. (2007) Global dissemination of a single mutation conferring white pericarp in rice. PLoS Genet 3(8): e133. doi:10.1371/journal.pgen.0030133
21. Huson DH, Bryant D (2006) Application of phylogenetic networks in evolutionary studies. Molecular Biology and Evolution 23(2), 254−267.
22. Pritchard JK, Stephens M, Donnelly P (2000) Inference of population structure using multilocus genotype data. Genetics 155, 945-959.
23. Falush D, Stephens M, Pritchard JK (2007) Inference of population structure using multilocus genotype data: dominant markers and null alleles. Molecular Ecology 7(4): 574–578.
24. Nei M (1987) Molecular Evolutionary Genetics. Columbia University Press, New York.
25. Nuijten E (2005) Farmer management of gene flow: The impact of gender and breeding system on genetic diversity and crop improvement in The Gambia. PhD-thesis, Wageningen University, The Netherlands, 271 p.
26. Ishii T, Terachi T, Tsunewaki K (1988) Restriction endonuclease analysis of chloroplast DNA from A-genome diploid species of rice. Japanese Journal of Genetics 63: 523-536.
27. Dally AM, Second G (1990) Chloroplast DNA diversity in wild and cultivated species of rice (Genus *Oryza*, section Oryza). Cladistic-mutation and genetic distance analysis. Theoretical and Applied Genetics 80: 209-222.
28. Longley C, Richards P (1993) Selection strategies of rice farmers in Sierra Leone. In: Cultivating knowledge: genetic diversity, farmer experimentation and crop research. De Boef, W., Amanor, K. & Wellard K. (ed). London, Intermediate Technology Publications, pp. 51−57.
29. Richards P (1986) Coping with hunger: hazard and experiment in an African rice-farming system. London: Allen & Unwin. 192 p.
30. Richards P (1997) Towards an African Green Revolution? An anthropology of rice research in Sierra Leone, In E. Nyerges, ed., The ecology of practice: studies of food crop production in sub-Saharan West Africa. Newark: Gordon & Breach. pp. 201-252.
31. Richards P (2006) The history and future of African rice: food security and survival in a West African war zone. Afrika Spectrum 41(1), 77−93.
32. Brydon L (1981) Rice, yams and chiefs in Avatime: speculations on the development of a social order. Africa 51(2), 659−677.

Table S 2.1

Variety name	Origin	Taxonomy	P (Gla)	P (Ind)	P (Jap)	P (Cl4)
A. Farmer varieties						
Kaomo black	Ghana	*O. glaberrima*	1.00	0.00	0.00	0.00
Kaomo black (with awns)	Ghana	*O. glaberrima*	1.00	0.00	0.00	0.00
Kaomo krukutuwa	Ghana	*O. glaberrima*	1.00	0.00	0.00	0.00
Kaomo krukutuwa signaweh	Ghana	*O. glaberrima*	1.00	0.00	0.00	0.00
Kaomo signaweh	Ghana	*O. glaberrima*	1.00	0.00	0.00	0.00
Kaomo signaweh black	Ghana	*O. glaberrima*	1.00	0.00	0.00	0.00
Kaomo white	Ghana	*O. glaberrima*	1.00	0.00	0.00	0.00
Jangjango	Guinea Bissau	*O. glaberrima*	1.00	0.00	0.00	0.00
Jangjango	Guinea Bissau	*O. glaberrima*	1.00	0.00	0.00	0.00
Kurekimbeli	Guinea Bissau	*O. glaberrima*	1.00	0.00	0.00	0.00
Uassolondji	Guinea Bissau	*O. glaberrima*	1.00	0.00	0.00	0.00
Dixi Wansan Lot 1	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Saali Fire	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Saali Fore	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Saali Fore	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Saali Fore	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Saali Fore	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Saali Fore	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Siiga?	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Tombo Bokary	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Tombo Bokary	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Tombo Bokary	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Tombo Bokary	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Tombo Bokary	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Tombo Bokary	Guinea Conakry	*O. glaberrima*	1.00	0.00	0.00	0.00
Mani Musoo	Senegal	*O. glaberrima*	1.00	0.00	0.00	0.00
Mani Musoo	Senegal	*O. glaberrima*	1.00	0.00	0.00	0.00
Damba	Sierra Leone	*O. glaberrima*	1.00	0.00	0.00	0.00

Saliforeh	Sierra Leone	*O. glaberrima*	1.00	0.00	0.00	0.00
Mani Ba	The Gambia	*O. glaberrima*	1.00	0.00	0.00	0.00
Mani Ba	The Gambia	*O. glaberrima*	1.00	0.00	0.00	0.00
Mani Ba	The Gambia	*O. glaberrima*	1.00	0.00	0.00	0.00
Mani Ba	The Gambia	*O. glaberrima*	1.00	0.00	0.00	0.00
Awinto blanc	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Awinto yibo	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Danyi moli	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Danyi moli	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Kpakpalipke	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Xleti etoh (three months)	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Xleti eve	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Yibo riz	Togo	*O. glaberrima*	1.00	0.00	0.00	0.00
Kaomo signaweh white	Ghana	*O. glaberrima*	0.99	0.00	0.00	0.00
Saali Koute	Guinea Conakry	*O. glaberrima*	0.99	0.01	0.00	0.00
Tombo Bokary	Guinea Conakry	*O. glaberrima*	0.99	0.00	0.00	0.00
Mani Musoo	Senegal	*O. glaberrima*	0.99	0.01	0.00	0.00
Sanganyaa	Sierra Leone	*O. glaberrima*	0.99	0.00	0.00	0.01
Dixi Wansan Lot 2	Guinea Conakry	*O. glaberrima*	0.98	0.00	0.01	0.00
Safaary	Guinea Conakry	*O. glaberrima*	0.98	0.00	0.00	0.01
Siiga	Guinea Conakry	*O. glaberrima*	0.98	0.01	0.01	0.01
Tombo Bokary	Guinea Conakry	*O. glaberrima*	0.98	0.00	0.00	0.02
Gbankeyi	Guinea Conakry	*O. glaberrima*	0.97	0.01	0.00	0.02
Safaary	Guinea Conakry	*O. glaberrima*	0.96	0.01	0.02	0.01
Awinto blanc	Togo	*O. glaberrima*	0.93	0.03	0.00	0.03
Maalay	Sierra Leone	*O. glaberrima*	0.92	0.03	0.03	0.02
Saali Fore	Guinea Conakry	*O. glaberrima*	0.91	0.06	0.02	0.01
Saali Fore	Guinea Conakry	*O. glaberrima*	0.91	0.00	0.02	0.07
Mani Musoo	Senegal	*O. glaberrima*	0.82	0.14	0.00	0.04
Wansarang	Guinea Bissau	*O. glaberrima*	0.81	0.02	0.14	0.02
Siiga	Guinea Conakry	*O. glaberrima*	0.01	0.98	0.00	0.01
Dalifode	Guinea Conakry	*O. glaberrima*	0.10	0.67	0.01	0.22
Trimont (white)	Sierra Leone	*O. glaberrima*	0.00	0.00	0.00	1.00
Pa Trimont	Sierra Leone	*O. glaberrima*	0.00	0.00	0.00	0.99
Painy-pain	Sierra Leone	*O. glaberrima*	0.00	0.00	0.00	0.99
Pindie	Sierra Leone	*O. glaberrima*	0.00	0.00	0.00	0.99
Pa Trimont (red)	Sierra Leone	*O. glaberrima*	0.01	0.01	0.00	0.98
Saliforeh	Sierra Leone	*O. glaberrima*	0.00	0.01	0.03	0.96
Samba	Guinea Conakry	*O. sativa*	0.97	0.01	0.02	0.01
Adeisi	Ghana	*O. sativa*	0.00	1.00	0.00	0.00
Akpasseh	Ghana	*O. sativa*	0.00	1.00	0.00	0.00
Red saka	Ghana	*O. sativa*	0.00	1.00	0.00	0.00
Zomojo	Ghana	*O. sativa*	0.00	1.00	0.00	0.00
Bissau	Guinea Bissau	*O. sativa*	0.00	1.00	0.00	0.00
Sajar	Guinea Bissau	*O. sativa*	0.00	1.00	0.00	0.00
Kaniya	Guinea Conakry	*O. sativa*	0.00	1.00	0.00	0.00
Momodou male	Guinea Conakry	*O. sativa*	0.00	1.00	0.00	0.00
Saidou fire (red grain)	Guinea Conakry	*O. sativa*	0.00	1.00	0.00	0.00
Soumaila	Guinea Conakry	*O. sativa*	0.00	1.00	0.00	0.00
Ablie Koyo	Senegal	*O. sativa*	0.00	1.00	0.00	0.00
Fadass	Senegal	*O. sativa*	0.00	1.00	0.00	0.00
Kuboni	Senegal	*O. sativa*	0.00	1.00	0.00	0.00
Madina Koyo	Senegal	*O. sativa*	0.00	1.00	0.00	0.00
Buttercup	Sierra Leone	*O. sativa*	0.00	1.00	0.00	0.00
Yainky-Yanka	Sierra Leone	*O. sativa*	0.00	1.00	0.00	0.00
Akacha	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Barafita koyo	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Baraso	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Bendou	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Chinese short	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Derisa Mano	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Foni Mano	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Off-type (in Binta Sambou)	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Peking	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Peking	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Tensi	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Tombom	The Gambia	*O. sativa*	0.00	1.00	0.00	0.00
Adeta red rice	Ghana	*O. sativa*	0.00	0.99	0.00	0.01
Awonyo (two months)	Ghana	*O. sativa*	0.00	0.99	0.01	0.01
Bouake	Ghana	*O. sativa*	0.00	0.99	0.00	0.01
James rice	Ghana	*O. sativa*	0.00	0.99	0.00	0.01
Red saka	Ghana	*O. sativa*	0.00	0.99	0.00	0.00
Red saka (off-type?)	Ghana	*O. sativa*	0.00	0.99	0.00	0.01
Red variety	Ghana	*O. sativa*	0.00	0.99	0.00	0.00
Aninha de lugar	Guinea Bissau	*O. sativa*	0.00	0.99	0.00	0.01

Wankarang	Guinea Bissau	*O. sativa*	0.00	0.99	0.00	0.00
Saidou Fire	Guinea Conakry	*O. sativa*	0.00	0.99	0.00	0.00
Saidou Fire	Guinea Conakry	*O. sativa*	0.00	0.99	0.00	0.01
Saidou Gbeeli	Guinea Conakry	*O. sativa*	0.00	0.99	0.00	0.00
Saidou Gbeeli	Guinea Conakry	*O. sativa*	0.00	0.99	0.00	0.00
Jina Mano	Senegal	*O. sativa*	0.00	0.99	0.00	0.00
Kuboni Juuno	Senegal	*O. sativa*	0.00	0.99	0.00	0.00
Rok31	Sierra Leone	*O. sativa*	0.00	0.99	0.00	0.00
Bonti	The Gambia	*O. sativa*	0.00	0.99	0.00	0.01
Kadi Dabo	The Gambia	*O. sativa*	0.00	0.99	0.00	0.00
Mani Suntungo-1	The Gambia	*O. sativa*	0.00	0.99	0.00	0.01
Mani Suntungo-2	The Gambia	*O. sativa*	0.00	0.99	0.00	0.00
Muso Noringo	The Gambia	*O. sativa*	0.00	0.99	0.00	0.01
Peking	The Gambia	*O. sativa*	0.00	0.99	0.00	0.01
Sainey Kolly	The Gambia	*O. sativa*	0.00	0.99	0.01	0.01
Teiba	The Gambia	*O. sativa*	0.00	0.99	0.00	0.01
Awuie red	Togo	*O. sativa*	0.00	0.99	0.00	0.00
Awuie white	Togo	*O. sativa*	0.00	0.99	0.00	0.01
White saka	Ghana	*O. sativa*	0.00	0.98	0.00	0.02
Sambaconcon	Guinea Bissau	*O. sativa*	0.02	0.98	0.00	0.00
CK 21	Guinea Conakry	*O. sativa*	0.01	0.98	0.01	0.01
Pode 1	Guinea Conakry	*O. sativa*	0.00	0.98	0.01	0.01
Sorie Kunde	Sierra Leone	*O. sativa*	0.00	0.98	0.01	0.01
Chinese red	The Gambia	*O. sativa*	0.00	0.98	0.00	0.02
Saidou fire (white grain)	Guinea Conakry	*O. sativa*	0.01	0.97	0.01	0.01
Saidou Gbeeli	Guinea Conakry	*O. sativa*	0.01	0.97	0.02	0.00
Yaka (Rok3)	Sierra Leone	*O. sativa*	0.01	0.97	0.01	0.02
Viotto (off-type?)	Ghana	*O. sativa*	0.00	0.95	0.04	0.01
Zomojo	Ghana	*O. sativa*	0.01	0.95	0.04	0.01
Zomojo (off-type?)	Ghana	*O. sativa*	0.00	0.95	0.00	0.04
Baraso	The Gambia	*O. sativa*	0.00	0.95	0.00	0.04
Sarjo Keeba Mano	The Gambia	*O. sativa*	0.01	0.94	0.04	0.01
Yaka	Sierra Leone	*O. sativa*	0.00	0.93	0.01	0.07
Pa Bad-scent	Sierra Leone	*O. sativa*	0.06	0.92	0.01	0.01
Viono short	Ghana	*O. sativa*	0.00	0.91	0.08	0.00
Wonyonwonyon yi	Guinea Conakry	*O. sativa*	0.02	0.89	0.04	0.05
Terfatch	The Gambia	*O. sativa*	0.01	0.82	0.01	0.16
Damansah 1	Ghana	*O. sativa*	0.00	0.81	0.00	0.18
Mani Koyo	Senegal	*O. sativa*	0.00	0.74	0.01	0.25
Damansah 4	Ghana	*O. sativa*	0.00	0.62	0.06	0.31
Off-type (in Hombo Wulengo)	The Gambia	*O. sativa*	0.00	0.61	0.00	0.38
Bondiyaa Karejang	Senegal	*O. sativa*	0.00	0.54	0.00	0.46
Off-type (in Tabuyaa Mani Koyo)	Guinea Bissau	*O. sativa*	0.00	0.53	0.01	0.46
Aqua blue	Ghana	*O. sativa*	0.00	0.48	0.44	0.07
Aqua blue	Ghana	*O. sativa*	0.00	0.00	1.00	0.00
Aqua blue with awns	Ghana	*O. sativa*	0.00	0.00	1.00	0.00
Gokpui	Ghana	*O. sativa*	0.00	0.00	1.00	0.00
Mateggi	Ghana	*O. sativa*	0.00	0.00	1.00	0.00
Buba Njie	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Bumali	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Conakry	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Demba Ba	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Jahuun (sutungo)	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Kissidugô	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Nahawa	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Off-type (in Sefa Fingo)	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Sefa Fingo	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Senkiliba	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Toba	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Umobel	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Usefa Udjenel	Guinea Bissau	*O. sativa*	0.00	0.00	1.00	0.00
Conakry	Guinea Conakry	*O. sativa*	0.00	0.00	1.00	0.00
Bobordeen	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Boikortor	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Gbengben	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Gbengben	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Jobboi	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Jumukui	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Kondaylah	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Kortigbongoi	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Nduluwai	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Pamanneh	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Pla Gbon	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Sembehun nyaha	Sierra Leone	*O. sativa*	0.00	0.00	1.00	0.00
Hombo Wulengo	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00

Kukone	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Kukur	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Mani Tima	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Nerica koyo	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
off-type (in Hombo Wulengo)	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Off-type (in Sefa Koyo)	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Off-type (Samano?)	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Sefa Fingo	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Sefa Fingo (red)	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Sefa Koyo	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Sonna Mano	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Wesiwes	The Gambia	*O. sativa*	0.00	0.00	1.00	0.00
Aquablue	Togo	*O. sativa*	0.00	0.00	1.00	0.00
Ujogade	Guinea Bissau	*O. sativa*	0.01	0.00	0.99	0.00
Uyeey	Guinea Bissau	*O. sativa*	0.00	0.00	0.99	0.00
Bonyaha	Sierra Leone	*O. sativa*	0.01	0.00	0.99	0.00
Coffeegay..	Sierra Leone	*O. sativa*	0.00	0.00	0.99	0.00
Konowanjei	Sierra Leone	*O. sativa*	0.00	0.00	0.99	0.01
Nerica wulengo	The Gambia	*O. sativa*	0.00	0.00	0.99	0.00
Sefa Nunfingo	The Gambia	*O. sativa*	0.00	0.00	0.99	0.00
Sefa Nunfingo (white)	The Gambia	*O. sativa*	0.00	0.01	0.99	0.00
Wab 56-50	The Gambia	*O. sativa*	0.00	0.00	0.99	0.00
Aqua blue	Ghana	*O. sativa*	0.00	0.00	0.98	0.01
Off-type (in Kadidjango)	Guinea Bissau	*O. sativa*	0.00	0.01	0.98	0.01
Otcha	Guinea Bissau	*O. sativa*	0.00	0.01	0.98	0.00
Mabargie	Sierra Leone	*O. sativa*	0.00	0.01	0.98	0.01
Yonnie	Sierra Leone	*O. sativa*	0.01	0.00	0.98	0.01
Berengdinto Koyo	Guinea Bissau	*O. sativa*	0.00	0.01	0.97	0.01
Nerigay	Sierra Leone	*O. sativa*	0.00	0.02	0.97	0.01
Yabasie	Sierra Leone	*O. sativa*	0.01	0.02	0.97	0.00
Gbengben	Sierra Leone	*O. sativa*	0.00	0.00	0.96	0.04
Gbengben	Sierra Leone	*O. sativa*	0.03	0.00	0.96	0.01
Musugomie	Sierra Leone	*O. sativa*	0.02	0.01	0.96	0.01
Jetteh	Sierra Leone	*O. sativa*	0.00	0.04	0.95	0.00
Off-type (lost variety)	The Gambia	*O. sativa*	0.00	0.02	0.95	0.02
Jewule	Sierra Leone	*O. sativa*	0.04	0.01	0.94	0.02
Konko	Guinea Conakry	*O. sativa*	0.00	0.07	0.93	0.00
Ngiligortie	Sierra Leone	*O. sativa*	0.05	0.02	0.93	0.00
Red saka	Ghana	*O. sativa*	0.02	0.00	0.91	0.06
Off-type (lost variety)	The Gambia	*O. sativa*	0.00	0.01	0.90	0.09
Wapu	Guinea Bissau	*O. sativa*	0.00	0.04	0.89	0.07
Off-type (in Uyeeye)	Guinea Bissau	*O. sativa*	0.00	0.06	0.87	0.07
Kolosarr, original	Guinea Bissau	*O. sativa*	0.00	0.00	0.00	1.00
Daakulo Koyo	Senegal	*O. sativa*	0.00	0.00	0.00	1.00
Kumoi	The Gambia	*O. sativa*	0.00	0.00	0.00	1.00
M Mesengo	The Gambia	*O. sativa*	0.00	0.00	0.00	1.00
Mani Wulengo	The Gambia	*O. sativa*	0.00	0.00	0.00	1.00
Kolosarr, Bondiya	Guinea Bissau	*O. sativa*	0.00	0.01	0.00	0.99
Konsonkuto	Guinea Bissau	*O. sativa*	0.00	0.00	0.00	0.99
Maimuna	Guinea Bissau	*O. sativa*	0.00	0.00	0.00	0.99
Kissi Foundeyi	Guinea Conakry	*O. sativa*	0.00	0.00	0.00	0.99
Wonyonwonyon yi	Guinea Conakry	*O. sativa*	0.00	0.01	0.01	0.99
Ablie Mano	Senegal	*O. sativa*	0.00	0.00	0.00	0.99
Einu	Senegal	*O. sativa*	0.00	0.01	0.00	0.99
Madina Wulengo	Senegal	*O. sativa*	0.00	0.01	0.00	0.99
Kari Saba	The Gambia	*O. sativa*	0.00	0.01	0.00	0.99
Mani Mesendingo	The Gambia	*O. sativa*	0.00	0.01	0.00	0.99
Off-type (in Mani Wulendingo)	The Gambia	*O. sativa*	0.00	0.01	0.00	0.99
Kolosarr, M Wulendingo	Guinea Bissau	*O. sativa*	0.00	0.02	0.00	0.98
Mesemese	Guinea Bissau	*O. sativa*	0.00	0.02	0.00	0.98
Off-type (in Madina Wulengo)	Senegal	*O. sativa*	0.00	0.02	0.01	0.98
Binta Sambou	The Gambia	*O. sativa*	0.00	0.02	0.00	0.98
Mani Wulendingo	The Gambia	*O. sativa*	0.00	0.02	0.00	0.98
Off-type (in Madina Wulengo)	Senegal	*O. sativa*	0.00	0.01	0.03	0.95
Kong	Senegal	*O. sativa*	0.00	0.05	0.02	0.93
Moti	The Gambia	*O. sativa*	0.00	0.03	0.08	0.89
Off-type (in Madina Wulengo)	Senegal	*O. sativa*	0.00	0.02	0.11	0.88
Daakulo	Senegal	*O. sativa*	0.00	0.41	0.00	0.59
Trimonte	Guinea Conakry	Hybrid	0.00	1.00	0.00	0.00
Off-type (in Daakulo)	Senegal	Hybrid	0.00	0.99	0.00	0.00
Ataa	Ghana	Hybrid	0.00	0.71	0.00	0.28
Off-type (in WAB 56-50)	The Gambia	Hybrid	0.20	0.64	0.15	0.01
Aquablue awinto	Togo	Hybrid	0.00	0.00	1.00	0.00
Khaki	Togo	Hybrid	0.00	0.00	1.00	0.00
Aqua blue signaweh	Ghana	Hybrid	0.00	0.00	0.99	0.00

Pa Three Month2	Sierra Leone	Hybrid	0.00	0.01	0.99	0.01
Nerica 2 (off-type)	Ghana	Hybrid	0.00	0.01	0.94	0.04
Nerica 2	Ghana	Hybrid	0.12	0.00	0.87	0.00
Sewa	Guinea Conakry	Hybrid	0.00	0.13	0.86	0.00
Off-type (in WAB 56-50)	The Gambia	Hybrid	0.20	0.00	0.80	0.00
Dissi	Guinea Bissau	Hybrid	0.00	0.00	0.00	0.99
Jangjango	Guinea Bissau	Hybrid	0.00	0.00	0.00	0.99
Untufa	Guinea Bissau	Hybrid	0.00	0.00	0.01	0.99
Wansarang	Guinea Bissau	Hybrid	0.00	0.00	0.00	0.99
Tebeleh	Sierra Leone	Hybrid	0.01	0.00	0.01	0.98
Pa Three Month1	Sierra Leone	Hybrid	0.00	0.05	0.01	0.95
Pa Three Month3	Sierra Leone	Hybrid	0.00	0.01	0.10	0.88
Kaomo with awns	Ghana	unclear	1.00	0.00	0.00	0.00
Kolonkalan 1b	Sierra Leone	unclear	1.00	0.00	0.00	0.00
Off-type 1A	Sierra Leone	unclear	1.00	0.00	0.00	0.00
Pindie	Sierra Leone	unclear	1.00	0.00	0.00	0.00
Egomu	Ghana	unclear	0.97	0.01	0.01	0.01
Off-type 1B	Sierra Leone	unclear	0.96	0.02	0.00	0.02
Pugulu undef.	Ghana	unclear	0.00	0.99	0.00	0.01
Pugulu white	Ghana	unclear	0.00	0.99	0.00	0.00
Viono tall	Ghana	unclear	0.00	0.99	0.01	0.00
Pa Follah	Sierra Leone	unclear	0.00	0.99	0.00	0.00
Tema	Togo	unclear	0.00	0.97	0.00	0.03
Pugulu red	Ghana	unclear	0.00	0.95	0.02	0.03
Pla-Camp	Sierra Leone	unclear	0.01	0.87	0.02	0.11
Damansah 3	Ghana	unclear	0.01	0.60	0.03	0.35
Pugulu undef.	Ghana	unclear	0.00	0.00	1.00	0.00
Gbondobai	Sierra Leone	unclear	0.00	0.00	1.00	0.00
Pugulu undef.	Ghana	unclear	0.00	0.00	0.99	0.00
Jebbeh-komie	Sierra Leone	unclear	0.01	0.00	0.98	0.00
Bogootie	Sierra Leone	unclear	0.00	0.02	0.96	0.02
Pindi-pabai 1a red	Sierra Leone	unclear	0.00	0.00	0.00	1.00
Pa DC	Sierra Leone	unclear	0.00	0.00	0.00	0.99
Pa Yariken	Sierra Leone	unclear	0.00	0.00	0.00	0.99
Pa DC	Sierra Leone	unclear	0.01	0.01	0.00	0.98
Trimont (white)	Sierra Leone	unclear	0.01	0.00	0.05	0.95
B. Modern varieties						
I Kong Pao	CIRAD	*O. sativa*	0.00	1.00	0.00	0.00
CCA	NARI	*O. sativa*	0.00	1.00	0.00	0.00
Parasana	NARI	*O. sativa*	0.00	1.00	0.00	0.00
Se 302 G (IRAT 11)	CIRAD	*O. sativa*	0.00	0.99	0.00	0.01
Se 319 G (IRAT 12)	CIRAD	*O. sativa*	0.00	0.99	0.00	0.01
IR66-23	IRRI	*O. sativa*	0.00	0.99	0.00	0.00
DJ 12-519	ISRA	*O. sativa*	0.00	0.99	0.00	0.00
DJ 8-341	ISRA	*O. sativa*	0.00	0.99	0.01	0.00
Off-type (in DJ-11-307)	NARI	*O. sativa*	0.00	0.99	0.00	0.00
RC18-3	IRRI	*O. sativa*	0.00	0.98	0.01	0.01
DJ-11-307	NARI	*O. sativa*	0.00	0.97	0.00	0.03
RC10-43	IRRI	*O. sativa*	0.00	0.94	0.01	0.05
IR36-63	IRRI	*O. sativa*	0.00	0.76	0.01	0.23
IRAT 10	CIRAD	*O. sativa*	0.00	0.00	1.00	0.00
IRAT 110	WARDA	*O. sativa*	0.00	0.00	1.00	0.00
IRAT 112	WARDA	*O. sativa*	0.00	0.00	1.00	0.00
OS 6 (Faro 11)	WARDA	*O. sativa*	0.00	0.00	1.00	0.00
WAB 365-B-2-H3-HB	WARDA	*O. sativa*	0.00	0.00	0.99	0.00
WAB 450-I-B-P-163-4-1	WARDA	Hybrid	0.00	0.00	1.00	0.00
WAB 450-I-B-P-105-HB	WARDA	Hybrid	0.06	0.00	0.93	0.00
Nerica 1	MOFA	Hybrid	0.08	0.02	0.77	0.14
C. Wild and semi-wild material						
O. barthii black	The Gambia	*O. barthii*	1.00	0.00	0.00	0.00
O. barthii white	The Gambia	*O. barthii*	1.00	0.00	0.00	0.00
Devil rice	Guinea Conakry	*O. barthii*	0.97	0.01	0.01	0.01
Ngafa bei	Sierra Leone	*O. barthii*	0.84	0.10	0.01	0.06
Ngewobei	Sierra Leone	*O. barthii*	0.75	0.19	0.02	0.04

ROBUSTNESS AND STRATEGIES OF ADAPTATION WITHIN A LARGE SET OF FARMER VARIETIES OF AFRICAN RICE (*ORYZA GLABERRIMA* STEUD.) AND ASIAN RICE (*ORYZA SATIVA* L.) ACROSS WEST AFRICA

Mokuwa*, A., E. Nuijten*, F. Okry*, B. Teeken*, H. Maat, P. Richards and P.C. Struik

* These authors have contributed equally to this paper

Submitted to PLoS ONE

Abstract

This study aims to increase insight for complementary strategies of rice (*Oryza glaberrima* and *O. sativa*) variety promotion – which farmer varieties should be recognised and further disseminated as a way of protecting West African food security, in a general environment in which development agencies seek to expand the range of high-yielding cultivars to meet urban rice demand. The study shows that farmer varieties are tolerant to sub-optimal conditions. Our experiments in five West African countries showed that farmer varieties were robust but expressed different strategies to cope with stress making them suitable to farmers' conditions. *Oryza glaberrima*, considered a product of farmers' agency, was the most robust. The results showed that farmer varieties can adapt to different environments in contrast to the rather common belief that they adapt only to local conditions. Hence, farmer varieties may be material suitable for breeding programmes and should be incorporated (together with improved varieties) in dissemination projects to protect farmers' food security under sub-optimal conditions.

Keywords: *Oryza glaberrima*, *Oryza sativa*, robustness, adaptation, farmer varieties, West Africa

3.1 INTRODUCTION

It is often supposed that crops should only be grown where conditions are favourable. This is not an option for low-resource farmers cultivating crops for local food security. They have to grow what they need with the conditions they have been given. In short, they have to cope with sub-optimality. For these farmers, adaptability of varieties under sub-optimal conditions is an essential requirement [1,2]. Hypothetically, we should expect to find this adaptability among farmer varieties since these are to a large extent the product of farmer selection. This would mean that farmer varieties are the result of interplay between local ecological and social factors.

In large parts of West Africa small scale farmers rely upon the cultivation of upland rice under low input conditions in a great diversity of micro-environments. The first rice farming in West Africa was based exclusively on African rice (*O. glaberrima* Steud.). The cultivation of African rice is entirely a result of farmer agency as African rice has never been disseminated by extension programmes. Asian rice (*Oryza sativa*) is a more recent introduction, perhaps during the period of the Atlantic Slave trade (beginning c. 1550), or earlier via trans-Saharan trade routes. Today, farmers in the region mainly grow Asian rice. Nevertheless in certain areas African rice remains an important crop type [2-6]. These areas all seem to show a recent or longer-term history of rice cultivation taking place against a background of special difficulty, such as war, population displacement or harsh ecological conditions [7]. This suggests the species may be selected for its greater tolerance to sub-optimal conditions when compared to Asian rice. The logic of the present study, therefore, is to compare African and Asian rice, in farmer conditions, in order to understand the extent to which plasticity and adaptability are factors in farmer varietal choice. The overall aim of the study is to secure a better knowledge base for possible complementary strategies of variety promotion. These complementary strategies would give due consideration both to varieties developed through scientific research and varieties produced by farmer selection. The objective is to assess the case for protecting farmer varieties as an important aspect of local food security, in an environment in which development agencies seek more generally to expand the range of high-yielding cultivars to meet urban rice demand across the region. Our study reports on differences in response of a large sample of farmer varieties across five West African countries with varying environments in the high-rainfall coastal zone.

The study tests the hypothesis that African rice may be more robust than Asian rice in West African farmer conditions. Here robustness is seen as the ability of a variety or group of varieties to perform well in a diversity of cultivation conditions.

The following research questions are posed:

1. Are farmer varieties of *O. glaberrima* better suited to sub-optimal agro-ecological conditions than varieties of *O. sativa*?
2. Do farmer varieties of *O. glaberrima* adapt better to different environmental conditions than varieties of *O. sativa*?
3. What are the physiological processes and social and eco-regional patterns underlying the adaptation of farmer varieties across environments?

In achieving robustness, varieties can respond to environmental conditions by showing phenotypic plasticity in a range of traits [8,9]. Different varieties or groups of varieties achieve robustness by combining variability and stability of different traits, thus constituting different physiological strategies. Hence, this study investigates whether different botanical groups of rice, or certain groups of varieties within those botanical groups, have developed different physiological strategies to achieve adaptation.

The hypothesis that African rice might be robust than Asian rice in West African conditions would make sense of a number of observations already reported. Richards [7] has offered some general evidence that African rice is an important food reserve suggested for communities experiencing especial difficulty (e.g. when displaced by war). Dingkuhn et al. [10] and Johnson et al. [11]

showed evidence that *O. glaberrima* has a vegetative vigour superior to that of *O. sativa*, thus is better able to suppress weeds. Sumi and Katayama [12] provided evidence that African rice has a yield potential similar to Asian counterparts.

Definition of concepts and notions

Robustness: the persistence of a system's characteristic behaviour under sub-optimal conditions, implying stable performance across environments. In the context of this paper, robustness is taken to be the ability of a variety or a group of varieties to yield well across environments.

Adaptability: the ability of a variety or a group of varieties to be robust. Adaptability implies significant Genotype (G) × Environment (E) interactions.

Plasticity: the physiological process through which varieties adjust their phenotypes in response to different environmental conditions [13]. A plastic response of this nature does not require changes in gene frequencies (i.e. evolution). Such phenotypic shifts can allow varieties to achieve adaptability [9].

Sub-optimal farming (in subsistence and semi-subsistence agriculture): characterised by no or limited mineral fertilisation, no or natural pest and disease control, rain fed moisture conditions, rarely mono cropping, and below an optimal or standard level of output.

Tolerance: the ability of a variety to survive adverse conditions with only a small reduction in performance.

3.2 MATERIALS AND METHODS

3.2.1 Ethics statement

We confirm that no specific permits were required for the locations where the described field trials were conducted, that these locations were not protected in any way, and that none of these field studies involved endangered or protected species. We thank local authorities, NGOs, research institutions and farmers for their support.

3.2.2 Variety collection and selection

From June to December 2007 we carried out field work in seven countries of Coastal West Africa, i.e. The Gambia, Ghana, Guinea, Guinea Bissau, Senegal, Sierra Leone and Togo (Figure 1.1). The field work aimed at (1) listing rice varieties/accessions used by farmers, (2) observing the development/physiology of these varieties in farmers' fields, and (3) collecting varieties at harvest. A total of 231 accessions were collected in 2007. After seed collection we carried out molecular analysis (AFLP) on the collected varieties in February and March 2008. Output of this molecular analysis was combined with the output of an analysis of 84 accessions performed in 2002 [14]. Based on the output of the molecular analysis, 24 commonly cultivated farmer varieties (*O. glaberrima* and *O. sativa*, including representatives of both the indica and japonica groups) were selected for further study (Table 3.1).

Results of AFLP analysis suggested several clusters within the various botanical groups. These clusters were more or less coinciding with the regions where the varieties were collected. The *glaberrima* divided into a cluster from the Upper Guinea Coastal region (Glab_UpperCoast) and a cluster from the Lower Guinea Coastal region (Glab_LowerCoast) (Figure 3.1). The indica divided into indica from Ghana (Ind_Gh) and indica from Guinea (Ind_Gc) (Figure 3.2) and the japonica into japonica from Ghana and Guinea Bissau (Jap_GbGh) and japonica from Sierra Leone (Jap_SL) (Figure 3.3). It is possible the differences in the japonica group reflect different histories of introduction (Portuguese trading connections linking the Ghana and Guinea Bissau group, and British sources supplying Sierra Leone in the late 18th/early 19th centuries [cf. 16]. We used these molecular clusters in the analysis of robustness and adaptability.

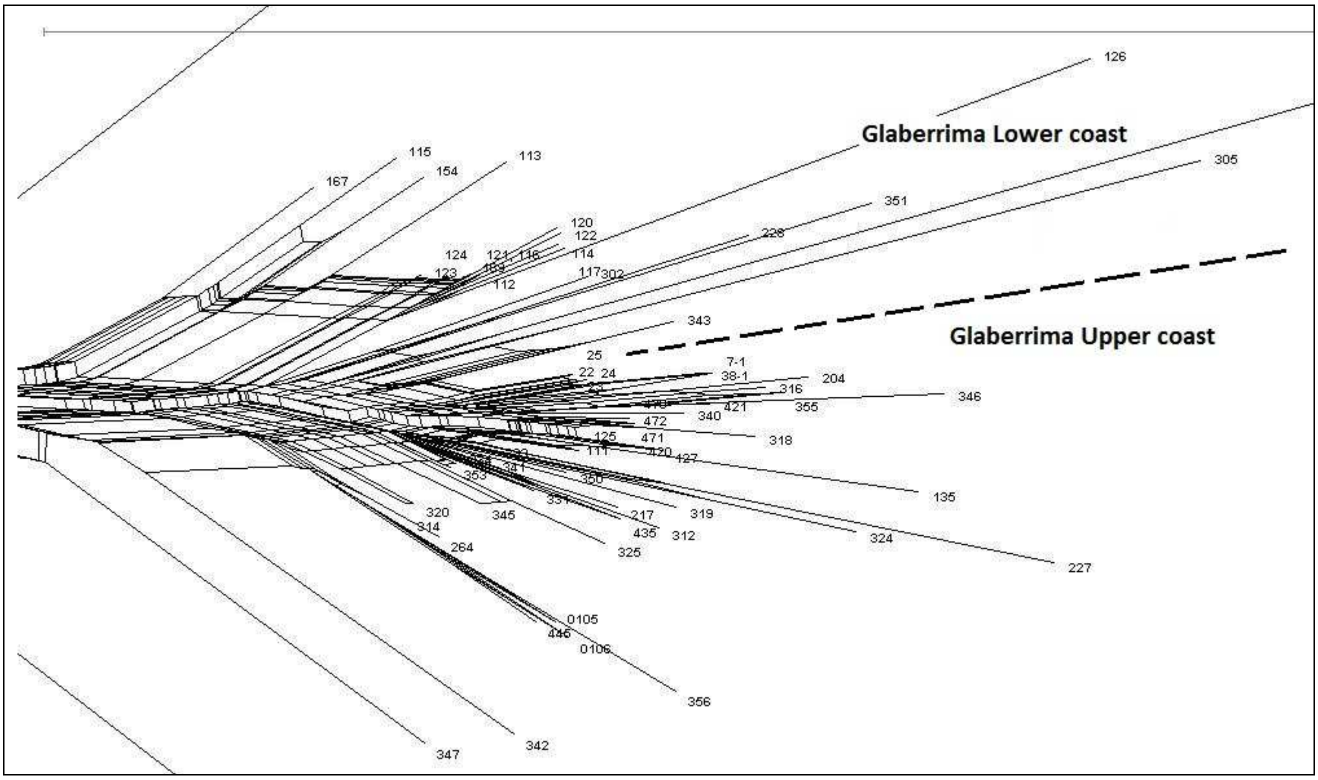


Figure 3.2: Phylogenetic relationships of *glaberrima* and its sub-clusters

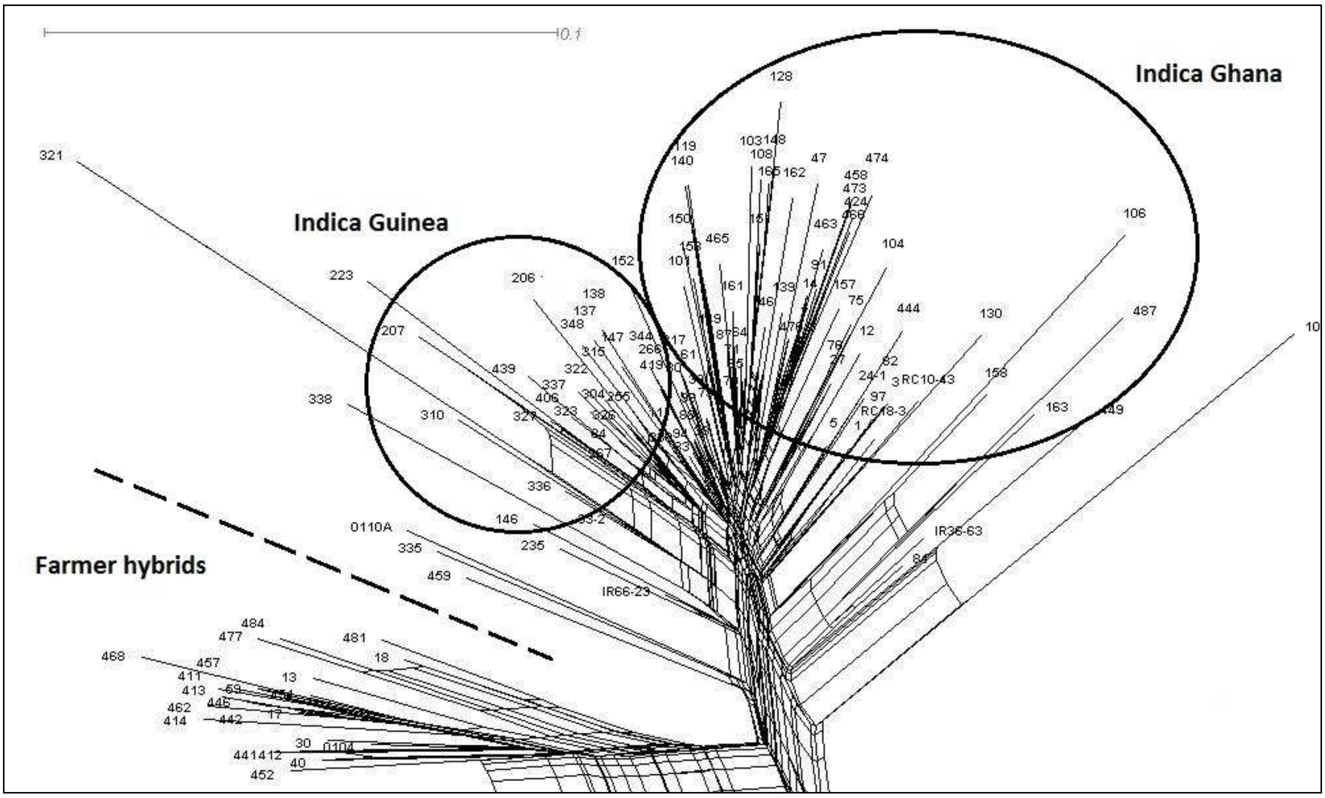


Figure 3.3: Phylogenetic relationships of indica and its sub-clusters

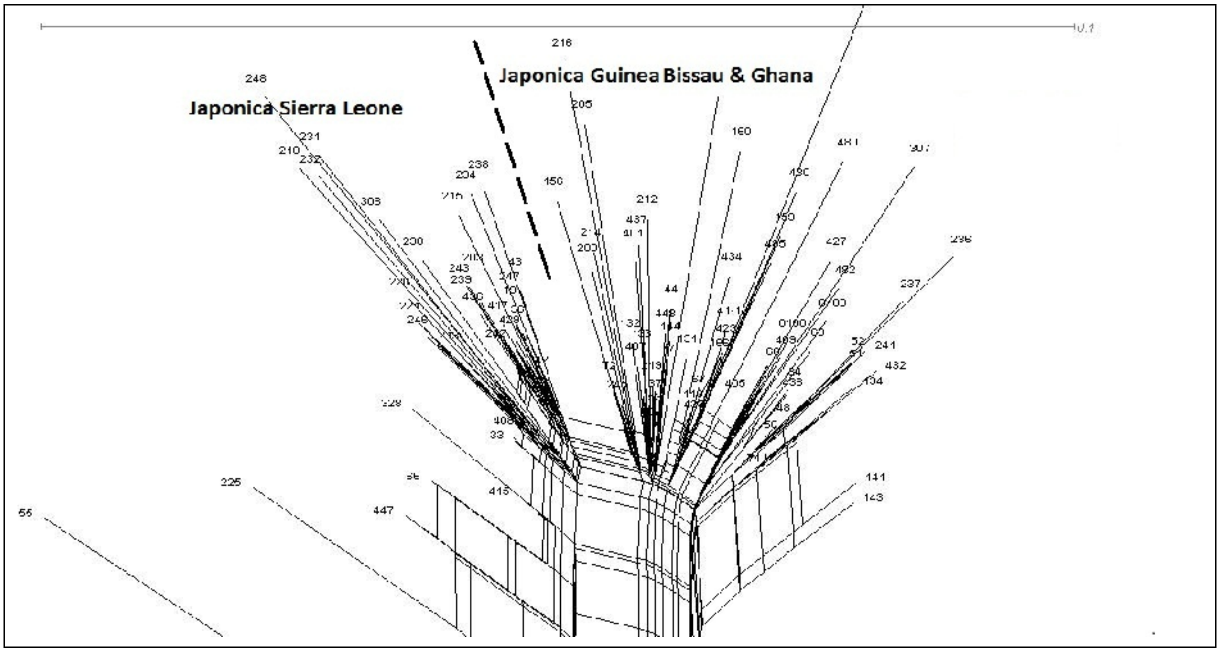


Figure 3.3: Phylogenetic relationships of japonica and its sub-clusters

Table 3.1: List of varieties used in the study

Code	Name of variety	Molecular cluster	Country of collection	Ecology of cultivation
O. glaberrima				
333	Saali Firê	Glab_UpperCoast	Guinea	Upland
347	Safaary	Glab_UpperCoast	Guinea	Upland
334	Tombo Bokary	Glab_UpperCoast	Guinea	Upland
318	Saali Forê	Glab_UpperCoast	Guinea	Upland
420	Jangjango	Glab_UpperCoast	Guinea Bissau	Upland/transition
435	Kurekimbeli	Glab_UpperCoast	Guinea Bissau	Upland/transition
113	Kaomo black	Glab_LowerCoast	Ghana (Togo mountain ranges)	Upland
124	Xleti eve	Glab_LowerCoast	Togo (Togo mountain ranges)	Upland
135	Kpakpalipke	Glab_LowerCoast	Togo (Togo mountain ranges)	Upland
272	Saliforeh	Glab_UpperCoast	Sierra Leone	Transition/upland
249	Maalay	Glab_UpperCoast	Sierra Leone	Transition/upland
O. sativa type indica				
348	Saidou Firê	Ind_Gc	Guinea	Upland
349	Saidou Gbéli	Ind_Gc	Guinea	Upland
130	Zomojo	Ind_Gh	Ghana (Togo mountain ranges)	Upland/transition/lowland
128	Viono tall	Ind_Gh	Ghana (Togo mountain ranges)	Upland/transition/lowland
163	Ataa	Ind_Gh	Ghana (Togo mountain ranges)	Upland/transition
O. sativa type japonica				
407	Demba Ba	Jap_GbGh	Guinea Bissau	Upland
427	Uyeey	Jap_GbGh	Guinea Bissau	Upland
432	Usefa Udjenel	Jap_GbGh	Guinea Bissau	Upland
141	Aqua blue	Jap_GbGh	Ghana (Togo mountain ranges)	Upland/transition
274	Nduliwa	Jap_SL	Sierra Leone	Transition/upland
210	Gbengbeng	Jap_SL	Sierra Leone	Transition/upland
215	Jebbeh-komi	Jap_SL	Sierra Leone	Transition/upland
408	Buba Njie	Jap_GbGh	Guinea Bissau	Upland/transition

Transition: variety cultivated in transitional zone between lowland and upland. Ind_Gc= cluster of indica from Guinea. Ind_Gh= cluster of indica from Ghana. Jap_GbGh= cluster of japonica from Guinea Bissau and Ghana. Jap_SL= cluster of japonica from Sierra Leone. Glab_LowerCoast= cluster of *glaberrima* from Lower Guinea coast. Glab_UpperCoast= cluster of *glaberrima* from Upper Guinea coast.

3.2.3 Trials

Locations

Five trials were conducted in Guinea, Guinea Bissau, Ghana, Togo and Sierra Leone from June 2008 to January 2009. Table 3.2 summarizes the characteristics of the experimental sites.

Experimental design

In each of the five trials, the varieties were sown in a randomized block design with two sowing dates and five replications, resulting in 26 × 2 × 5 = 260 plots. Sowing dates were determined by following the farmers' practices in each region. The time between the first and the second sowing was two to three weeks. Each plot was 1.5 m × 2.1 m and contained 70 pockets, spaced 30 cm between rows and 15 cm within rows. Three to five grains were sown in each pocket and pockets were thinned to one plant within four weeks after sowing.

Measurements

Table 3.3 summarises the measured variables, the methodology of assessment and the trials in which they were recorded.

The percentage of canopy coverage was determined during the growing cycle using frames of 60 cm × 75 cm (in Togo and Ghana) and 60 cm × 45 cm in Guinea that were put in the plot and photographed from straight above. A series of about 20 photos representing a wide range of canopy cover values was analysed with Matlab 7 and DIP image [17], to allow calculation of the percentage green in a photo. Based on this calibration the percentages of canopy coverage were estimated for all photos.

Determination of the canopy cover development

For each plot, canopy coverage curves were made on the basis of 6 to 12 measurements. As curves for the different replications showed a large variation and a block effect was not found we decided to carry out curve fitting on the average values of the five replications.

To describe the canopy development we used a modified version of the model developed by Khan et al. [18] for potato. The model of Khan et al. distinguishes three development phases for potato: the build-up phase, the phase where the canopy cover remains constant and the decline phase. In our case, possibly because of stress the plants experienced, the canopy never reached 100% coverage, nor did it reach a plateau level maintained for any period of time. This simplified the model because the time that the maximum canopy cover was reached (t_1) and the time it started to decline (t_2) coincided, resulting into a two-phase model:

Phase 1

$$v = v_{\max}\left(1 + \frac{t_1 - t}{t_1 - t_{m1}}\right)\left(\frac{t}{t_1}\right)^{\frac{t_1}{t_1 - t_{m1}}} \text{ with } 0 \le t \le t_1 \qquad (1)$$

Phase 2

$$v = v_{\max}\left(\frac{t_e - t}{t_e - t_1}\right)\left(\frac{t}{t_1}\right)^{\frac{t_1}{t_e - t_1}} \text{ with } t_1 \le t \le t_e \qquad (2)$$

where:
v = canopy cover (%); v_{max}= maximum canopy cover (%); t_{m1} = the inflexion point; t_1 = the time the maximum canopy cover is reached; t_e = the time when the canopy has declined to 0.
t_{m1}, t_1, v_{max} and t_e were estimated using SAS.

Table 3.2: Characteristics of the experimental sites

	Guinea	**Guinea Bissau**	**Ghana**	**Togo**	**Sierra Leone**
GPS coordinates	10.00275 N 12.91770 W 379 m asl	12.131734 N 15.93607 W 10 m asl	7.26429 N 0.46984 W 213 m asl	7.27028 N 0.71598 W 809 m asl	8.14917 N 11.90806 W 58 m asl
Ecology	Upland	Upland	Upland	Upland	Upland
Soil characteristics					
pH (water)	4.8	4.6	4.6	4.9	4.2
OC%	2.9	1.6	1.9	5.4	4.1
total N g kg^{-1}	0.9	0.2	0.7	0.9	0.6
ppm Meh P	8.1	0.6	7.8	7.0	5.5
sand%	69.0	81.3	63.0	65.0	16.0
clay%	13.7	12.8	8.0	19.0	7.0
silt%	11.1	5.3	28.0	10.0	70.0
soil type	Sandy loam	Loamy sand	Sandy loam	Sandy (clay) loam	Silty loam
Background of experiment sites	- One year fallow - Previous crops (successively): rice, groundnut (*Arachis hypogaea*), cassava (*Manihot esculenta*) - Presence of *Imperata cylindrica*	-At least 5 years of fallow	-5 year fallow -Previous crop: maize (*Zea mays*)	-3 years fallow -Previous crop: maize (*Zea mays*)	24 years fallow. Previous crops: rice mixed cropping (cropped with squash, cucumber (*Cucumis spp.*), eggplant (*Solanum spp.*), pepper (*Capsicum spp.*), sorrel (*Hibiscus spp.*), legumes, *Zea mays*, *Manihot esculenta*, *Ipomoea batatas*, *Arachis hypogaea*, etc. -Presence of *Pennisetum purpureum* -Home for natural pests: rodents, stems borers etc.
Average annual rainfall (mm)	2800-4000	1500	1500	1200	2100-3000
Duration rainfall (months)	6	4 to 5	7	7	6 to 7
General observation	Stress and plant mortality observed during crop establishment phase	Good germination and growth. The late maturing varieties suffered from drought and rodent damage	Most plants showed excellent germination and growth	Most plants showed some traces of acidity damage	-Excellent germination and growth -Low to moderate pest (rodents, termites, cut worms, stem borers) incidences were most specific to *O. sativa* ssp. japonica
Trial setup dates					
First sowing	28 June 2008	29 June 2008	16 July 2008	09 July 2008	12 June 2008
Second sowing	16 July 2008	13 July 2008	06 August 2008	30 July 2008	04 July 2008

Table 3.3: Measured parameters and countries of measurement

Parameters	**Indication on methods of measurement**	**Trials where parameters were measured**
Canopy cover	See: Determination of the canopy cover development	Ghana, Guinea and Togo
Plant height (cm)*	Measured from the base of the plant to the tip of the panicle of the main tiller	Ghana, Guinea, Guinea Bissau, Sierra Leone, Togo
Number of tillers*	Total number of tillers per plant	Ghana, Guinea, Guinea Bissau, Sierra Leone, Togo
Days to 50% flowering	The number of days between the sowing date and the date 50% of the plants flowered	Ghana, Guinea, Guinea Bissau, Sierra Leone, Togo
Number of panicles*	Total number of panicles per plants	Guinea, Guinea Bissau, Sierra Leone
Panicle length (cm)*	Measured from the base to the tip of the panicle of the main axis	Ghana, Guinea, Guinea Bissau, Sierra Leone, Togo
Panicle weight (g)	Weight of the grains of 14 panicles	Ghana and Togo
200 grain weight (g)	Weight of 200 filled grain. Unfilled and partially filled grains were excluded	Ghana, Guinea, Guinea Bissau, Togo
Plot yield ($kg.ha^{-1}$)	Weight of the three inner rows	Ghana, Guinea Bissau, Sierra Leone, Togo

*Measured on 6 plants randomly selected from the inner rows.

The accumulated canopy cover A, represented by the sum of surfaces under the curves of phase 1 and 2, was estimated by using the following formulae:
Surface under the curve for phase 1 (A_1):

$$A_1 = v_{\max}\left(\frac{2t_1(t_1 - t_{m1})}{3t_1 - 2t_{m1}}\right) \quad (3)$$

Surface under the curve for phase 2 (A2):

$$A_2 = \frac{v_{\max}(t_e - t_1)}{2t_e - t_1}\left(t_e\left(\frac{t_e}{t_1}\right)^{\frac{t_1}{t_e - t_1}} - 2t_1\right) \quad (4)$$

Estimation of the accumulated canopy cover (A):

$$\mathrm{A} = \mathrm{A}_1 + \mathrm{A}_2 \quad (5)$$

3.2.4 Data analysis

G×E interactions

As different botanical groups and molecular clusters were compared, interactions between genotypes and environment were analysed through ANOVA (analysis of variance) to assess differences in responses to different environments within and between botanical groups. Significant G×E interactions point to the presence of such a variation in response and indicate that the botanical group or cluster contains varieties that respond differently to different environments, which can be considered an indicator of adaptability within a specific botanical group or cluster. We used the Tukey test to compare means.

Wide sense heritability estimates

$H^2=100 \times Vg/(Vg+1/rsVgs+1/rlVgl+1/rslVgls+1/rVe)$

where:

H^2 = wide sense heritability; *Vg* = genetic variance; *Vgs* = variance genetic × sowing interactions
Vgl = variance genetic × location interactions; *Vgls* = variance genetic × location × sowing interactions
Ve = error variance; *r* = number of replications (5); *s* = number of sowings (2); *l* = number of locations (2, 3, 5)

Descriptive statistics
Averages and standard deviations were calculated.

3.3 RESULTS AND DISCUSSION

In the following sections the parameters are investigated for each botanical group and cluster. The parameters are dealt with one by one and cross references are made among them to unravel strategies of adaptation. Graphs are used to compare performance of each parameter across environments. ANOVAs provided important information on adaptability, as they provided estimates of G×E interactions (Tables 3.4a, 3.4b1, 3.4b2, 3.4b3, 3.4c1, 3.4c2, 3.4c3, 3.4d1, 3.4d2 and 3.4d3).

Table 3.4: Interaction between genotype, sowing date and trial location (location) regarding main crop characteristics

Table 3.4a: All botanical groups and clusters together

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.000***	0.758	0.026*	0.092	0.881	0.029*	-
A [d]	0.000***	0.435	0.027*	0.014*	0.444	0.001***	-
Plant height [f]	0.000***	0.922	0.002**	0.612	0.000***	0.000***	0.264
# Tillers[f]	0.000***	0.533	0.006**	0.043*	0.000***	0.000***	0.986
50% Flowering [f]	0.000***	0.011*	0.000***	0.008**	0.000***	0.003**	0.000***
# Panicles [a]	0.000***	0.334	0.112	0.005**	0.000***	0.000***	0.947
Panicle length [a]	0.000***	0.890	0.003**	0.023*	0.000***	0.000***	0.017*
Panicle weight [e]	0.000***	0.140	0.502	0.236	0.157	0.194	0.012*
200 grains weight [b]	0.000***	0.318	0.006**	0.069	0.018*	0.031*	0.850
Yield [c]	0.000***	0.070	0.042*	0.583	0.873	0.020*	0.000***

Table 3.4b1: Glaberrima botanical group

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.190	0.373	0.083	0.464	0.319	0.000***	-
A [d]	0.260	0.217	0.055	0.268	0.132	0.000***	-
Plant height [f]	0.000***	0.797	0.009**	0.471	0.001***	0.000***	0.469
# Tillers[f]	0.097	0.246	0.003**	0.268	0.000***	0.014*	0.612
50% Flowering [f]	0.000***	0.007**	0.001***	0.069	0.014*	0.024*	0.000***
# Panicles [a]	0.314	0.267	0.117	0.025*	0.000***	0.000***	0.998
Panicle length [a]	0.000***	0.810	0.001***	0.024*	0.004**	0.009**	0.024*
Panicle weight [e]	0.051	0.255	0.081	0.359	0.088	0.279	0.563
200 grains weight [b]	0.000***	0.457	0.003**	0.584	0.019*	0.103	0.940
Yield [c]	0.000***	0.458	0.254	0.619	0.981	0.002**	0.000***

Table 3.4b2: Cluster of Glaberrima from Lower Guinea coast (Glab_Lower Coast)

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.137	0.737	0.176	0.330	0.877	0.172	-
A [d]	0.740	0.464	0.082	0.129	0.609	0.053	-
Plant height [f]	0.567	0.566	0.218	0.685	0.665	0.641	0.042*
# Tillers[f]	0.852	0.061	0.002**	0.638	0.026*	0.347	0.935
50% Flowering [f]	0.014*	0.001***	0.004**	0.086	0.061	0.534	0.022*
# Panicles [a]	0.840	0.243	0.086	0.145	0.091	0.008**	0.963
Panicle length [a]	0.582	0.164	0.178	0.144	0.791	0.441	0.393
Panicle weight [e]	0.274	0.081	0.370	0.641	0.330	0.926	0.517
200 grains weight [b]	0.056	0.421	0.119	0.654	0.325	0.258	0.218
Yield [c]	0.099	0.316	-	0.570	0.899	0.604	0.017*

Values in the table are p values (three-way ANOVA). *: Significant at 0.05 level. **: significant at 0.01 level. ***: Significant at 0.001 level. a: ANOVA performed for Guinea Bissau, Guinea and Sierra Leone. b: ANOVA performed for Guinea Bissau, Guinea, Ghana and Togo. c: ANOVA performed for Guinea Bissau, Ghana, Sierra Leone and Togo. d: ANOVA performed for Ghana, Guinea and Togo. e: ANOVA performed for Ghana and Togo. f: ANOVA performed for all five countries. -: not assessed.

Table 3.4b3: Cluster of Glaberrima from Upper Guinea coast (Glab_Upper Coast)

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.589	0.276	0.076	0.973	0.178	0.001***	-
A [d]	0.545	0.170	0.055	0.667	0.184	0.002**	-
Plant height [f]	0.003**	0.702	0.027*	0.209	0.000***	0.000***	0.956
# Tillers[f]	0.664	0.397	0.031*	0.27	0.008**	0.056	0.145
50% Flowering [f]	0.000***	0.017*	0.005**	0.455	0.29	0.091	0.000***
# Panicles [a]	0.372	0.294	0.144	0.025*	0.000***	0.000***	0.982
Panicle length [a]	0.018*	0.919	0.010**	0.003**	0.000***	0.000***	0.439
Panicle weight [e]	0.309	0.300	0.242	0.322	0.128	0.221	0.454
200 grains weight [b]	0.202	0.581	0.001***	0.464	0.013*	0.329	0.98
Yield [c]	0.000***	0.519	0.412	0.344	0.902	0.001***	0.039*

Table 3.4c1- Indica botanical group

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.017*	0.931	0.06	0.16	0.746	0.171	-
A [d]	0.031*	0.588	0.038*	0.177	0.508	0.055	-
Plant height [f]	0.089	0.591	0.000***	0.72	0.000***	0.010**	0.057
# Tillers[f]	0.553	0.998	0.001***	0.022*	0.001***	0.006**	0.979
50% Flowering [f]	0.027*	0.005**	0.000***	0.233	0.003**	0.432	0.120
# Panicles [a]	0.358	0.654	0.149	0.100	0.002**	0.315	0.829
Panicle length [a]	0.162	0.474	0.002**	0.595	0.063	0.377	0.047*
Panicle weight [e]	0.174	0.029*	0.230	0.377	0.271	0.732	0.457
200 grains weight [b]	0.001***	0.053	.	0.339	0.794	0.866	0.365
Yield [c]	0.001***	0.002**	0.358	0.630	0.441	0.916	0.000***

Table 3.4c2: Cluster of Indica from Ghana (Ind_Gh)

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.057	0.362	estimate.	0.229	0.943	0.756	-
A [d]	0.099	0.762	0.439	0.253	0.891	0.370	-
Plant height [f]	0.385	0.480	0.001 ***	0.798	0.022*	0.124	0.012*
# Tillers[f]	0.361	0.580	0.005 **	0.078	0.055	0.201	0.702
50% Flowering [f]	0.026*	0.026*	0.011*	0.245	0.172	0.539	0.019*
# Panicles [a]	0.448	0.548	0.864	0.222	0.038*	0.644	0.44
Panicle length [a]	0.158	0.872	0.081	0.475	0.170	0.287	0.139
Panicle weight [e]	-	0.119	-	-	-	-	-
200 grains weight [b]	-	-	-	-	-	-	-
Yield [c]	0.016*	0.062	0.061	0.385	0.192	0.342	0.000 ***

Table 3.4c3: Cluster of Indica from Guinea (Ind_Gc)

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.103	0.657	0.025*	0.242	0.074	0.033*	-
A [d]	0.052	0.439	0.017*	0.122	0.100	0.035*	-
Plant height [f]	0.962	0.957	0.000***	0.829	0.025*	0.008**	0.964
# Tillers[f]	0.634	0.440	0.018*	0.384	0.006**	0.031*	0.973
50% Flowering [f]	0.286	0.003**	0.029*	0.551	0.118	0.823	0.391
# Panicles [a]	0.500	0.189	0.114	0.774	0.038*	0.242	0.876
Panicle length [a]	0.781	0.369	0.021*	0.416	0.180	0.397	0.368
Panicle weight [e]	0.412	0.032*	0.377	0.336	0.358	0.761	0.540
200 grains weight [b]	0.272	0.481	0.350	0.535	0.573	0.494	0.302
Yield [c]	0.598	0.097	0.090	0.112	0.454	0.022*	0.501

Values in the table are p values (three-way ANOVA). *: Significant at 0.05 level. **: significant at 0.01 level. ***: Significant at 0.001 level. a: ANOVA performed for Guinea Bissau, Guinea and Sierra Leone. b: ANOVA performed for Guinea Bissau, Guinea, Ghana and Togo. c: ANOVA performed for Guinea Bissau, Ghana, Sierra Leone and Togo. d: ANOVA performed for Ghana, Guinea and Togo. e: ANOVA performed for Ghana and Togo. f: ANOVA performed for all five countries. -: not assessed.

Table 3.4d1: Japonica botanical group

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.047**	0.178	0.047**	0.703	0.468	0.011**	-
A [d]	0.176	0.318	0.065	0.818	0.285	0.002***	-
Plant height [f]	0.021*	0.562	0.000***	0.846	0.000***	0.001***	0.404
# Tillers[f]	0.000***	0.755	0.033*	0.965	0.008**	0.000***	0.963
50% Flowering [f]	0.001***	0.431	0.005**	0.108	0.007**	0.000***	0.012*
# Panicles [a]	0.010**	0.803	0.653	0.946	0.282	0.020*	0.121
Panicle length [a]	0.000***	0.86	0.038*	0.043*	0.000***	0.000***	0.784
Panicle weight [e]	0.182	0.158	0.405	0.813	0.608	0.368	0.022*
200 grains weight [b]	0.000***	0.197	0.085	0.178	0.936	0.216	0.660
Yield [c]	0.001***	0.006**	estimate.	0.644	0.987	0.884	0.000***

Table 3.4d2: Cluster of Japonica from Guinea Bissau and Ghana (Jap_GbGh)

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.331	0.116	0.030*	0.637	0.472	0.142	-
A [d]	0.355	0.205	0.028*	0.725	0.347	0.069	-
Plant height [f]	0.080	0.607	0.000***	0.693	0.004**	0.045*	0.229
# Tillers[f]	0.000 ***	0.764	0.035*	0.891	0.714	0.005**	0.661
50% Flowering [f]	0.857	0.574	0.007**	0.851	0.006**	0.000***	0.408
# Panicles [a]	0.027*	0.805	0.466	0.860	0.995	0.106	0.036*
Panicle length [a]	0.005 **	0.808	0.028*	0.014*	0.001***	0.000***	0.835
Panicle weight [e]	0.074	0.188	0.576	0.495	0.547	0.352	0.091
200 grains weight [b]	0.000 ***	0.571	0.129	0.339	0.917	0.278	0.705
Yield [c]	0.856	0.329	0.089	0.442	0.605	0.016*	0.039*

Table 3.4d3: Cluster of Japonica from Sierra Leone (Jap_SL)

	Genotype	Sowing	Location	Genotype* Sowing	Genotype * Location	Sowing* Location	Genotype*Sowing* Location
V_{max} [d]	0.433	0.293	0.097	0.526	0.461	0.133	-
A [d]	0.550	0.473	0.128	0.578	0.306	0.044*	-
Plant height [f]	0.072	0.568	0.003**	0.736	0.005**	0.005**	0.845
# Tillers[f]	0.062	0.747	0.049*	0.775	0.072	0.023*	0.949
50% Flowering [f]	0.067	0.305	0.002**	0.044*	0.069	0.037*	0.052
# Panicles [a]	0.199	0.812	0.218	0.88	0.125	0.088	0.816
Panicle length [a]	0.032*	0.988	0.229	0.251	0.006**	0.02*	0.637
Panicle weight [e]	0.977	0.634	-	0.917	0.673	0.728	0.082
200 grains weight [b]	0.328	1.000	-	0.735	0.948	0.925	0.067
Yield [c]	0.114	0.082	0.619	0.516	0.943	0.422	0.000***

Values in the table are p values (three-way ANOVA). *: Significant at 0.05 level. **: significant at 0.01 level. ***: Significant at 0.001 level. a: ANOVA performed for Guinea Bissau, Guinea and Sierra Leone. b: ANOVA performed for Guinea Bissau, Guinea, Ghana and Togo. c: ANOVA performed for Guinea Bissau, Ghana, Sierra Leone and Togo. d: ANOVA performed for Ghana, Guinea and Togo. e: ANOVA performed for Ghana and Togo. f: ANOVA performed for all five countries. -: not assessed.

Table 3.5 shows the average performance of the studied genotypes (grouped into botanical groups and clusters) for ten parameters used to analyse the vegetative growth and yield components: maximum canopy cover (V_{max}; %), accumulated canopy cover (A; %.d), plant height (cm), number of tillers per plant (# tillers), days to 50% flowering (50% flowering), number of panicles per plant (#panicles), panicle length (cm), panicle weight (g), 200 grain weight (g) and grain yield (kg ha^{-1}).

3.3.1 Maximum canopy cover (Vmax) and accumulated canopy cover (A)

V_{max} and A correlated positively (r = 0.984**) at 0.01 level. The same trend was observed for all botanical groups and clusters in all environments (Table 3.8; Figure 3.4). Accumulated canopy cover (A) can therefore represent V_{max} and vice versa. In all cases the surface under the canopy curves (A) can be conceived as a triangle with the cycle length (Te) as base and V_{max} as height. Variations in cycle length (Te), inflexion point (Tm1) and the time V_{max} was reached (T1) appear to confirm that A is linearly related to V_{max}.

Table 3.5: Average performance of several clusters of rice for main crop characteristics

	Vmax (%)	A (%d)	Plant height (cm)	# Tillers	50% Flowering (d)	# Panicles	Panicle length (cm)	Panicle weight (g)	200 grains weight (g)	Yield (kg/ha)
a- Botanical groups										
Glaberrima	46.1±19.9 C	2908±1281 B	101.1± 18.0 B	6.8±2.1 B	97.1±11.8 A	6.4±2.7 C	23.4±3.1 B	2.0±0.5 A	4.3±0.8 A	1349±619 C
Indica	41.7±19.0 B	2889±1267 B	97.8± 23.7 A	7.6±2.8 C	108.9±12.7 C	5.5±2.6 B	22.1±2.0 A	1.9±0.6 A	4.14±1.43 A	757±754 A
Japonica	35.0±16.4 A	2269±982 A	97.2± 16.9 A	4.0±1.5 A	101.8±14.0 B	2.8±1.1 A	22.5±3.0 A	3.1±1.0 B	4.32±1.69 A	967±658 B
b- Clusters*										
Glab_UpperCoast	44.5 bcd	2794 bcd	104.2 de	6.5 c	96.7 b	6.2 cd	23.9 b	2.1 b	4.1 ab	1376 cd
Glab_LowerCoast	50.2 d	3214 d	92.7 ab	7.5 d	98.4 bc	7.2 d	21.9 a	1.8 ab	4.9 c	1265 bcd
Jap_GbGh	36.8 ab	2320 ab	97.0 abc	4.4 b	101.9 c	3.1 a	22.7 ab	2.9 c	4.6 bc	1095 bc
Jap_SL	31.1 a	2085 a	98.7 cd	3.3 a	107.8 d	2.2 a	22.0 a	2.9 c	3.9 a	691 a
Ind_Gc	44.2 bcd	2984 cd	104.2 de	7.7 d	110.0 d	6.2 cd	21.6 a	1.7 ab	4.5 bc	1064 b
Ind_Gh	40.0 bc	2826 cd	91.8 a	7.4 d	110.7 d	4.8 b	22.4 a	1.5 a	3.7 a	551 a

In the cells are Means ± standard deviations. Means in a column followed by the same letter are not significantly different from each other at 0.05% (based on Tukey tests). * See materials and methods section for coding of the clusters.

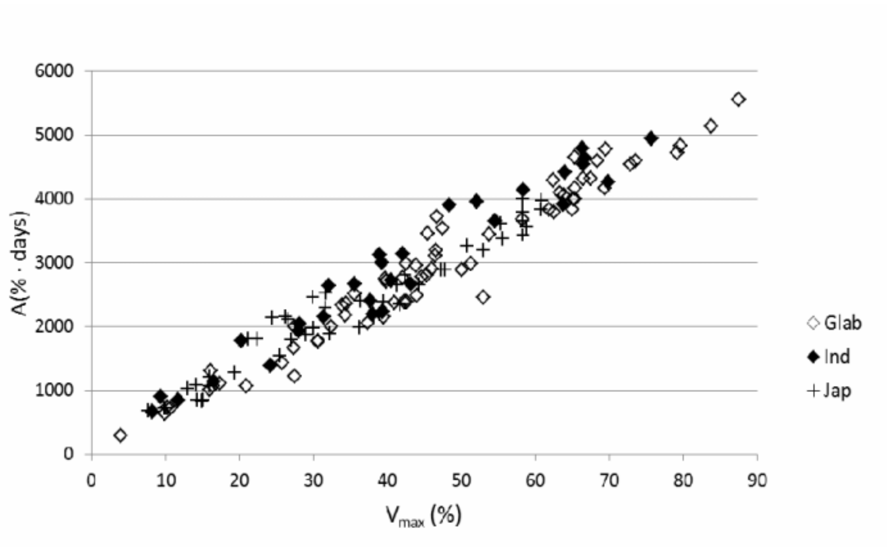


Figure 3.4: Relation between the maximum canopy cover (V_{max}) and the accumulated canopy cover over the whole growing cycle (A).
The series Glab, Ind and Jap refer to the data for the *glaberrima*, indica and japonica botanical groups.

None of the botanical groups or clusters showed G×E interactions for A or V_{max} (Tables 3.4b1-3.4b3, 3.4c1-3.4c3 and 3.4d1-3.4d3). This means that within all botanical groups and clusters the varieties responded comparably for A and V_{max} across environments.

However, for all three botanical groups significant sowing × location interactions were found, in particular for *glaberrima* and japonica. Sowing × location interactions were highly significant for the *glaberrima* botanical group and Glab_UpperCoast but not significant for the Glab_LowerCoast cluster. Glab_LowerCoast therefore maintained better A and V_{max} across environments, since its genotypes reacted in a similar way to different environments. However the developed canopy did not turn into a yield increase as Glab_UpperCoast yielded more than Glab_LowerCoast (Table 3.5).

Of the indica group, it was only in the Ind_Gc cluster that significant sowing × location interactions were found for A and V_{max}. The indica group showed a significant location effect for A. No significant effects were found for the Ind_Gh cluster. This indicates that the Ind_Gh maintained better V_{max} and A than the Ind_Gc but often failed to yield (Figures 3.5 and 3.6).

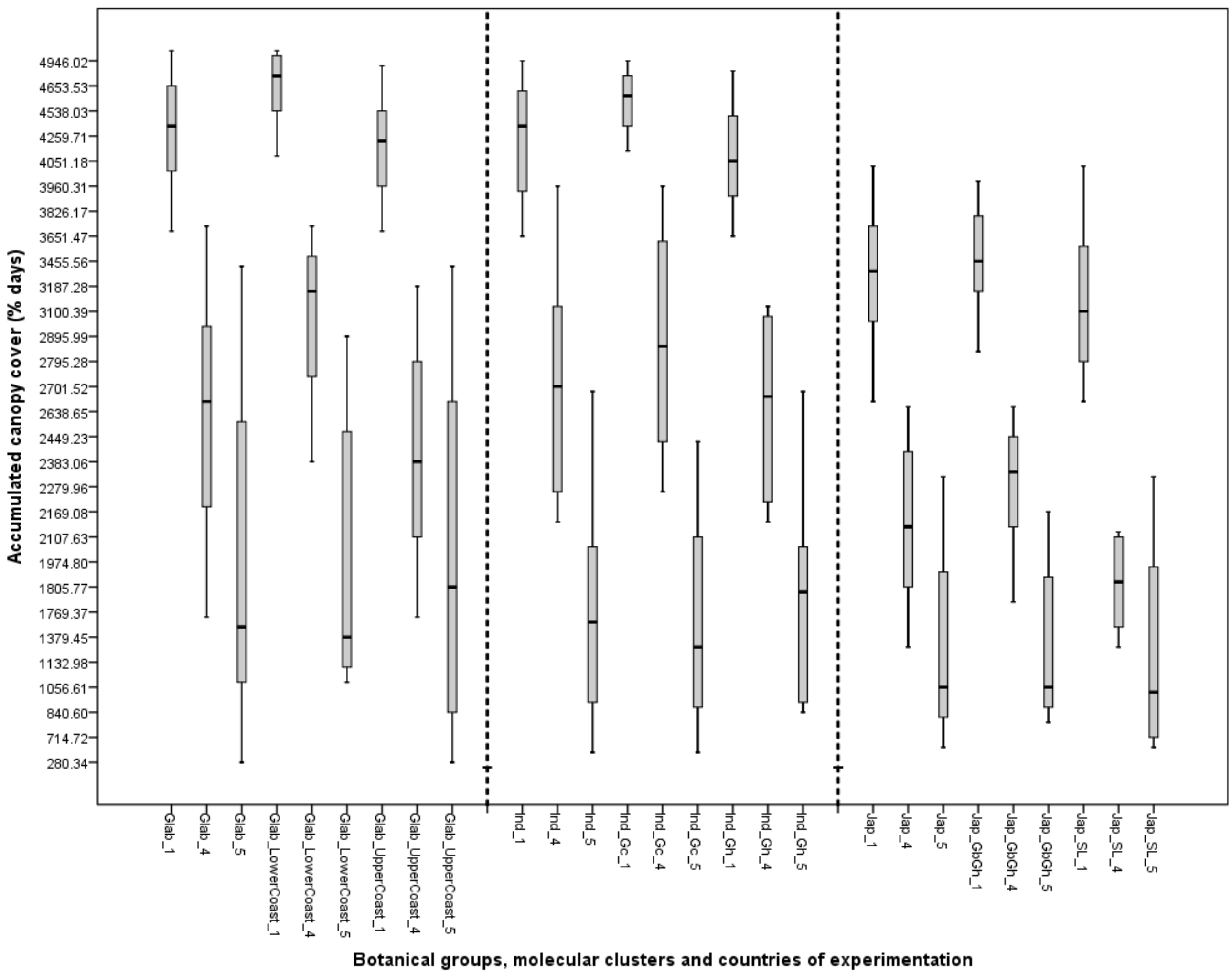


Figure 3.5: Accumulated canopy cover (A) in three experimental sites.
1: Ghana; 4: Togo and 5: Guinea. See materials and methods section for coding of the clusters

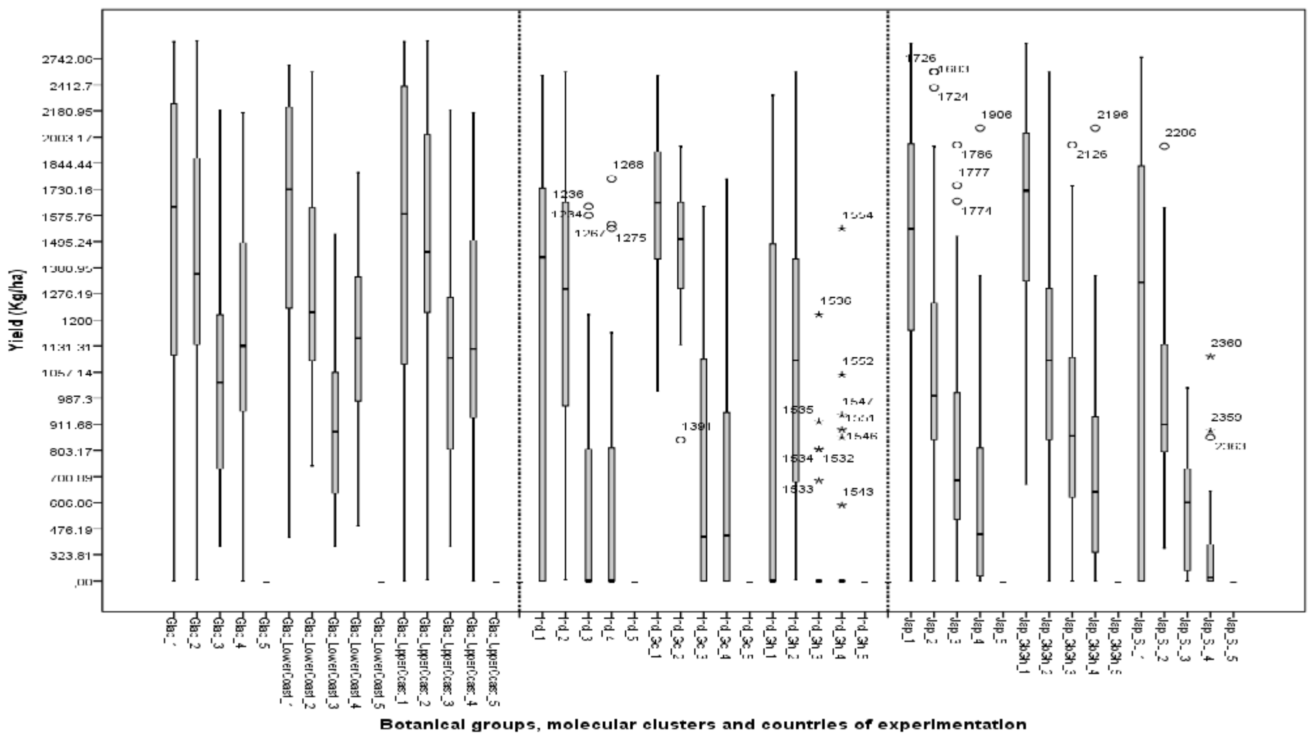


Figure 3.6: Yield in four experimental sites.
1: Ghana; 2: Sierra Leone; 3: Guinea Bissau; 4: Togo and 5: Guinea (yield was not measured). See materials and methods section for coding of the clusters.

The japonica group showed significant sowing × location interactions, suggesting that (for the two japonica clusters) A and V_{max} varied across environments. At cluster level significant sowing × location interactions were found for Jap_SL for V_{max} only, while for the Jap_GbGh cluster the location effects were significant for both A and V_{max}. This suggests that Jap_SL maintained A across environments better than Jap_GbGh. However Jap_SL showed considerable yield variation (Figure 3.6), suggesting that the relative stability observed for A did not contribute to yield stability.

3.3.2 Yield

The analyses of variance performed for all genotypes and at botanical group level showed a highly significant three-way interaction for yield (Tables 3.4a-d). This suggests that the studied rice varieties generally responded differently in yield across environments and sowing dates. The yield variability studied at cluster level also revealed significant G×E interactions (Tables 3.4b2, 3.4b3, 3.4c2, 3.4d2, 3.4d3) with the exception of the indica cluster from Guinea (Ind_Gc). The yield therefore varied in a similar manner across environments for genotypes of Ind_Gc.

The *glaberrima* botanical group showed the highest yields across all environments (Table 3.5 and Figure 3.6). “Zero” yields (complete crop failure) occurred only with indica and japonica. At cluster level, *glaberrima* from upper Guinea coast (Glab_UpperCoast) showed the highest yield. *Glaberrima* from the Lower Guinea coast (Glab_LowerCoast) had the same yield range as japonica from Guinea Bissau and Ghana (Jap_GbGh) and Ind_Gc. Ind_Gh and Jap_SL showed the lowest average yield.

A comparison of the botanical groups on the yield across environments (Figure 3.6) shows that, within the same environment, *glaberrima* yielded more than indica and japonica. In Ghana where the average plot yield was generally high, some indica varieties showed “zero” yield. Zero yield occurred for japonica only in Guinea Bissau and Togo. These are the two countries where the overall yield was generally lowest.

Figure 3.6 also shows that the two clusters of the *glaberrima* group maintained a minimum yield of 660 kg ha^{-1} in all environments. We observed that in trials in two countries where yields were relatively high (Ghana and Sierra Leone) the indica sourced from Guinea maintained a yield level close to that of *glaberrima*. But in the Guinea Bissau and Togo trials, the likelihood of crop failure was high overall. This might be due to the relatively short rainy season in Guinea Bissau and to the acidity of the soil in Togo. In contrast, varieties in the Ind_Gh cluster yielded only in Sierra Leone and to a lesser extent in Ghana, with a high frequency of zero yield. In Ghana and Sierra Leone Jap_GbGh showed a yield level similar to that of the *glaberrima* clusters. In Guinea Bissau and Togo, Jap_GbGh had a low yield but still reached at least 320 kg ha^{-1}.

In contrast, Jap_SL only showed a good yield level (without zero yield) in Sierra Leone. In Guinea Bissau the yield for Jap_SL dropped to 200 kg ha^{-1} and the frequency of crop failure increased in Togo and Ghana. Jap_SL thus seemed to be specifically well adapted to the ecology of Sierra Leone. Like Jap_SL, Ind_Gh produced only in Sierra Leone. This might be attributed to the characteristics of the varieties (Viono tall and Zomojo). These varieties from Ghana are mostly cultivated in the lowlands but have proven to suit certain specific upland niches in Ghana for which the conditions were apparently not met in the Ghana trial but were approached best in Sierra Leone. Okry et al. [19] also reported on such transfer of varieties across agro-ecologies. They provided a case where farmers were trying CK 21, a typical lowland variety in the upland in the region of Guinea known as Guinea Maritime. Given that farmers have decided, for their own reasons, to shift this variety from the recommended domain, it could be counted as an instance of G×E×S (society) interaction.

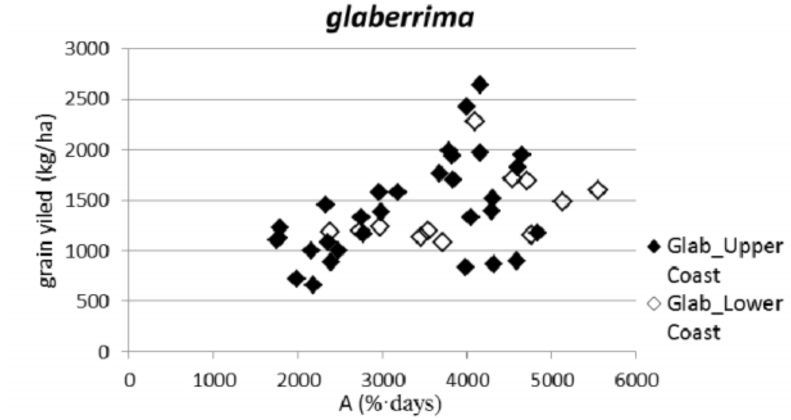
These findings on the yield show that clusters differed in yield performance across environments. Glab_Upper coast, Glab_Lower coast, Jap_GbGh and Ind_Gc were best able to maintain their yield across environments. Farmers often look for varieties that assure minimum yield in environments with variable and stressful conditions. These varieties seemingly satisfy such objectives of farmers.

This section has explored the yield performance across environments. The following sections analyse the physiological processes during the vegetative and reproduction phases that lead to the observed yield.

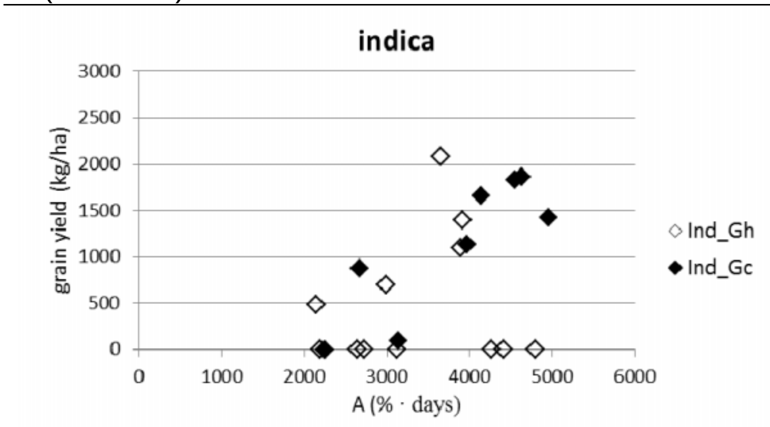
Figures 3.7a-c show the graphical representations of the relationships between yield and A for each botanical group. At cluster level different relationships were observed. The relation between yield and A was similarly low for Glab_LowerCoast and Glab_UpperCoast ($r = 0.451$ and $r = 0.476^{**}$ respectively). This shows that *glaberrima* can yield well even when relatively low accumulated canopy cover is produced.

For the indica and japonica clusters clear differences in the relationship between A and yield were found. A significant relationship between yield and A was found for Ind_Gc ($r = 0.857^{**}$) but not for Ind_Gh ($r = 0.137$). Also a significant Pearson correlation coefficient was found for Jap_GbGh ($r = 0.848^{**}$) but not for Jap_ SL ($r = 0.497$). These findings suggest that Ind_Gc and Jap_GbGh increased their yields by producing a correspondingly dense canopy. The absence of significant correlation values for Ind_Gh and Jap_SL was caused by a number of crop failures that could be related to them being narrowly adapted to Sierra Leone only (Figures 3.7b and 3.7c).

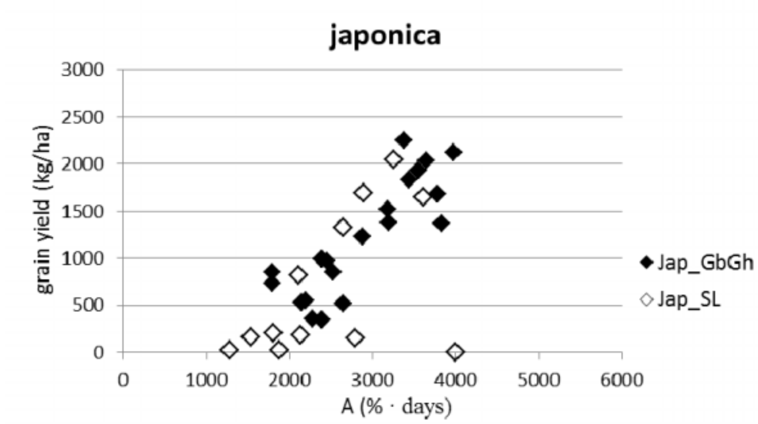
A minimum A is indispensable for yield formation, as shown by the various associations between A and yield observed for the various clusters. But from our observation only the *glaberrima* clusters were able to yield well with low canopy development.



a (r=0.476**)



b (r=0.483*)



c (r=0.706**)

Figure 3.7: The relation between yield and accumulated canopy cover.
Values presented are averages of 5 replications. a: varieties belonging to *glaberrima*; r=0.476** ($P<0.01$); b: varieties belonging to indica; r=0.483* ($P<0.05$); c: varieties belonging to japonica; r=0.706*** ($P<0.001$). See materials and methods section for coding of the clusters.

Observations of average performance at cluster level revealed that canopy development and yield scenarios also differed between and within botanical groups. Glab_UpperCoast and Glab_LowerCoast showed the highest values for V_{max}, A and yield. The two clusters of indica, Ind_Gh and Ind_Gc, showed similar values for V_{max} and A, although the latter significantly outperformed the former in yield. Moreover, Ind_Gc had a canopy development (V_{max} and A) and yield similar to Glab_LowerCoast and Jap_GbGh. Whereas Jap_GbGh and Jap_SL did not significantly differ in V_{max} or A, Jap_GbGh had a significantly higher yield than Jap_SL. Additionally, Jap_GbGh - although displaying low values of V_{max} and A - showed an average yield similar to that of *glaberrima* and Ind_Gc. The clusters Jap_SL and Ind_Gh developed a smaller canopy and also had the lowest yield. From these findings we infer that lower A can be associated with higher yield, and high canopy growth can be associated with lower yields. These associations are strongest for Ind_Gh (lower yield with higher A) and Jap_GbGh (higher yield with lower A).

3.3.3 Plant height

Significant G×E interactions for plant height were observed for all botanical groups and their respective clusters. This implies that across environments genotypes within botanical groups and clusters responded differently in plant height, suggesting the existence of varied strategies of adaptation for the different botanical groups and clusters. This finding confirms that plant height is in general sensitive to environmental conditions.

A decreasing trend was observed for plant height from countries with higher yield to countries with lower yield (Figure 3.8).

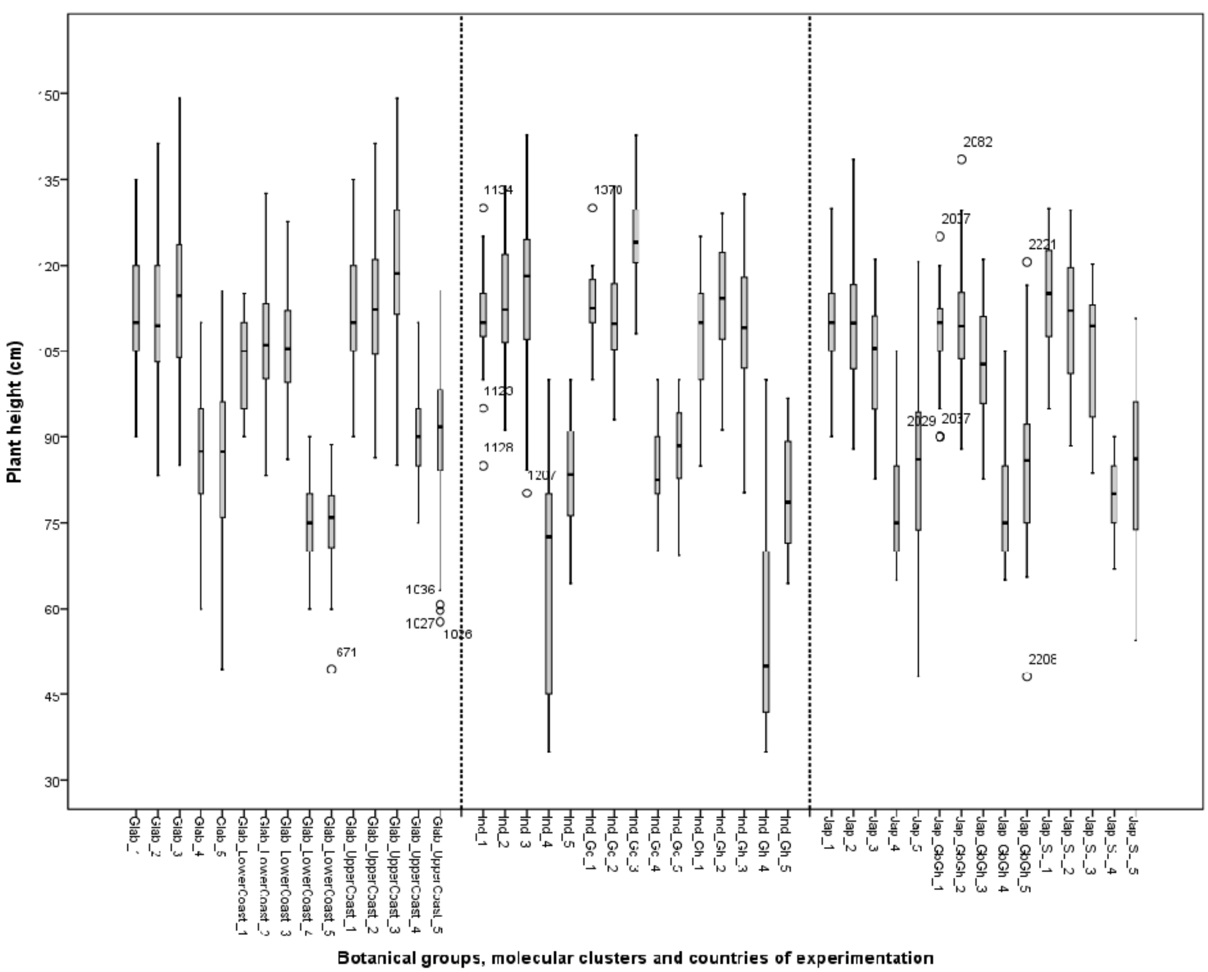


Figure 3.8: Plant height in five experimental sites

1: Ghana; 2: Sierra Leone; 3: Guinea Bissau; 4: Togo and 5: Guinea. See materials and methods section for coding of the clusters

The *O. glaberrima* group showed significantly greater average plant height than the indica and japonica groups (Table 3.5). At cluster level, we found that Glab_UpperCoast had taller plants than Glab_LowerCoast and that Ind_Gc had taller plants than Ind_Gh. The japonica clusters did not show significant differences for plant height (Table 3.5).

The relation between plant height and A is more strongly positive for Glab_UpperCoast (r = 0.826**, Figure 3.10a) than for Glab_LowerCoast. This difference is, however, absent when considering the relation between plant height and yield (Figure 3.10b), confirming that when more canopy was produced Glab_LowerCoast no longer invested in its height but rather in the number of its tillers, which was significantly higher for Glab_LowerCoast than for Glab_UpperCoast (Table 3.5, Figure 3.12). This suggests two distinct strategies adopted by the Glab_LowerCoast cluster and the Glab_UpperCoast cluster to arrive at similar A, and V_{max}: the second cluster produces higher plants and fewer tillers and the first cluster produces shorter plants but more tillers.

Within indica, the cluster Ind_Gc had the tallest plants and showed a highly significant relationship between plant height and A (r = 0.784**). These observations, together with observations of high V_{max} and A for Ind_Gc, imply that Ind_Gc had a better vegetative growth compared to Ind_Gh. Cluster Ind_Gc also displayed the same average plant height as Glab_UpperCoast.

Japonica clusters did not show significant differences for plant height (Table 3.5) nor for the relationship between plant height and A: r = 0.635** and r = 0.640** for Jap_GbGh and Jap_SL, respectively.

3.3.4 Number of panicles

The *glaberrima* and indica groups showed significant G×E interactions for number of panicles, while the japonica group did not (Tables 3.4b1, 3.4c1 and 3.4d1). At cluster level Glab_UpperCoast, Ind_Gc Ind_Gh and Jap_GbGh showed significant G×E interactions (Tables 3.4b2, 3.4b3, 3.4c2, 3.4c3, 3.4d2 and 3.4d3). There was no such interaction for genotypes of the clusters Jap_SL and Glab_LowerCoast.

The *glaberrima* group showed the highest average number of panicles. Cluster Ind_Gc showed a significantly higher average number of panicles than Ind_Gh and performed similar to the *glaberrima* group (Table 3.5). Within the japonica group, the highest number of panicles was observed with Jap_SL cluster in Sierra Leone, the origin of the cluster. For all botanical groups and variety clusters, the number of panicles was relatively low in Sierra Leone and Guinea Bissau and highest in Guinea (Figure 3.9). An opposite trend was observed only with Jap_SL. This cluster showed more panicles in Sierra Leone. This strengthens our view that Jap_SL is specifically adapted to conditions in Sierra Leone.

The japonica group showed the lowest numbers of panicles throughout the whole range of A and yield values (Figures 3.10c and 3.11d) and across locations (Figure 3.9). The number of panicles in relation to A and yield hardly overlapped for g*laberrima* and japonica (Figures 3.10c and 3.10d) and differed significantly (Table 3.5). The *glaberrima* group showed a decreasing trend in panicle number as yield values increased (r = -0.453**). For the japonica and indica groups no such decreasing trend was observed. For the indica group, the relation between panicle number and yield seemed to be intermediate between the tendencies for the g*laberrima* and japonica groups (Figure 3.10d), thus confirming its group distinctiveness (Table 3.5).

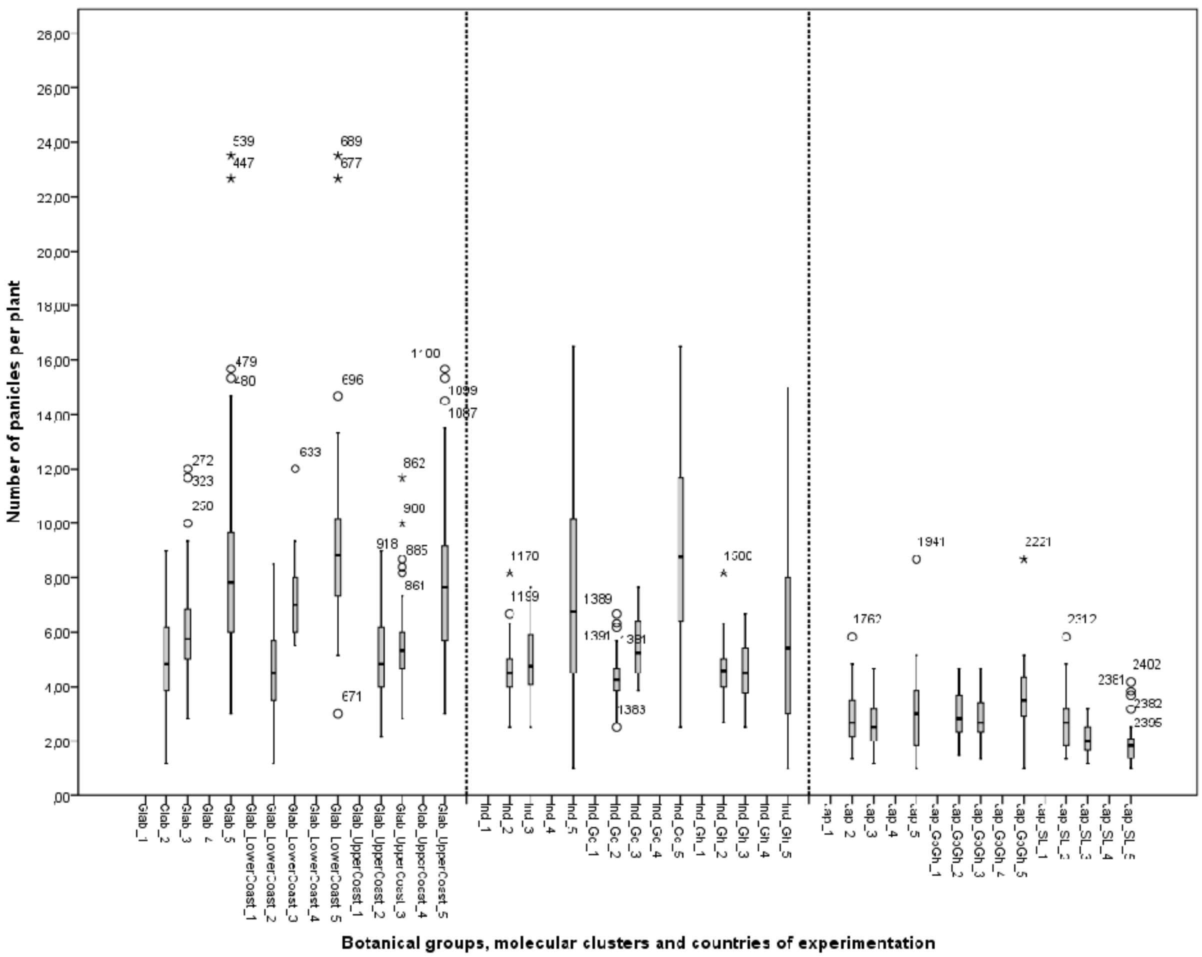
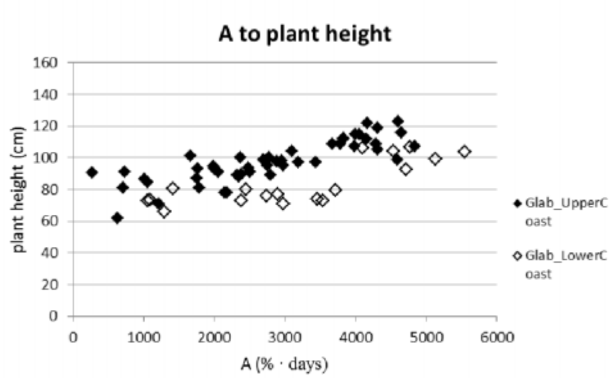
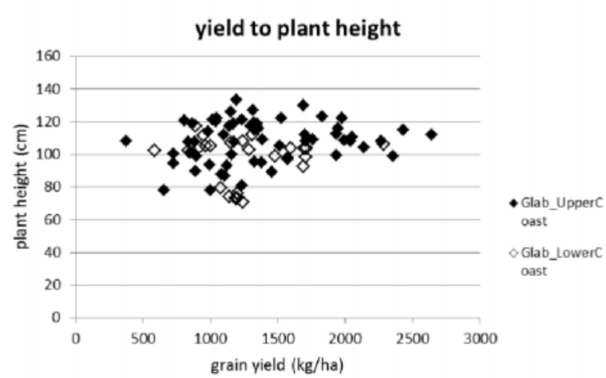


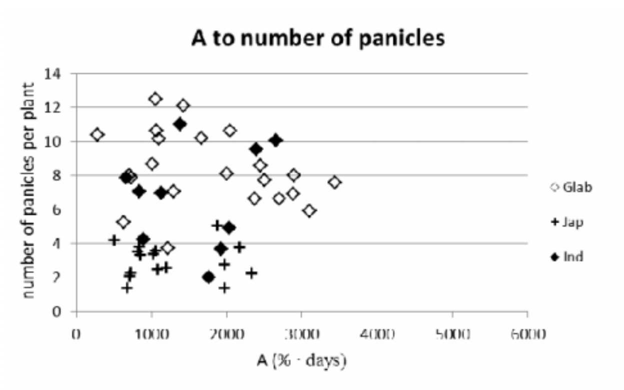
Figure 3.9: Number of panicles in five experimental sites.
1: Ghana; 2: Sierra Leone; 3: Guinea Bissau; 4: Togo and 5: Guinea. See materials and methods section for coding of the clusters

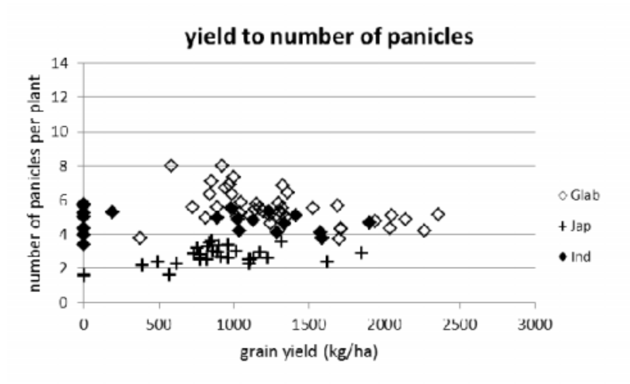


a



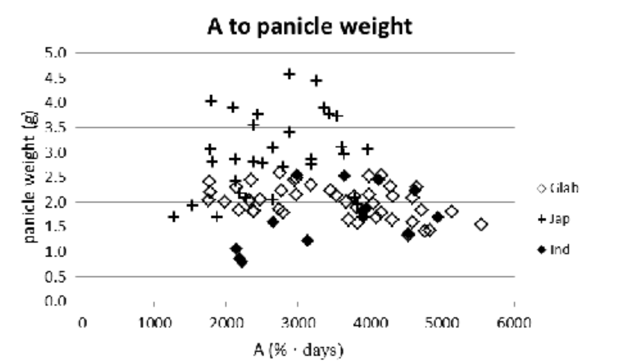
b

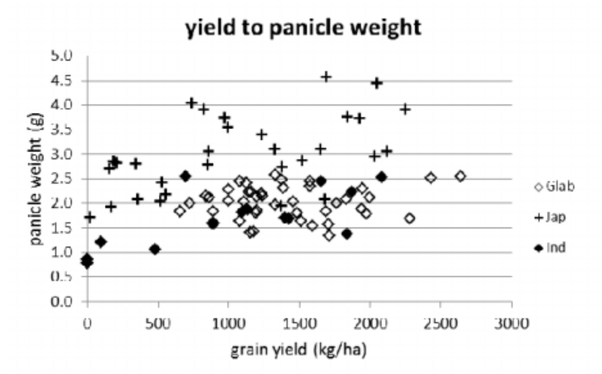




c

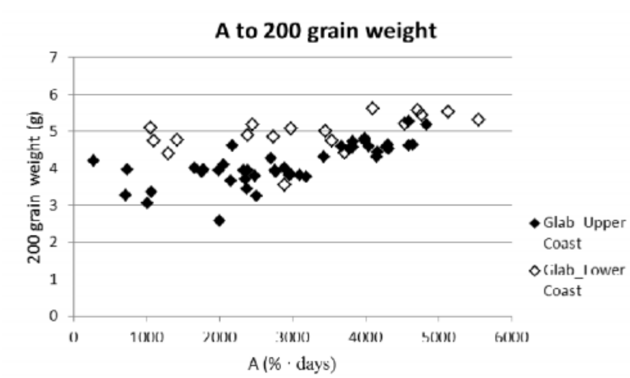
d

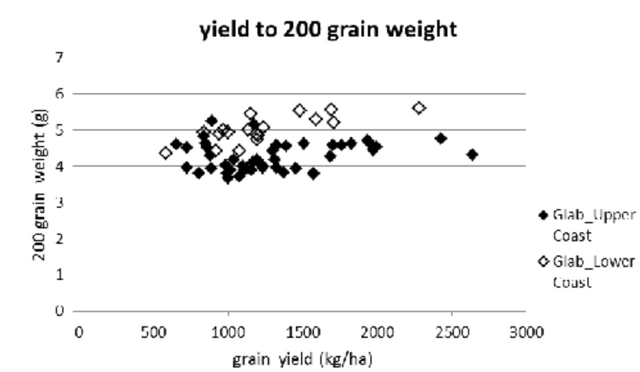




e

f





g

h

Figure 3.10: Accumulated canopy cover or yield plotted against some yield components
The legend shows the different botanical groups or the clusters within the *glaberrima* botanical group. Values presented are averages of 5 replications. See materials and methods section for coding of the clusters.
The legend shows the different botanical groups or the clusters within the *glaberrima* botanical group. Values presented are averages of 5 replications. See materials and methods section for coding of the clusters

3.3.5 Number of tillers

The three botanical groups showed significant G×E interactions for the number of tillers produced per plant. This means that, in general, genotypes composing the three botanical groups followed different strategies in tiller production across environments (Figure 3.11). At cluster level, G×E interactions were also found for the two *glaberrima* clusters and for the Ind_Gc cluster, but were absent for the

Ind_Gh cluster and the two clusters of japonica. This implying that within the japonica clusters and the Ind_Gh cluster genotypes all vary tiller production in a similar way across environments.

Indica as well as *glaberrima* showed intensive tillering (Table 3.5). An increase in tiller number was observed from more favourable (Sierra Leone and Ghana) to less favourable environments (Guinea, Togo and Guinea Bissau) for the indica cluster (Figure 3.11). One of the underlying mechanisms facilitating the increase of tillers under less favourable conditions is that generally (for all botanical groups and clusters) under less favourable conditions (Guinea and Togo) the time to flowering is longer than under more favourable conditions (Sierra Leone and Ghana) (Figure 3.14). It seems particularly the case that the indica group uses this time to produce tillers while the japonica and *glaberrima* groups responded in various other ways.

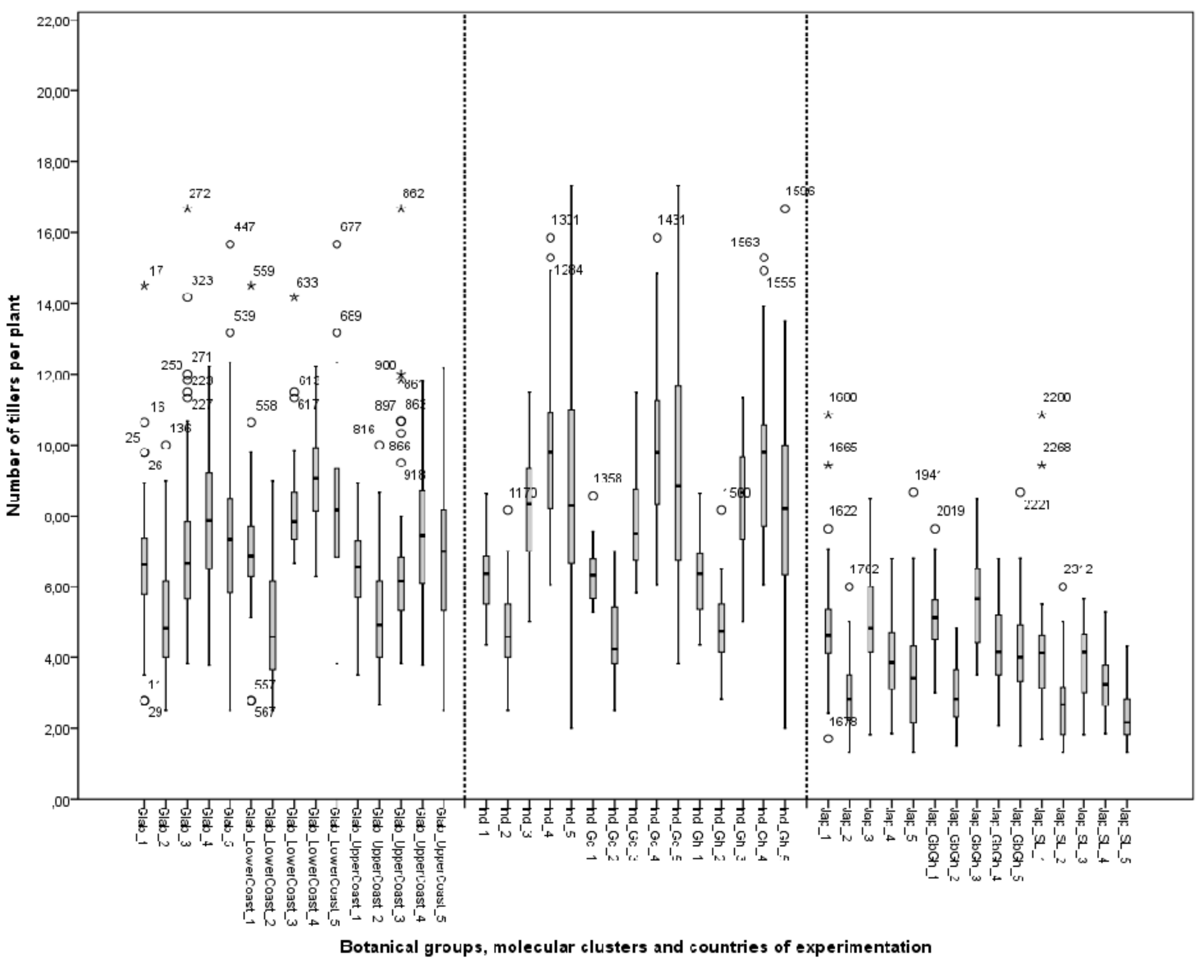


Figure 3.11: Number of tiller per plant in five experimental sites
1: Ghana; 2: Sierra Leone; 3: Guinea Bissau; 4: Togo and 5: Guinea. See materials and methods section for coding of the clusters

Figures 3.12b and 3.12d indicate that for the indica group there is a positive relationship between canopy cover and tillering in Guinea and Togo, while tillering remains constant at high A in Ghana (Figures 3.12b). However the positive relation in Guinea and Togo does not match with the relation between number of tillers and yield at low A because tillering remained high even when the crop failed to yield (Figure 3.12e).
Japonica showed a positive relationship between number of tillers and A (r = +0.604**, Figure 3.12c), but not for number of tillers and yield (Figure 3.12f). The two japonica clusters showed a similar

positive relation between A and number of tillers. The Jap_GbGh cluster clearly produced more tillers than the Jap_SL cluster (Table 3.5). This higher number of tillers contributed to a higher panicle number (although not significantly higher) which in turn might be linked to the significantly higher yield observed for Jap_GbGh.

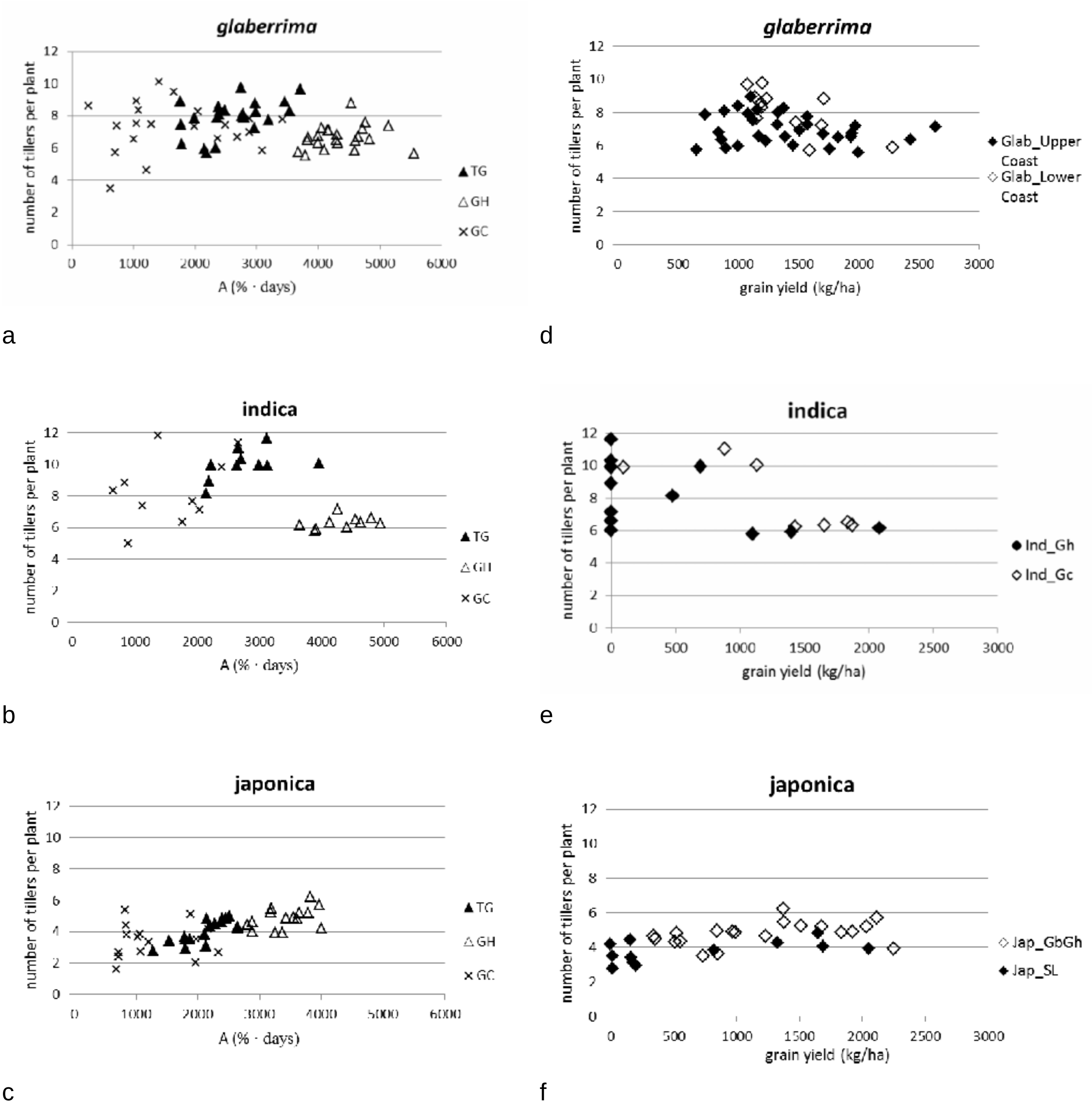


Figure 3.12: Relation between tiller number and accumulated canopy and tiller number and yield for botanical groups and molecular clusters.

Series TG, GH and GC respectively indicate observations from Togo, Ghana and Guinea. The numbers 1 and 2 indicate the first and second sowing. Values presented are averages of 5 replications. See materials and methods section for coding of the clusters.

Looking at the overall averages in Table 3.5 the ratio number of panicles over number of tillers was highest for *glaberrima* (0.94), followed by indica (0.72) and japonica (0.70), suggesting that the tillers of *glaberrima* produced more panicles. Particularly under less favourable conditions (e.g. Guinea Bissau) a difference was observed between botanical groups in the ratio of the number of panicles and tillers (Table 3.6). Of the botanical groups, only the clusters of the indica group varied, with tillers of Ind_Gc producing more panicles than those of Ind_Gh (0.8 and 0.65 respectively). However, looking at the averages per country for each botanical group and molecular cluster we observed that the increase in tillering for the indica group resulted in increased panicle production: the ratio of number of panicles over number of tillers remained stable or even increased at lower yield (Table 3.6). The combination of the high number of tillers and panicles for Ind_Gh together with low yield suggests that its panicles have a large percentage of non-formed (i.e. empty) grains.

In general the number of tillers correlated (r = 0.800**) with the number of panicles per plant which in turn correlated with A. The fact that the relationship between the number of tillers and A was not clear for all botanical groups might imply that other variables such as the size of the tillers, leaf width, leaf length and leaf blade angle, which were not measured in these experiments, might account for the overall poor relationships we observed between A and the number of tillers per plant. Vigour-related variables are known to vary between rice species, *O. glaberrima* being often more vigorous than *O. sativa* [10-12].

3.3.6 Time to 50% flowering

We observed that at low yield levels the time to 50% flowering was consistently higher for all genotypes than at higher yield levels (Figure 3.14). This suggests that under less favourable conditions genotypes generally delayed their flowering.

The longest average period until 50% flowering was observed with the indica group. The *glaberrima* group showed the shortest period until 50% flowering, suggesting that this group had a shorter vegetative cycle. The result agrees with farmers' assertions that *glaberrima* (e.g. farmer varieties Malaa and Jangjango) are often earlier than other traditional *sativa* varieties and thus are used to beat the pre-harvest hunger gap [20].

Comparing the negative relationship between time to 50% flowering and A it can be said that this relation is most clear for japonica and indica (r = -0.880** and r = -0.855** respectively). The same relation was observed at cluster level for these two botanical groups. The *glaberrima* group and its clusters showed lower correlations between 50% flowering and A (r = -0.538** for the botanical group). This might imply that the environmental conditions determining accumulated canopy cover (A) affected 50% flowering of the *glaberrima* and its clusters less than that of the other varieties. This suggests that *glaberrima* is more stable in terms of time to 50% flowering. An advantage of such stability would be that even under high stress conditions farmers do not run the risk that the crop will delay its flowering beyond the scope of the rainy season. This is more likely the case for the varieties from Upper Guinea Coast. Varieties from Lower Guinea Coast usually experience a short dry period 2 to 4 weeks after planting. In such conditions it is important for the rice crop not to flower too early. The stability in flowering time for the glaberrima group takes care of that.

Table 3.6: Average yield (kg ha^{-1}) in descending order from left to right, panicle number per plant, tiller number per plant and ratio between panicle number and tiller number across countries. The values for Guinea are put in the uttermost right column as the yield was not assessed

Botanical groups and clusters*		Ghana	Sierra Leone	Togo	Guinea Bissau	Guinea
Glaberrima	Yield	1660	1510	1164	1034	-
	Panicles	-	5.0	-	5.9	8.0
	Tillers	6.6	5.0	7.9	6.9	7.2
	Ratio		1.00		0.86	1.11
		Ghana	Sierra Leone	Guinea Bissau	Togo	Guinea
Japonica	Yield	1513	1061	759	504	-
	Panicles	-	2.9	2.6	-	3.0
	Tillers	4.9	2.9	5.1	4.0	3.5
	Ratio		0.98	0.52		0.86
		Sierra Leone	Ghana	Togo	Guinea Bissau	Guinea
Indica	Yield	1248	1132	329	317	-
	Panicles	4.5	-	-	4.9	7.2
	Tillers	4.7	6.3	9.3	8.2	8.3
	Ratio	0.96			0.60	0.88
		Ghana	Sierra Leone	Togo	Guinea Bissau	Guinea
Glab_UpperCoast	Yield	1664	1568	1160	1100	-
	Panicles	-	5.1	-	5.5	7.8
	Tillers	6.5	5.1	7.5	6.4	6.9
	Ratio		1.01		0.86	1.13
		Ghana	Sierra Leone	Togo	Guinea Bissau	Guinea
Glab_LowerCoast	Yield	1651	1356	1174	872	-
	Panicles	-	4.7	-	7.0	8.6
	Tillers	6.7	4.7	9.0	8.1	8.2
	Ratio		1.00		0.87	1.06
		Ghana	Sierra Leone	Guinea Bissau	Togo	Guinea
Jap_SL	Yield	1127	958	525	242	-
	Panicles	-	2.7	2.1	-	2.0
	Tillers	4.4	2.8	4.0	3.3	2.4
	Ratio		0.98	0.51		0.81
		Ghana	Sierra Leone	Guinea Bissau	Togo	Guinea
Jap_GbGh	Yield	1741	1123	869	662	-
	Panicles	-	2.9	2.9	-	3.6
	Tillers	5.1	3.0	5.5	4.4	4.1
	Ratio		0.98	0.52		0.88
		Sierra Leone	Ghana	Togo	Guinea Bissau	Guinea
Ind_Gh	Yield	1096	742	196	153	-
	Panicles	4.6	-	-	4.5	5.7
	Tillers	4.9	6.3	9.2	8.5	7.9
	Ratio	0.95			0.53	0.72
		Ghana	Sierra Leone	Guinea Bissau	Togo	Guinea
Ind_Gc	Yield	1699	1476	553	529	-
	Panicles	-	4.4	5.4	-	8.8
	Tillers	6.4	4.6	7.8	9.4	8.7
	Ratio		0.96	0.69		1.02

- : not measured. *See materials and methods section for coding of the clusters

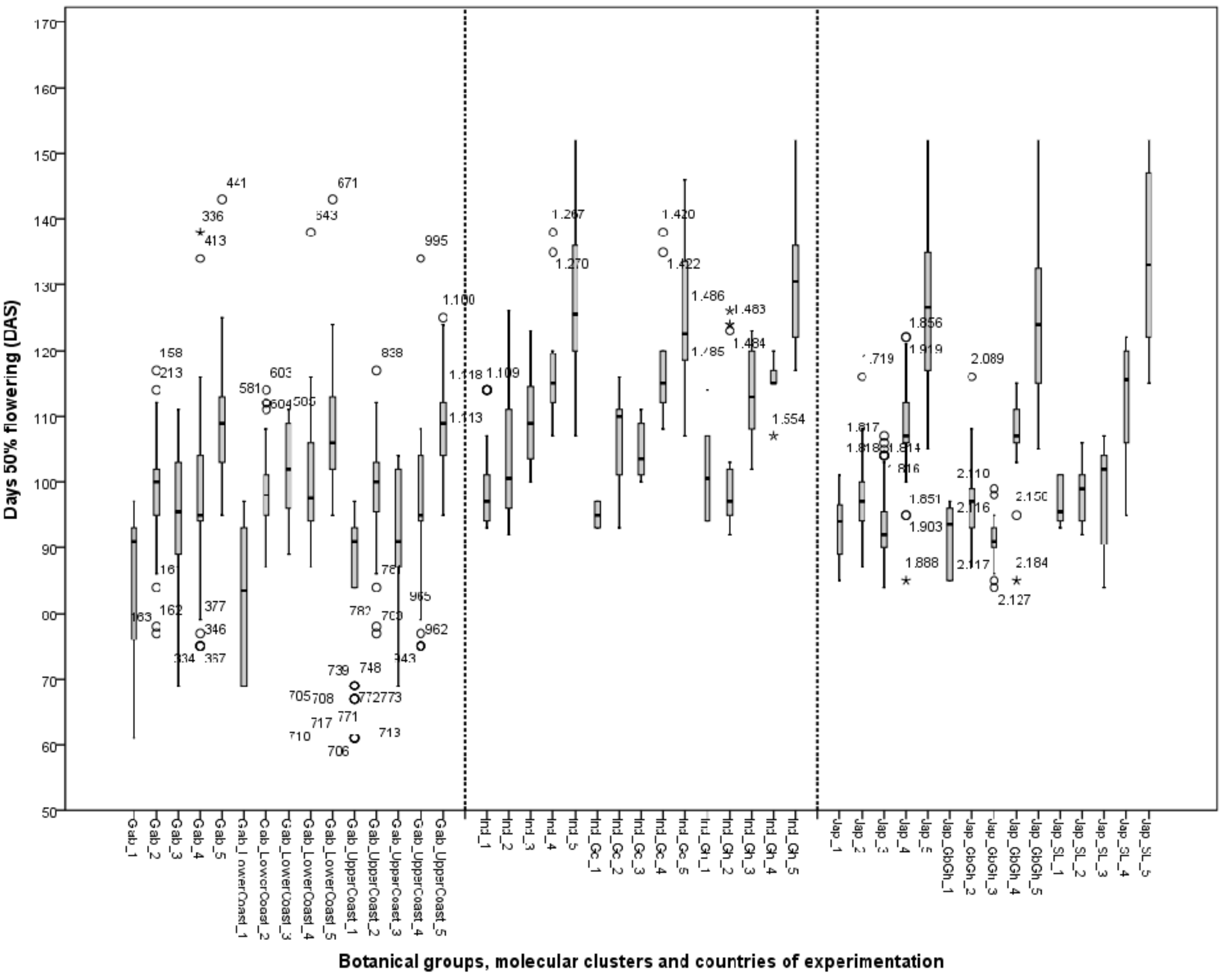


Figure 3.14: Days to 50% flowering in five experimental sites.
1: Ghana; 2: Sierra Leone; 3: Guinea Bissau; 4: Togo and 5: Guinea. See materials and methods section for coding of the clusters

3.3.7 Panicle weight

Significant G×E interactions were found only for japonica. Sowing effects were observed for japonica group (as part of the three way interaction between sowing, location and genotype), for the indica botanical group, and for the Ind_Gc cluster. Of the clusters only Ind_Gc showed variations of panicles weight by sowing dates. The panicle weight and yield highly correlated positively for Ind_Gc (r = 0.755*) and Jap_SL (r = 0.824**). For other clusters no significant relations were observed between panicle weight and yield. These observations suggest that the japonica and indica groups were more sensitive to sowing date (less robust) than the *glaberrima* group and its clusters.

Panicle weight for *glaberrima* and indica was significantly lower than for japonica (Table 3.5). When yield and A increased, panicle weight also increased, for the indica group (0.549*). For the japonica group there was no relation between panicle weight and A. However, an increasing trend in panicle weight was observed when yield increased (0.601**) (Figures 3.10e and 3.10f). Such trends were not observed for the *glaberrima* group, suggesting that panicle weight of *glaberrima* was more stable. No significant differences or trends were found, for clusters within the *glaberrima*, japonica and indica groups, for panicle weight, with the exception of Jap_SL, which showed a positive relation with A (r = 0.674*). Panicle weight for cluster Jap_GbGh showed no relation with A.

3.3.8 Panicle length

Significant G×E interactions were found for all botanical groups. The Glab_UpperCoast, Jap_GbGh and Jap_SL clusters all showed significant G×E interactions. There was a tendency towards short panicle production in Ghana and Sierra Leone, the countries where the yields were generally high (Figure 3.14).

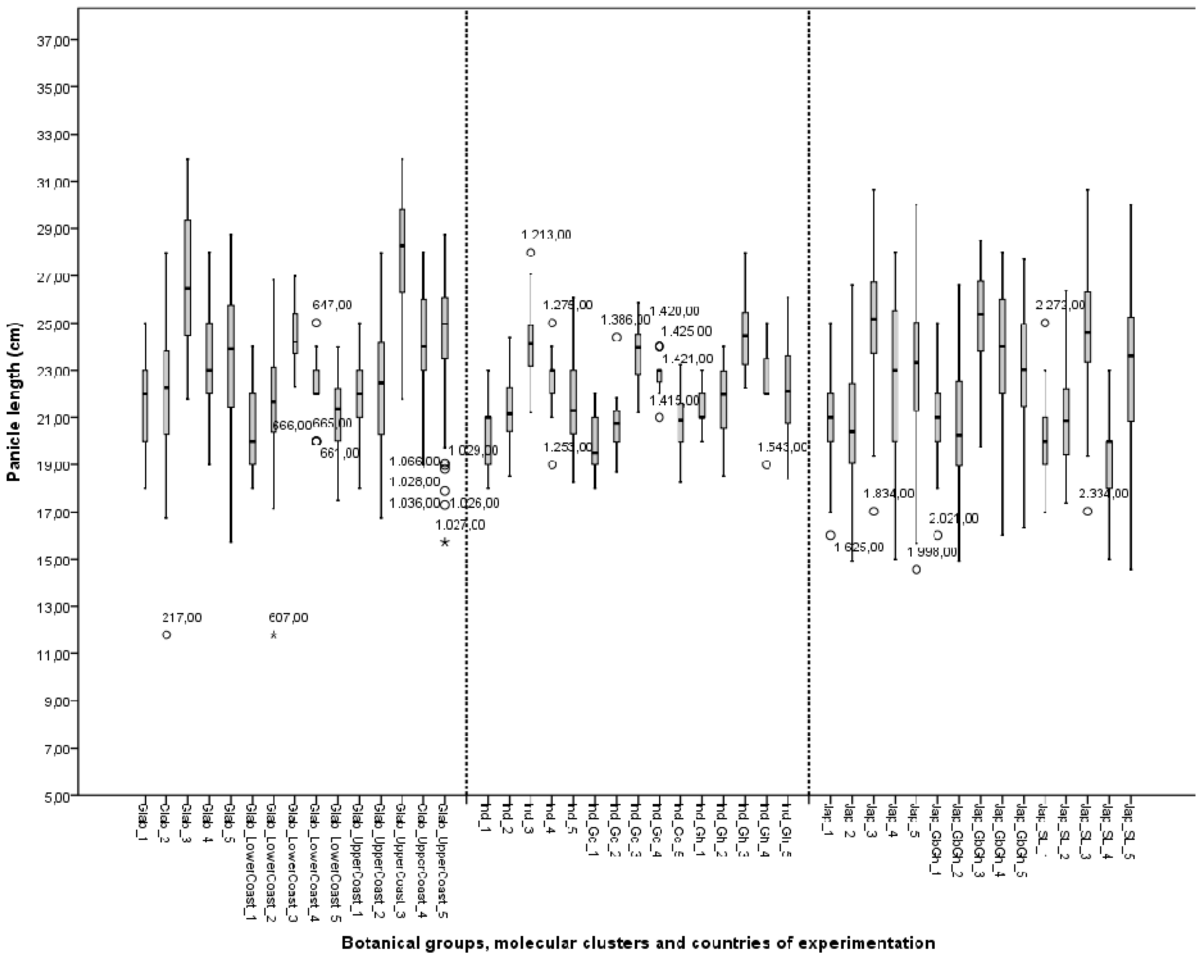


Figure 3.14: Panicle length in five experimental sites.

1: Ghana; 2: Sierra Leone; 3: Guinea Bissau; 4: Togo and 5: Guinea. See materials and methods section for coding of the clusters

The cluster Glab_UpperCoast produced significantly longer panicles than all other clusters except for Jap_GbGh. The fact that the Glab_UpperCoast cluster had a panicle weight similar to that of Glab_LowerCoast implies that Glab_UpperCoast produced more grains of smaller size per panicle than Glab_LowerCoast. The cluster Glab_UpperCoast also showed a rather slight negative correlation between panicle length and yield (r = -0.332**), A (r = -0.335*) and a somewhat stronger negative correlation with the 200 grain weight (r = -0.427**). This means that for Glab_UpperCoast cluster production of short panicles corresponded with high A, yield and grain weight. This implies that under stress conditions (i.e. low yield and low A) Glab_UpperCoast invested more in panicle length (Figure 3.14). The negative relation between yield and panicle length was also observed, somewhat more strongly, for Glab_LowerCoast (r = -0.708**), Ind_Gc (r = -0.850**), Ind_Gh (r = -0.664**) and Jap_GbGh (r = -0.450**). Jap_SL did not show any relation between yield and panicle length.

3.3.9 200 grain weight

Significant G×E interactions were found for 200 grain weight for the *glaberrima* group and the Glab_UpperCoast cluster, suggesting that the genotypes composing the Glab_UpperCoast cluster responded differently across environments for 200 grain weight. This might be a factor in observed robustness in yield for this cluster. The absence of G×E interactions within the other botanical groups suggests that the 200 grain weight is genetically determined. The high estimate of wide sense heritability (H^2 = 80%; Table 3.7) confirms this general trend for indica. However, the relatively low wide sense heritability estimate for japonica (H^2 = 32%; Table 3.7) as compared to other botanical groups indicates that environmental conditions might have some considerable impact on the 200 grain weight of japonica. However, it is only with the *glaberrima* group, and not for japonica or indica, that a significant location effect was found.

Significant genotype effects were observed for the japonica group and Jap_GbGh cluster. No significant genotype effect was observed for the varieties of the Jap_SL cluster, suggesting little variation for 200 grain weight in the Jap_SL cluster and large genotypic variation in the Jap-GbGh cluster. The indica group also showed a significant genotype effect. Not enough data were available for an ANOVA of the Ind_Gh group.

The botanical groups showed little variation for 200 grain weight, but the average 200 grain weight varied significantly among the clusters of each botanical group. Within the *glaberrima* group the Glab_UpperCoast average was lower than that of the Glab_Lower coast cluster. The average 200 grain weight for the Jap_GbGh cluster was higher than that of the Jap_SL cluster and the Ind_Gc cluster average was higher than that of Ind_Gh cluster.

Japonica showed a fairly strong positive correlation between A and 200 grain weight: r = 0.70**, against r = 0.596** and r = 0.581** for the *glaberrima* and indica groups, respectively. At low values of A, the Ind_Gh cluster and japonica group tended to produce more empty or poorly developed grains, as represented in Figure 3.15. This is consistent with our summary finding under the section on tillering that extra tillers were produced at lower levels of A and yield contained more empty grains. The trends observed between A and 200 grain weight were also observed between 200 grains weight and yield, but only with the indica and japonica groups.

A clear divide was observed for the 200 grain values for Glab_UpperCoast and Glab_LowerCoast (Figures 3.10g, 3.10h). Figures 3.10g and 3.10h show that when canopy cover decreased the 200 grain weight for the Glab_UpperCoast cluster decreased more than the 200 grain weight for the Glab_LowerCoast cluster. Therefore, it can be concluded that the Glab_LowerCoast cluster was less susceptible to variation in environment. The 200 grain weight for clusters within indica and japonica decreased in a similar way when A and yield decreased. These clusters were similarly sensitive to the environment. In general, all *glaberrima* clusters (and also Ind_Gc) maintained their grain weight across environments even at low yield (Figure 3.15). This is contrary to the Ind_Gh and two japonica clusters, for which the empty grains increased at lower yield levels. This underscores the claim we make for the robustness of farmer varieties of *glaberrima* and Ind_Gc, and the consequent ability of these types consistently to produce good grains throughout a range of difficult environments.

Table 3.7: Wide sense heritability estimates (per botanical group and cluster)

	V_{max}	A	Plant height	# Tillers	50% Flowering	# Panicles	Panicle length	Panicle weight	200 grain weight	Yield/ha
All genotypes	60	45	60	79	86	77	67	75	49	76
Glaberrima	35	12	68	17	86	1	61	48	65	43
Indica	50	55	61	0	64	5	30	56	80	90
Japonica	76	63	45	62	59	56	69	48	32	59

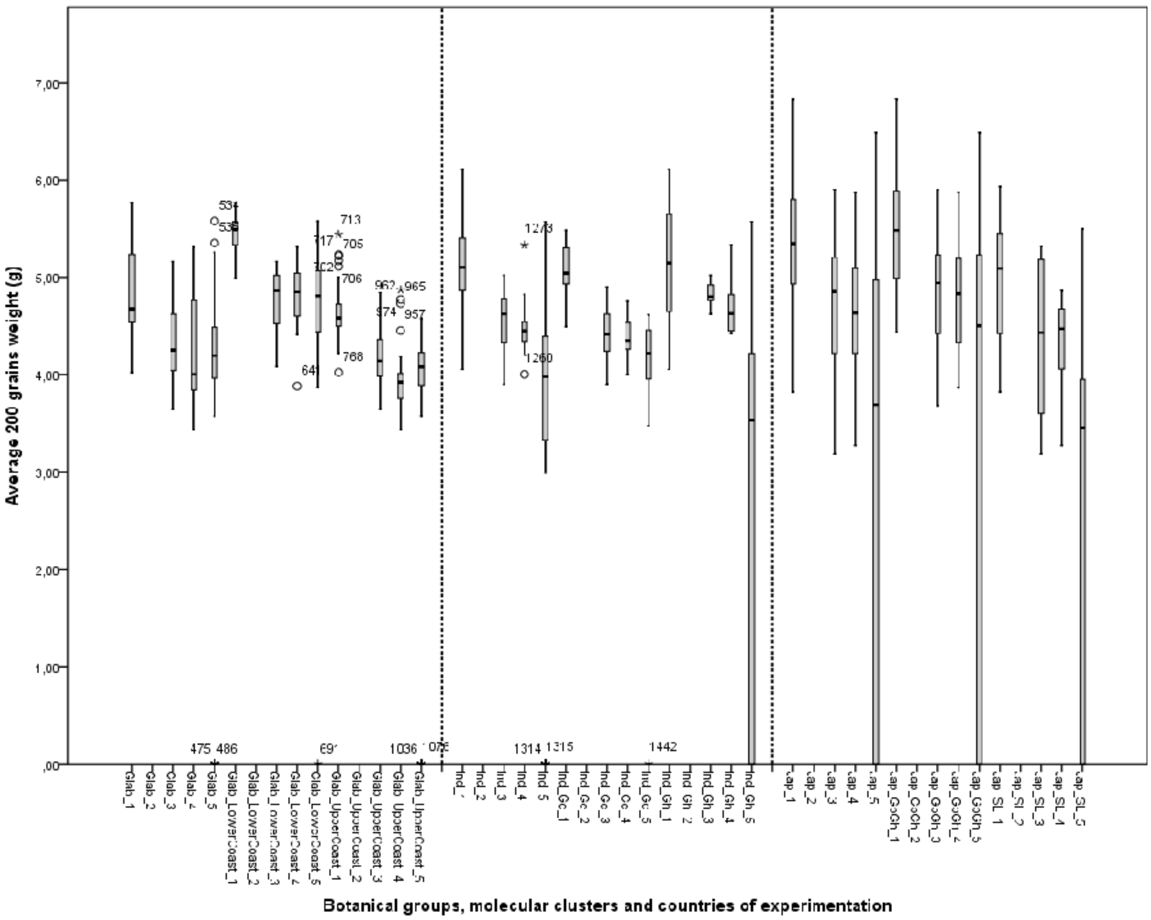


Figure 3.15: Average 200 grain weight in five experimental sites
1: Ghana; 2: Sierra Leone; 3: Guinea Bissau; 4: Togo and 5: Guinea. See materials and methods section for coding of the clusters

3.4 SIGNIFICANCE OF THE FINDINGS AND CONCLUDING REMARKS

3.4.1 Summarizing the relation between the yield and yield determining parameters

This study shows that a large number of farmer varieties are able to adapt to large variations in environment. Our findings on tillering, yield, A, flowering and number of panicles suggest the existence of three different physiological strategies of adaptability for each of the botanical groups, which we now attempt to summarise.

Glaberrima

Across environments *O. glaberrima* consistently showed the highest values for maximum canopy, plant height, number of panicles and yield. Also remarkable was the absence of crop failure for the *glaberrima* group; this helps explain why it makes a more reliable and secure choice for farmers with limited inputs and obliged to farm under stressful conditions. In addition, the *glaberrima* group showed the shortest time to 50% flowering, a useful property for farmers affected by a pre-harvest hunger gap [20].

Overall, accumulated canopy, maximum canopy cover and yield were similar for Glab_LowerCoast and Glab_Upper coast clusters. But the two clusters differed in their strategy of canopy building: Glab_LowerCoast invested more in tiller production while Glab_UpperCoast produced taller plants.

When A decreased, Glab_LowerCoast was better able to maintain its grain weight than Glab_UpperCoast and therefore appears to be more stable in grain weight. Under stress conditions (i.e. low yield and low A) Glab_UpperCoast invested more in panicle length. Also *glaberrima* from the lower coast showed higher values for 200 grain weight and the decrease of the 200 grain weight at lower yield levels was also less. However, the panicle weight for Glab_LowerCoast was less than that of the cluster Glab_UpperCoast. This also applies to panicle length and plant height. The Glab_LowerCoast varieties thus tended to invest more in grain weight, whereas Glab_UpperCoast varieties produced more grains per panicle. These two distinct strategies led to similar yields for these two clusters.

In sum, among the studied genotypes, those of *O. glaberrima* developed different strategies of adaptation, but interestingly, these strategies led to similar performance throughout the range of environments tested, demonstrating the robustness of this group of rices when compared to other botanical groups. These strategies relate to the area of collection of the varieties and also coincide with molecular groupings [cf. 15].

The *glaberrima* showed more G×E interactions than indica and japonica. This is worthy of note, since it is sometimes assumed that *O. glaberrima* is genetically less diverse than indica and japonica. Molecular analysis conducted by Nuijten et al. [15] showed that *glaberrima* and japonica were roughly similar in terms of genetic diversity: (H_e = 0.034; n = 66) and (H_e = 0.045; n = 87), respectively).

Indica

In less favourable environments varieties of the indica group produced more tillers than in the more favourable environments. The underlying mechanism seems to be that under less favourable conditions flowering is delayed and at the same time the tillering period is prolonged. The result is that at higher yield levels indica produced fewer tillers. At lower yield levels indica seemed less vigorous, as the increase in number of tillers did not lead to an increase in A. These tillers were, however, productive because an increase in tillering led to an increase in panicle production. The fact that an increase in panicle production did not lead to an increase in yield is a product of the crop failure observed for many plots in the less favourable environments, and the many panicles with unfilled grains.

The cluster Ind_Gc showed the highest plant height. This observation together with observations of high V_{max} and A for Ind_Gc implies that Ind_Gc is more vigorous compared to Ind_Gh. This vigour tuned into higher yield for Ind_Gc. The Ind_Gc cluster also displayed the same average plant height as the Glab_Upper coast cluster.

This shows that the Ind_Gc cluster, like *glaberrima,* is able to maintain its yield. At lower yield levels, however, it follows a different physiological strategy of adaptation than *glaberrima,* as it produced the largest number of tillers. But compared to *glaberrima*, these tillers contributed less to A and contributed also less to yield maintenance, as there were high numbers of unfilled grains.

In sum, the indica from Guinea resembled the *glaberrima* group in several ways. Like *glaberrima* it was able to maintain its number of tillers and also increased its number of panicles at low yield levels. Like *glaberrima*, it showed significant G×E interactions that helped to stabilise A and V_{max}.

Japonica

Low canopy cover and limited tiller and panicle production seem typical for the japonica group. At a high level of A, japonica consistently produced more tillers. This relation seemed linear, as was the relation between yield and accumulated canopy, thus suggesting that an increase in tillering contributes to canopy formation and yield. In addition, japonica slightly increased its panicle number while tillering, A and V_{max} were not maintained at low yield levels. Instead of investing in high tiller number japonica invested more in panicle weight: when compared with *glaberrima* and indica panicle weight was approximately 50% to 100% higher.

The Jap_GbGh cluster maintained a yield across environments similar to that of the *glaberrima* group and indica cluster from Guinea, although it failed to maintain A at lower yield level. In contrast, varieties in the Jap_SL cluster only yielded well in Sierra Leone. This might suggest that these japonica varieties were highly adapted to a specific niche. In Sierra Leone, however, varieties in the japonica group are often found bridging an ecological gradient from lowland to upland [20].

3.4.2 Observed behaviour of the studied genotypes in relation to the area of collection

Glab_LowerCoast: Farmers in the Togo Hills (Togo mountain ranges) in Ghana and Togo traditionally used these varieties mainly on stony hills and slopes with poor soil because political conflict and war drove them into mountainous areas, since life on the plains was too dangerous. Reliability of yield was very important in these conditions and rice was probably once the main carbohydrate crop. The data for this cluster indeed show that they are highly reliable in relation to yield. Nowadays these varieties are cultivated on the Ghanaian slopes of the Togo Hills only for ceremonial reasons, because lowland farming has been added to the local farming repertoire since the 1960s, and other crops like cassava and maize are now more important than previously [21]. Occasionally African rice is used on the Ghanaian slopes and in the lowlands of the Togo Hills when farmers are very late with sowing rice. African rice is used because of its short cycle. Farmers in the Togo Hills (Danyi Plateau) grow only African rice, which is an important secondary crop. They said they have tried other varieties but nothing works as well in the hills as the rices of the Glab_LowerCoast cluster.

Glab_UpperCoast: The upper West African coast includes f two secondary centres of domestication and diversity for *O. glaberrima* [22], so we might not expect a great deal of similarity in the behaviour of genotypes collected from this region (on a transect from Senegal to Sierra Leone). When comparing the Glab_LowerCoast to Glab_UpperCoast in our experiments the differences observed within and between clusters appear to reflect the fact that rice farmers on the Upper Coast grow rice as their main staple, and work a much broader range of environments (and thus exercise a larger range of selection pressures) than the farmers in the Togo Hills. Farmers experience quite different constraints in their farming systems. In the semi-arid zone of the upper coast (Senegal, Gambia and Guinea Bissau), a short rainy seasons (3 to 4 months) may have forced farmers to select for short duration *glaberrima* types better adapted to their conditions. In these conditions, farmers appear to have selected taller plants with longer panicles and fewer tillers.

In the forest belt of Sierra Leone and Guinea, with a much longer rainfall period (6 to 7 months) the environment is favourable for longer duration crops. However, farmers still cultivate *O. glaberrima* to some extent because of its adaptability to poor, eroded soils and tolerance to drought at the beginning and end of the rainy season. In the forest belt farmers report many weed problems [20], particularly in areas with short fallow periods. Selecting for tall plants could also help in suppressing weed. In addition farmers seem to have selected *glaberrima* types that were less photoperiod sensitive, facilitating the planting of short-duration types to be sown in late April and used as hunger breaker crops.

Ind_Gc: These varieties appeared to be stable in yield and in that way resemble *O. glaberrima* and Jap_GbGh. The Ind_Gc types are widely cultivated in the area of collection, under typical upland conditions on poor soils. Farmers state that rices in the Ind_Gc cluster resemble *O. glaberrima* in being well adapted to poor soils. They are also drought tolerant when compared to other *O. sativa* varieties (e.g. Samba, Dalifodé, Podê) and also yield well under good conditions (as well as well enough, under poor conditions). They dominate upland rice cultivation in their area of collection because, as farmers state, *O. glaberrima* lodges at complete maturity, as frequently mentioned as a drawback by a number of rice researchers [7,23,24]. Farmers claim this results in low yields, especially when they lack sufficient labour for a timely harvest.

Ind_Gh: These are varieties that performed relatively poorly in our experiments, except in Sierra Leone. In addition to cultivation under upland conditions (in the Ghanaian Togo Hills) these varieties are also cultivated very successfully in the adjacent lowlands. Since the 1960s lowland cultivation has been added to the farming systems of the different minority groups living at the foot of the Togo Hills. Ever since that time farmers have been experimenting with lowland varieties in the upland area and vice versa. The varieties in the Ind_Gh cluster are probably adapted to very specific upland conditions in the Ghanaian Togo mountain ranges, conditions apparently replicated in experimental conditions at the foot of the Sierra Leonean escarpment (Kamajei Chiefdom).

Jap_GbGh: These varieties are commonly planted under upland conditions. They are equal in yield to the two *O. glaberrima* clusters and the Ind_Gc cluster. Farmers grow them for their white pericarp, good taste and the fact that they fit the rainy season calendar very well, being not too short, and not too long. Farmers visiting the trial in Guinea Bissau were very impressed with the growth of some varieties of this japonica cluster, and indicated they would like to grow these varieties in the following season. However, upon realising the pericarp colour was red these farmers lost interest, as they have a strong preference for white seed colour. Elsewhere (in Ghana and Sierra Leone, for example) farmers actually prefer varieties with red pericarp. This underlines the importance of taking into account cultural factors in crop development [4].

Jap_SL: These varieties seem to be very specifically adapted to Sierra Leonean conditions. They are widely cultivated in this area of collection. Farmers who are conversant with them typically look for toposequences to allow flexible planting up and down slopes, taking account of the stage of the season. They are thus adapted to a mid-slope planting scenario, between wetland and upland varieties. The mid-slope niche is very common in an undulating, well-watered country such as Sierra Leone, but is less common in the other areas in which we carried out experiments. This may explain why this particular group only seemed to do well in its zone of collection. It has been selected for robustness in a niche.

3.5 CONCLUSION

It can be concluded, that the *glaberrima* group as a whole, and the indica cluster from Guinea and japonica from Guinea Bissau and Ghana, were more plastic than other rices in the study, allowing them to be more constant in yield, A, and in number of tillers and panicles. Seemingly, farmer selection in Guinea has created a group of Asian rices that resemble in performance the highly adapted African rices of the region.

This paper has presented evidence that farmer rice varieties in coastal West Africa are, for the most part, highly robust, and well-adapted to a range of sub-optimal farming conditions. A case has been made that much of this robustness is a product of adaption. An implication is that many farmer varieties will maintain their performance across a range of low-input conditions, and thus might be very useful to farmers in neighbouring countries. More efforts should be made to conserve, evaluate and distribute farmer-selected rice planting materials in the region. Farmers themselves should be consulted about the best way to develop relevant modalities of dissemination, and involved directly in any such activity.

Table 3.8: Pearson correlations between yield components and crop characteristics

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
A (%)	All	-,661**	,596**	-,256**	,165*	,122	-,225*	,568**	,478**	1
	Glab	-,538**	,671**	-,355**	-,130	-,280	-,417**	,596**	,450**	1
	Ind	-,855**	,555**	-,132	-,314	,137	,503	,581**	,483*	1
	Jap	-,880**	,621**	-,317*	,604**	-,009	,251	,692**	,706**	1
	Glab_LowerCoast	-,668**	,796**	-,362	-,512*	-,521	-,551	,499*	,451	1
	Glab_UpperCoast	-,482**	,826**	-,335*	-,087	-,228	-,268	,725**	,476**	1
	Ind_Gc	-,854**	,784**	-,227	-,532	,478	,623	,834**	,857**	1
	Ind_Gh	-,873**	,485	,040	-,170	,314	,574	,612*	,137	1
	Jap_GbGh	-,896**	,635**	-,319	,608**	,076	-,046	,708**	,848**	1
	Jap_SL	-,877**	,640**	-,479	,784**	-,034	,674*	,628*	,497	1

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
Plant height (cm)	All	-,390**	1	,225**	-,206**	-,168*	,179	,301**	,346**	,596**
	Glab	-,194*	1	,337**	-,384**	-,530**	-,067	,051	,168	,671**
	Ind	-,693**	1	,274	-,495**	-,113	,580*	,631**	,392*	,555**
	Jap	-,593**	1	,034	,093	-,017	,442*	,348**	,420**	,621**
	Glab_UpperCoast	-,113	1	,290**	-,191	-,408**	-,098	,438**	,181	,826**
	Glab_LowerCoast	-,335	1	,152	-,550**	-,677**	-,788**	,359	,020	,796**
	Ind_Gh	-,649**	1	,450*	-,520**	,143	,674	,682*	,393	,485
	Ind_Gc	-,751**	1	,123	-,583**	-,673*	,670	,615*	,228	,784**
	Jap_GbGh	-,699**	1	-,139	,061	-,134	,229	,359*	,482**	,635**
	Jap_SL	-,548**	1	,323	,300	,254	,727*	,368	,452*	,640**

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle Weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
Number of tillers	All	-,018	-,206**	,182**	1	,800**	-,562**	,147	-,125	,165*
	Glab	,111	-,384**	,107	1	,815**	,025	,145	-,328**	-,130
	Ind	,413**	-,495**	,484**	1	,677**	-,361	,089	-,573**	-,314
	Jap	-,432**	,093	,192	1	,518**	-,018	,564**	,239	,604**
	Glab_UpperCoast	,043	-,191	,220	1	,768**	,232	-,137	-,272*	-,087
	Glab_LowerCoast	,193	-,550**	,338	1	,857**	,296	-,389	-,446*	-,512*
	Ind_Gc	,497*	-,583**	,463*	1	,895**	-,527	-,488	-,616*	-,532
	Ind_Gh	,370	-,520**	,600**	1	,525*	-,110	,211	-,594**	-,170
	Jap_GbGh	-,274	,061	,335*	1	,301	-,357	,394*	,042	,608**
	Jap_SL	-,619**	,300	-,142	1	,420	,446	,705**	,236	,784**

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
Days to 50% flowering	All	1	-,390**	,073	-,018	,045	,101	-,581**	-,298**	-,661**
	Glab	1	-,194*	,211*	,111	,304*	,464**	-,515**	,080	-,538**
	Ind	1	-,693**	,115	,413**	,355	-,306	-,839**	-,316	-,855**
	Jap	1	-,593**	,138	-,432**	-,029	-,237	-,716**	-,511**	-,880**
	Glab_UpperCoast	1	-,113	,272*	,043	,385**	,641**	-,705**	,266*	-,482**
	Glab_LowerCoast	1	-,335	,189	,193	,099	,245	-,714**	-,428*	-,668**
	Ind_Gc	1	-,751**	,119	,497*	,589*	-,416	-,878**	-,403	-,854**
	Ind_Gh	1	-,649**	,073	,370	,262	-,221	-,862**	-,273	-,873**
	Jap_GbGh	1	-,699**	,058	-,274	,459*	-,054	-,685**	-,559**	-,896**
	Jap_SL	1	-,548**	,289	-,619**	-,449	-,611	-,702**	-,342	-,877**

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
Number of panicles	All	,045	-,168*	,120	,800**	1	.[a]	,282*	,150	,122
	Glab	,304*	-,530**	,023	,815**	1	.[a]	,083	-,453**	-,280
	Ind	,355	-,113	,124	,677**	1	.[a]	,638*	-,201	,137
	Jap	-,029	-,017	-,085	,518**	1	.[a]	,207	,474**	-,009
	Glab_LowerCoast	,099	-,677**	,099	,857**	1	.[a]	,159	-,824**	-,521
	Glab_UpperCoast	,385**	-,408**	,130	,768**	1	.[a]	-,335	-,281	-,228
	Ind_Gc	,589*	-,673*	-,145	,895**	1	.[a]	-,002	-,677	,478
	Ind_Gh	,262	,143	,485*	,525*	1	.[a]	,707	-,022	,314
	Jap_GbGh	,459*	-,134	,091	,301	1	.[a]	-,116	,038	,076
	Jap_SL	-,449	,254	-,353	,420	1	.[a]	,321	,717**	-,034

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
Panicle length (cm)	All	,073	,225**	1	,182**	,120	,102	-,187*	-,293**	-,256**
	Glab	,211*	,337**	1	,107	,023	,731**	-,542**	-,338**	-,355**
	Ind	,115	,274	1	,484**	,124	-,128	,240	-,767**	-,132
	Jap	,138	,034	1	,192	-,085	,065	-,159	-,338**	-,317*
	Glab_UpperCoast	,272*	,290**	1	,220	,130	,728**	-,427**	-,332**	-,335*
	Glab_LowerCoast	,189	,152	1	,338	,099	,525	-,319	-,708**	-,362
	Ind_Gc	,119	,123	1	,463*	-,145	-,488	-,328	-,850**	-,227
	Ind_Gh	,073	,450*	1	,600**	,485*	,868	,511	-,664**	,040
	Jap_GbGh	,058	-,139	1	,335*	,091	,087	-,136	-,450**	-,319
	Jap_SL	,289	,323	1	-,142	-,353	,465	-,379	-,313	-,479

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
Panicle weight (g)	All	,101	,179	,102	-,562**	.[a]	1	,231*	,228*	-,225*
	Glab	,464**	-,067	,731**	,025	.[a]	1	-,625**	,109	-,417**
	Ind	-,306	,580*	-,128	-,361	.[a]	1	,716**	,701**	,503
	Jap	-,237	,442*	,065	-,018	.[a]	1	,379*	,563**	,251
	Glab_UpperCoast	,641**	-,098	,728**	,232	.[a]	1	-,553**	,243	-,268
	Glab_LowerCoast	,245	-,788**	,525	,296	.[a]	1	-,299	-,347	-,551
	Ind_Gc	-,416	,670	-,488	-,527	.[a]	1	,778*	,755*	,623
	Ind_Gh	-,221	,674	,868	-,110	.[a]	1	,617	,702	,574
	Jap_GbGh	-,054	,229	,087	-,357	.[a]	1	,563**	,382	-,046
	Jap_SL	-,611	,727*	,465	,446	.[a]	1	,320	,824**	,674*

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
200 grain weight (g)	All	-,581**	,301**	-,187*	,147	,282*	,231*	1	,369**	,568**
	Glab	-,515**	,051	-,542**	,145	,083	-,625**	1	,218	,596**
	Ind	-,839**	,631**	,240	,089	,638*	,716**	1	,809**	,581**
	Jap	-,716**	,348**	-,159	,564**	,207	,379*	1	,621**	,692**
	Glab_UpperCoast	-,705**	,438**	-,427**	-,137	-,335	-,553**	1	,223	,725**
	Glab_LowerCoast	-,714**	,359	-,319	-,389	,159	-,299	1	,766**	,499*
	Ind_Gc	-,878**	,615*	-,328	-,488	-,002	,778*	1	,902**	,834**
	Ind_Gh	-,862**	,682*	,511	,211	,707	,617	1	,861*	,612*
	Jap_GbGh	-,685**	,359*	-,136	,394*	-,116	,563**	1	,600**	,708**
	Jap_SL	-,702**	,368	-,379	,705**	,321	,320	1	,599*	,628*

Parameter	Cluster	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	# Tillers	# Panicles	Panicle weight (g)	200 grain weight (g)	Yield (kg.ha^{-1})	A (%)
Yield (kg.ha^{-1})	All	-,298**	,346**	-,293**	-,125	,150	,228*	,369**	1	,478**
	Glab	,080	,168	-,338**	-,328**	-,453**	,109	,218	1	,450**
	Ind	-,316	,392*	-,767**	-,573**	-,201	,701**	,809**	1	,483*
	Jap	-,511**	,420**	-,338**	,239	,474**	,563**	,621**	1	,706**
	Glab_UpperCoast	,266*	,181	-,332**	-,272*	-,281	,243	,223	1	,476**
	Glab_LowerCoast	-,428*	,020	-,708**	-,446*	-,824**	-,347	,766**	1	,451
	Ind_Gc	-,403	,228	-,850**	-,616*	-,677	,755*	,902**	1	,857**
	Ind_Gh	-,273	,393	-,664**	-,594**	-,022	,702	,861*	1	,137
	Jap_GbGh	-,559**	,482**	-,450**	,042	,038	,382	,600**	1	,848**
	Jap_SL	-,342	,452*	-,313	,236	,717**	,824**	,599*	1	,497

a: non estimated

ACKNOWLEDGEMENTS

The authors would like to thank NWO-WOTRO (Science for Global Development, part of the Netherlands Organisation for Scientific Research), CSG (Centre for Society and Genomics), NUFFIC (Netherlands Organisation for International Cooperation in Higher Education) and Africa Rice Center for funding and facilitating the research. The authors would like to acknowledge the contributions of all those involved in the research, in particular the staff of the research stations and universities in the countries involved, the farmers in the different countries and the research assistants at the different trial sites.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: AM EN FO BT HM PR PCS. Performed the experiments: AM EN FO BT. Analyzed the data: AM EN FO BT. Contributed reagents/materials/analysis tools: AM EN FO BT. Wrote the manuscript: AM EN FO BT HM PR PCS. Supervised the research: EN HM PR PCS.

REFERENCES

[1] Ceccarelli S (1994) Specific adaptation and breeding for marginal conditions. Euphytica 77,205-219.
[2] Sall S, Norman D, Featherstone AM (1998) Adaptability of improved rice varieties in Senegal. Agricultural Systems 57 ,101-114.
[3] Linares OF (2002) African rice (Oryza *glaberrima*): history and future Potential. Proceedings National Academy of Sciences 99(25),16360-16365.
[4] Teeken B, Nuijten E, Okry F, Mokuwa A, Temudo M, Struik PC, Richards P (2010) Advocating the integration of socio-cultural factors in models for variety dissemination. Paper presented at the 28th International Rice Research Conference, 8-12 November 2010, Hanoi, Vietnam.
[5] Temudo M (2011) Planting knowledge, harvesting agro-biodiversity: a case study of Southern Guinea-Bissau rice farming. Human Ecology, Doi:10.1007/s10745-011-9404-0.
[6] Okry F, Nuijten E, Van Mele P, Struik PC, Richards P (forthcoming) Adaptation of the informal seed system to agrarian changes: the emergence of market oriented local seed dealers within the informal seed sector of rice in Guinea. Submitted to Journal of Agrarian Change.
[7] Richards P (2006) The history and future of African rice: food security and survival in a West African war zone. Afrika Spectrum 41(1),77-93.
[8] Stearns SC (1989) The evolutionary significance of phenotypic plasticity. BioScience 39(7),436-445.
[9] Mercer KL, Perales HR (2010) Evolutionary response of landraces to climate change in centers of crop diversity. Evolutionary Applications 3,480–493.
[10] Dingkuhn M, Johnson DE, Sow A, Audebert AY (1999) Relationship between upland rice canopy characteristics and weed competitiveness. Field Crops Research 61,79-95.
[11] Johnson DE, Dingkuhn M, Jones MP, Mahamane MC (1998) The influence of rice plant type on the effect of weed competition on *Oryza sativa* and *Oryza glaberrima*. Weed Research 38(3),207-216.
[12] Sumi A, Katayama TC (1994) Studies on agronomic traits of African rice (*Oryza glaberrima* Steud.): I. Growth, yielding ability and water consumption. Japanese Journal of Crop Science 63 (1),96-104.
[13] Sultan SE (1995) Phenotypic plasticity and plant adaptation. Acta Botanica Neerlandica 44,363-383.
[14] Nuijten E, Van Treuren R (2007) Spatial and temporal dynamics in genetic diversity in upland rice and late millet in The Gambia. Genetic Resources and Crop Evolution 54,989-1009.
[15] Nuijten E, Van Treuren R, Struik PC, Mokuwa A, Okry F, Teeken B, Richards P (2009) Evidence for the emergence of new rice types of interspecific hybrid origin in West African farmers' fields. PLoS ONE, 4 (10): e7335. doi:10.1371/journal.pone.0007335.
[16] Mouser B, Nuijten E, Richards P (2011) A Colour Bar? The commercialization of rice at Sierra Leone. Workshop, "New Histories of Rice", Max Planck Institute for the History of Science, Berlin, 25-26th March 2011.
[17] Hendriks CLL, Van Vliet LJ, Rieger B, Van Ginkel M, Ligteringen R (2005) DIPimage user manual. Quantitative imaging group. Faculty of Applied Physics, Delft University of Technology. Delft, The Netherlands.

[18] Khan MS, Struik PC, Van der Putten PEL, Yin X, Van Eck HJ, Van Eeuwijk FA (2011) Analyzing genetic variation in potato (*Solanum tuberosum* L.) canopy dynamics using standard cultivars and a segregating population. Submitted to Field Crops Research.
[19] Okry F, Van Mele P, Nuijten E, Struik PC, Mongbo RL (2011) Organizational analysis of the seed sector of rice in Guinea: stakeholders, perception and institutional linkages. Experimental Agriculture 47(1),137-157.
[20] Richards P (1986) Coping with hunger: hazard and experiment in an African rice-farming system, London: Allen and Unwin.
[21] Brydon L (1981) Rice, yams and chiefs in Avatime: speculations on the development of a social order. Africa 51(2),659-677.
[22] Portères R (19660 Les noms des riz en Guinée. Journal d'Agriculture Tropicale et de Botanique Appliquée 13,1-346.
[23] Semon M, Nielsen R, Jones MP, McCouch SR (2005) The population structure of African cultivated rice *Oryza glaberrima* (Steud.): evidence for elevated levels of linkage disequilibrium caused by admixture with *O*. *sativa* and ecological adaptation. Genetics 169,1639-1647.
[24] Futakuchi K, Sié M (2009) Better exploitation of African rice (*Oryza glaberrima* Steud.) in varietal development for resource-poor farmers in West and Central Africa. Agricultural Journal 4(2),96-102.

CHAPTER 4

ORGANIZATIONAL ANALYSIS OF THE SEED SECTOR OF RICE IN GUINEA: STAKEHOLDERS, PERCEPTION AND INSTITUTIONAL LINKAGES

Published as: Okry, F., P. Van Mele, E. Nuijten, P.C. Struik and R.L. Mongbo (2011). Organizational analysis of the seed sector of rice in Guinea: Stakeholders, perception and institutional linkages. Experimental Agriculture 47 (1): 137-157.

Abstract

This paper analyses the organization of the rice seed sector in Guinea with the overall objectives to assess how organizational settings affect seed supply to small-scale farmers and to suggest institutional changes that would favour seed service and uptake of varieties. Data were collected in Guinea, West Africa, using focus group discussions with extension workers, farmers, representatives of farmers' associations, agro-input dealers, researchers and non-governmental organization (NGO) staff, and surveys of 91 rice farming households and 41 local seed dealers. Findings suggest that the current institutional settings and perceptions of stakeholders from the formal seed sector inhibit smallholder farmers' access to seed. Seed interventions in the past two decades have mainly relied on the national extension system, the research institute, NGOs, farmers' associations and contract seed producers to ensure seed delivery. Although local seed dealers play a central role in providing seed to farmers, governmental organizations operating in a linear model of formal seed sector development have so far ignored their role. We discuss the need to find common ground and alternative models of seed sector development. In particular we suggest the involvement of local seed dealers in seed development activities to better link the formal and the informal seed systems and improve smallholder farmers' access to seed from the formal sector.

4.1 INTRODUCTION

Rice (*Oryza* spp.) is one of the major food crops on which global food security depends. Although most rice is produced in Asia, it is an important food crop in many other parts of the world, including West Africa, especially Guinea, where rice is the staple food. With a per capita consumption of 69 kg per year, Guinea is the second-largest consumer of rice in West Africa after Sierra Leone (WARDA, 2007). Despite production growth of 5.3% (2001–2005), this still cannot meet the local demand: 40% of the rice consumed is imported (MAEF, 2007a). Increasing domestic rice production is a priority in Guinea (MAEF, 2007b), as well as in other African countries.

As with any crop, seed availability and quality are considered bottlenecks in developing competitive agricultural sectors (Bam *et al.*, 2007; McDonald, 1998). Like many countries in the region, Guinea has tried to establish a formal national seed system, with several projects addressing seed production, multiplication and distribution (SNPRV, 2001). However, such efforts have yielded little success: only 8% of the rice farmers have access to seed from the formal sector (SNPRV, 2001). Most smallholder farmers, as in most developing countries, rely on the informal seed system (Almekinders and Louwaars, 2002; SNPRV, 2001; Tripp, 2001) and depending on the region and crop, 60–100% of the seed is locally produced and exchanged (Almekinders *et al.*, 2007; Duijndam *et al.*, 2007; Ndjeunga, 2002; Nuijten, 2005; Okry, 2005).

Seboka and Deressa (2000) argue that the lack of seed multipliers and inefficient distribution channels explain why farmers acquire informal seed through indigenous social networks. Witcombe *et al.* (1996) further argue that low adoption of new varieties is due to insufficient exposure of farmers to them. The formal seed sector's dependency on the extension system has often limited the number of farmers it can reach, especially in marginal and remote areas, making formal seed expensive due to high transaction and information-gathering costs (Almekinders *et al.*, 2007). Further aggravated by the declining support for public sector extension services, various donors believe that large private seed enterprises could offer a solution.

The formal and informal seed systems generally operate as two parallel systems serving different purposes (Sperling and Cooper, 2003). Recently, Almekinders and Thiele (2003) proposed combining attributes of both systems, but how to do that seems difficult since seed systems are poorly understood, especially informal ones (Thiele, 1999).

This paper contributes to the understanding of how the rice seed sector functions, using Guinea as a case study. It examines the organization of the seed systems, stakeholders, their roles and their perceptions of the other actors. The study:

1. Analyses previous formal seed interventions to provide a historical perspective and to shed light on alternative models;
2. Identifies the main players in seed supply and seed system governance;
3. explains why the formal interventions (and the formal seed sector) reached few smallholder farmers;
4. Assesses how current organizational settings, institutional linkages and perceptions inhibit seed flow towards small-scale farmers.

The paper ends by discussing how engaging local seed dealers may contribute to making the rice seed sector more effective and seed interventions more sustainable.

4.2 MATERIALS AND METHODS

Field activities were undertaken in Lower Guinea from June to December 2007 and from June to December 2008. Lower Guinea was chosen for primary data collection because: (i) stakeholders of the rice seed sector and their head offices are based in Lower Guinea, which includes Conakry, the capital; (ii) seed projects using CBSS (community-based seed system) and PVS (participatory varietal selection) approaches began in Lower Guinea in the late 1990s, with successful project components being subsequently copied in other regions of the country; (iii) Lower Guinea hosts two of the four seed centres of the country; (iv) Lower Guinea is the most representative region regarding the diversity of rice cropping systems (Barry *et al.* 2007).

Field research covered three sub-prefectures (local levels of government): Molota, Friguiagbé and Moussayah in the prefectures of Kindia and Forecariah. We selected 10 villages and, based on their proximity to each other, we grouped them into three research sites. Site 1 consisted of Bokariya (9° 20.582N; 12° 48.582W; 52.6 m asl) and Sangaran (9° 20.538N; 12° 48.010W; 66.8 m asl). They were chosen because of their remoteness (about 90 km from Kindia, the regional capital) to learn about farmers' seed strategies in a situation of poor infrastructure, limited interventions of development organizations and the absence of an important nearby market place. Site 2 consisted of Seifan (9° 54.136N; 12° 47.21W; 78.1 m asl) and Dentègueya (9° 54.303N; 12° 48.204W; 73.1 m asl). These two villages were selected because of their proximity to the rice seed centre of Kilissi and the Centre de Recherche Agronomique de Kilissi (CRAK), which is the national rice breeding unit. Site 3 covered Kinyaya (9° 58.044N; 12° 53.591W; 402 m asl), Hononkhouré (9° 57.143N; 12° 53.111W; 429 m asl), Tour (9° 57.273N; 12° 53.25W; 368 m asl), Yaya (9° 57.491N; 12° 54.479W; 436 m asl), Dandakhouré (9° 56.503N; 12° 53.897W; 400 m asl) and Sinta (9° 57.246N; 12° 53.105W; 390 m asl). They were selected because of their proximity to Kindia.

Primary data were also collected from Kindia, Friguiagbé and Sikhourou-Daffira markets, all in Kindia and Forecariah prefectures. These were the markets most often mentioned by the study households. Moreover, Sikhourou market was the major market closest to Site 1. Sikhourou and Daffira are actually two different physical markets. We combined them in this study because of the mobility of dealers from one market to another.

The study used various data collection methods arranged in ways that outputs of one method were complemented, fine-tuned and/or triangulated with data collected using another research method. Archive research, literature review and discussions with resource persons (local agricultural scientists and other experts on the rice seed system) elicited information on agricultural policy in Guinea, past and current rice seed projects and their stakeholders. We then held 14 focus group discussions to understand stakeholders' roles, their perception of the organization of the seed sector and to explore their views on changes they believe might be necessary for a functional rice seed sector. Focus group discussions involved farmers; representatives of the Fédération des Organisations Paysannes de la Basse-Guinée; representatives of local farmers' associations; staff of non-governmental organizations (NGOs): Association pour la Promotion Économique de Kindia (APEK) and Structure d'Appui aux Réseaux d'Agriculteurs et d'Agricultrices (SARA); researchers from the Institut de Recherche Agronomique de Guinée (IRAG); agro-input dealers: Comptoir Agricole (CA) and Société de Production et de Commercialisation des Intrants Agricoles (SPCIA) and extension agents from the Agence Nationale pour la Promotion Rurale et du Conseil Agricole (ANPROCA, ex-SNPRV). Focus group discussions involved on average nine participants and lasted for about two hours each.

Two surveys using distinct semi-structured questionnaires complemented the focus group discussions. One survey targeted 91 rice farming households and the other targeted 41 local seed dealers. The questionnaire administered to farmers addressed their seed use, means of seed acquisition, seed sources and preferred sources, and farmers' relationships with seed dealers. The respondents were selected according to their willingness to participate in the study, since it was conducted during the cropping season, to better capture seed flows and observe seed transactions. The questionnaire administered to seed dealers addressed seed dissemination, origins of seed and varieties sold, seed quality requested by customers, price indications and its progression throughout the year, and dealers' relationships with their customers. Local seed dealers were identified using the snowball sampling technique (see Vogt, 1999). Informal interviews and participant observation helped to collect data on farmers' relationships with seed dealers and gain additional insights in farmers' seed acquisition strategies.

4.3 RESULTS

4.3.1 Overview of the organization of the formal rice seed sector from the 1980s to 2007

Archival research, literature review and discussions with resource persons revealed that in the past two decades, the rice seed sector underwent three major types of interventions: a state-led intervention where bodies of the Ministry of Agriculture ran the seed sector, an NGO-led intervention using the framework of a public-private partnership for seed development and a collaborative intervention that opened the door to farmers' participation in varietal selection and seed development. Other interventions, minor in scope, were organized by local NGOs and agro-input dealers. This section describes the interventions, stakeholders and their roles, and analyses the intervention approaches.

A state-led intervention

This was the first ever formal intervention in the rice seed sector in Guinea. It began in the mid 1980s, as part of a broader food security programme. Two early-maturing and improved upland varieties, CK 5 and CK 7, were chosen among nine to increase national rice production (IRAG, 1996). Four well-equipped seed centres were built in Kilissi, Koba, Guéckédou and Bordo to process (cleaning, sorting and conservation), store and package seed of these two varieties.

The two main bodies of the Ministry of Agriculture, ANPROCA (extension) and IRAG (agricultural research), managed the project, with financial support from the World Bank and the national government. The agricultural research, through its rice breeding unit, was responsible for producing breeder and foundation seed. The newly created seed centres multiplied foundation seed, processed and packaged seed into 5 kg bags and developed, in collaboration with the extension service, technical notes about the characteristics and use of each variety. The extension service was responsible for disseminating the bags of seed and for training the farmers. Seed was distributed free of charge to selected farmers who were expected to diffuse seed and technical information within their community as stipulated by the training and visit extension approach (Benor *et al.,* 1984) in use in the 1980s. Seed distribution was coupled with farmer training sessions carried out with the Unités Expérimentales Paysannes (UEPs). During these sessions improved technologies were discussed and tried out, such as sowing techniques, weeding, mineral fertilization and other farming practices. Before adopting the UEP approach, the agricultural research system undertook conventional on-station research to generate technologies, including seed and varieties. Plant breeding and varietal selection happened on-station and only after registration were varieties released to farmers. In order to improve this classical scientist-led approach, the UEP was introduced in the early 1990s to include farmers' perspectives. Technological development then evolved through three stages. On-station experiments generated technologies which were tested on decentralized research stations (Points d'Essai). On these stations, farmers hardly interacted with scientists. Promising technologies were then transferred to farmers' fields (UEP) and the diffusion was believed to start from these on-farm experiments.

The two disseminated varieties (CK 5 and CK 7) did not meet farmers' expectations and were not adopted. Farmers and extension agents mentioned during focus group discussions that the varieties were susceptible to weeds and too early-maturing, requiring intensive bird-scaring at times when labour is needed for other crops. These varieties also required delicate post-harvest management as they ripened in the middle of the rainy season. The intervention therefore failed to meet its objective of supplying seed to small-scale farmers. The withdrawal in the early 1990s of World Bank and governmental funds as prescribed by the Structural Adjustment Programme did not give opportunities to develop improved follow-up state-led interventions. This led in 1997 to the closure of the seed centres that were unprepared to operate independently without subsidies. The seed centres were handed over to farmers' associations and agro-inputs dealers (SPCIA) in 2004, after which they have rarely functioned, with the exception of the one in Koba that processed 350 t of seed at request of the FAO (Food and Agriculture Organization of the United Nations) to cope with an emergency in 2007.

An NGO-led intervention

Since its establishment in 1996, Sasakawa Global 2000 (SG 2000) rapidly engaged in rice seed activities (SG 2000, 2005) focusing on the diffusion of improved lowland varieties originating from the national breeding unit (CK 4, CK 73, CK 21, CK 801 and CK 211) and upland varieties (Nerica 1, Nerica 3 and Nerica 4) from the Africa Rice Center (AfricaRice, ex-WARDA). SG 2000 initiating this intervention envisioned professionalizing and privatizing small-scale seed production without relying on the heavily equipped seed centres. The intention was that by the end of the intervention, farmers would have been trained as professional seed producers (hereafter referred to as formal seed producers) capable of establishing their own seed businesses. SG 2000 subsidized inputs (chemicals, fertilizers and seed) to stimulate these seed producers. In practice:

1. Extension and research identified farmers as potential seed producers based on land ownership, integrity and literacy. They recruited and trained them in techniques of seed production.
2. Formal seed producers signed a contract and received subsidized inputs from SG 2000 on credit. At the end of the season, SG 2000 bought the seed produced up to the value of the inputs received and distributed these to seed producers selected in other regions where there was a lack of seed.

In the course of the project SG 2000 continuously needed large amounts of seed to scale-up in other regions of Guinea. SG 2000 thus became the major customer of the formal seed producers and bought the entire seed produced throughout the project's life time. This same organizational setting is currently in use for Nerica multiplication and dissemination under the African Rice Initiative project. SG 2000 reduced its activities in 2003 and withdrew from the country shortly afterwards.

Like the state-led intervention, the NGO-led intervention also decided, based on on-station performance, on varieties that would suit farmers' conditions. Some did indeed. Interviews showed that 38% of the promoted varieties, namely CK 4, CK 21 and CK 801, were adopted by farmers and entered local seed trade. In 2007 for example, 4%, 2% and 1% of the rice farming households grew CK 21, CK 801 and CK 4 respectively. In 2008, CK 21 was the third most sold variety after Saidou Gbéli and Saidou Firê, the two most cultivated local varieties in the study area. CK 21 represented 14% of the total seed sales and was sold by 32% of the local seed dealers at open markets (Okry *et al.*, unpublished data). The total seed sale was estimated at 99.6 t in 2008. CK 4 and CK 801 were less represented in the seed trade at less than 1% of total seed sales each.

Contrary to the state-led intervention, the NGO-led intervention stressed the professionalization of small-scale seed producers to promote a more lateral seed distribution from many points at community level. It brought farmers into seed development activities and trained them in seed production. It thus built farmers' capacity, which is an essential step towards any professionalization. But the intervention was less successful in developing seed businesses to service local communities.

Farmers, extension agents and researchers said most of the formal seed producers abandoned their seed businesses after the project and subsidies ended.

A collaborative intervention

From 1997 and parallel to the NGO-led intervention, the national agricultural research and extension service in collaboration with international partners (AfricaRice and World Bank), launched a pilot programme to accelerate the diffusion of Nerica (varieties of interspecific hybrid origin: *O. glaberrima* × *O. sativa*) in Guinea. In order to allow farmers' interaction with Nerica, a total of 116 and 210 UEPs were conducted across the country in 1997 and 1998, respectively. Trials involved 15 varieties (3 landraces and 12 Nerica varieties). At the same time PVS was introduced, but at a small scale. In 1999, only PVS trials were conducted and led to the selection of four varieties: Nerica 3, Nerica 4, Nerica 6 and IAC 164 for large-scale diffusion (IRAG, 2000).

The introduction of Nerica was accompanied by a fundamental change in the research approach, triggered by this collaborative intervention. Prior to this intervention, the agricultural research used UEP (described above) as the final stage of research. After 1999 the UEP approach was abandoned in favour of PVS which is still the major on-farm research method in use. PVS and UEP are two similar approaches advocating farmers' participation in technology development. The difference is that PVS involves farmers throughout the entire process of variety selection while UEP brings in farmers only at the final stage with the sole purpose of distributing improved varieties and other technologies to farmers. The UEP approach was not specifically designed for variety selection as was PVS. The latter belongs to the range of participatory crop improvement approaches developed in the late 1980s to early 1990s to complement and/or improve the impact of the conventional breeding approaches. It advocates farmers' involvement at earlier stages of variety selection to assess a wide range of existing but novel varieties (Witcombe *et al.*, 1996) with the overall objective of valuing their perspectives (Dorward *et al.*, 2007; Morris and Bellon, 2004). Schematically, four phases commonly compose a PVS: identification of farmers' needs in cultivars, a search for suitable cultivars to test with farmers, experimentation of suitability of cultivars in farmers' field and a wider dissemination of suitable cultivars (Witcombe *et al.*, 1996). Hence the success of a PVS largely depends on the type of stakeholders involved (farmers, researchers, NGOs and other end-users), the way they have been selected and the degree of their involvement, activities and timing, scale, etc. (Dorward *et al.*, 2007). With PVS, farmers are exposed to more new cultivars, they have a larger stake in the selection of varieties compared to the conventional breeding approaches and seed dissemination is expected to start from PVS sessions using participating farmers as entry points to the community. As such PVS has the potential to link the formal and the informal seed systems. Participatory varietal selection is a flexible approach adaptable to the local context. During the collaborative intervention in Guinea, research and extension co-ordinated PVS activities. According to these stakeholders several technical and organizational aspects deviated the actual implementation of PVS in Guinea from the one recommended (see Witcombe *et al.*, 1996; Dorward *et al.*, 2007). Major weaknesses reported included:

1 Field staff were given limited time to learn the approach, to select participants and set up trials. In most cases, in response to time constraints, they selected farmers who were already formally collaborating as contact groups under the 'training and visit approach' and/or friends to participate in PVS activities.

2 Trial set-up was left to extension staff who were already involved in many other activities including seed dissemination activities of the NGO-led intervention. They could not devote much time to PVS trials.

3 Limited supervision was given from headquarters because of financial constraints.

4 Frequency of visits of farmers to PVS trials largely depended on budget availability. One or two

visits were generally organized, but not always at the most crucial growing stages (tillering, flowering and maturity).

According to informants, these limitations occurred at the beginning of the intervention and were gradually overcome. However, the first two phases of PVS (the identification of farmers' needs for cultivars and the search for suitable cultivars to experiment with farmers) have often been taken for granted, and the number of farmers involved and frequency of visits have largely depended on budget availability.

Like in the NGO-led intervention, the actual seed multiplication and dissemination after variety selection through PVS were done by formal seed producers. Surveys of 2007 and 2008 did not report any use of the introduced varieties in the study area.

Other interventions

Other interventions were limited in scope. APEK, a local NGO, supported research to implement participatory approaches such as PVS and CBSS. APEK, like many other local NGOs (e.g. SARA), also distributed seed in emergency situations at the request of the FAO and WFP (World Food Programme of the United Nations). In its regular activities of seed dissemination APEK targeted farmers' associations, rather than individual rice farmers, as requested by its donors and partners (Guinée 44, IFAD, FAO, etc.) and in line with donor-proposed changes in extension. Farmers organized in groups received seed of improved varieties from APEK. They were expected to develop communal seed management strategies to improve everyone's access to seed. The actual seed management varied from one farmers' association to another, but it often excluded some farmers. For example, in Bokariya-Tassen the farmers' association loaned seed to farmers at an interest rate of 20%, compared to the 50–100% charged by informal money lenders. However, only group members could borrow seed from the association. In Sangaran, 1.5 km from Bokariya-Tassen, the chairman charged 100% interest on seed loans.

Comptoir Agricole, a medium-sized agro-dealer was also involved in seed relief activities along with APEK at the request of the FAO and WFP. In addition, CA developed a seed business. It bought seed (local as well as improved varieties) mainly from individual farmers during harvest, which it stored and then sold at the start of the next season, but did little or no seed processing. By 2007, it had a market capacity of 200 t of seed per year. But CA met only 50% of this capacity in 2007. In July 2007, CA sold rice seed at about US$ 0.80 per kilogram.

Apart from learning from past interventions, to construct a more sustainable seed sector one also needs to understand the roles, perceptions and linkages of the different stakeholders involved. The next section explores this.

4.3.2 Stakeholders of the rice seed sector

Characteristics and roles of stakeholders

Archival research and focus group discussions with extension agents, researchers, NGO staff and farmers allowed us to identify and characterize stakeholders of the rice seed sector (both formal and informal). Subsequent surveys allowed further characterization. Following Jiggins and Collins (2003), we grouped stakeholders into three classes: primary, intermediary and key stakeholders (Table 4.1), and characterized them based on the roles they played and would potentially play in the rice seed sector.

The national government, SG2000, World Bank and AfricaRice were key stakeholders. They steered interventions through financial, technical and institutional support, and policy development. Of these key stakeholders only the national government was involved in all interventions described in the section above.

Table 4.1: Characterization of the stakeholders of the rice seed sector based on archives, surveys and focus group discussions 2007 and 2008.

Stakeholders	**Class of stakeholder**[†]	**Scope of intervention**	**Roles**	**Time frame of intervention**	**Involvement seed project**
Individual farmers	Primary	Local (village)	Seed use, management, production and dissemination	For many years: they built the farmer-seed sector	Yes
FOP-BG, Farmer's association	Primary	Local and national	Current manager seed centres Participation in participatory research activities	Since 2004 Since 1999	Yes
Local seed dealers	Primary	Local	Seed sale, purchase and production	14 years of experience (on average)	No
Agro-input dealers: - Comptoir Agricole - SPCIA	Primary/ Intermediary	Local and national	Seed sale Seed centre (Guéckédou) management	Since 1994 Since 2004	Yes
ANPROCA[‡] (extension service)	Intermediary	National	Training of farmers Improved variety dissemination	Founded in 1987 First rice seed project in 1995	Yes
IRAG (National Research Institute)	Intermediary	National	Research and breeding Elaboration and implementation of seed projects	Founded in 1989 Fist rice seed project in 1995	Yes
APEK (NGO)	Intermediary	National	Training, capacity building of farmers Seed project implementation Seed distribution	Founded in 1989	Yes
Ministry of Agriculture	Key	National	Agricultural development policy Funding	Since the 1980s	Yes
Sassakawa Global 2000[§]	Key	Supranational	Dissemination of improved varieties and agricultural inputs Funding	From 1996 to 2003	Yes
Africa Rice Center (AfricaRice)	Key	Supranational	Technical support	Founded in 1971 First intervention in 1997	Yes
WB, FAO, WFP, IFAD	Key	Supranational	Funding, Support policy development		Yes

[†] *Primary* stakeholders are those who are directly affected, either positively or negatively by seed projects or interventions in the seed sector. *Intermediary* stakeholders are the intermediaries in the delivery or execution of seed project, research programmes and resource flows. *Key* stakeholders are those with the power to influence or 'kill' activity (adapted from Jiggins and Collins 2003). [‡] Has suffered from lack of funds since early 2000s. [§] No longer intervening in Guinea.

Research and extension were mandated to implement the state's vision of agricultural development through the Ministry of Agriculture. They also acted as intermediaries for AfricaRice, World Bank and SG2000 to implement the seed projects described above. Research and extension were therefore the most influential intermediary stakeholders.

Comptoir Agricole and NGOs (e.g. APEK) were also intermediary stakeholders who: (i) as previously mentioned released emergency seed along with research and extension at request of FAO and WFP; (ii) trained farmers and (iii) implemented seed projects as partner of the national agricultural research and AfricaRice. In addition, CA has developed a seed business.

So far, the role of farmers in the formal seed sector has been limited to contractual labour provision for seed multiplication. Of course, those who took part in PVS helped to make decisions on the varieties to be disseminated by the formal seed sector. Rice farmers play a role mainly in the informal seed sector. Various studies have shown they have experience in seed and variety management (selection, use, production and dissemination) to meet diverse objectives of food production (Louwaars 2007; Nuijten et al., 2009; Richards 2009). From 2005 to 2007 each household used on average 77 kg of rice seed per year of which 70% were own farm-saved. Seed acquired from outside the farm was used for different purposes. For example, in 2007 seeds from outside the farm can be split in seed of new varieties (40%), seed for field enlargement (38%), seed to complement own seed because of shortage (18%) and seed to renew own seed because of mixture (3%). About 2% of it was used to establish new rice fields (youth).

Farmers developed several ways of acquiring seed. Our interviews revealed that from 2005 to 2007 seed from outside the farm was obtained through seed exchange with fellow farmers (50%), purchase with cash (35%), loan (7%), gift (4%), labour exchange (2%) and barter deals (2%). Of seed purchased with cash, 30% came from occasional seed sale by relatives and friends from the same village, 53% came from relatives, friends and seed dealers of neighbouring villages, 15% from local seed dealers established at open markets and 1% from CA. Interviewed households did not mention the formal seed producers as source of purchased seed. They were, however, mentioned as potential seed sources during focus group discussions. Table 4.2 presents outputs of such focus group discussion conducted in Dandakhouré to compare external seed sources (seed from outside the village). Five external seed sources were in use: the rice research unit of Kilissi (CRAK), the seed centre of Kilissi, a formal seed producer, local seed dealers established at open market and, friends, relatives and local seed dealers from neighbouring villages. According to farmers, seed from local dealers at open markets and seed from non-experienced local seed dealers at village level was often mixed, whereas seed from research and seed centres was pure. Nevertheless, farmers said that they did not often visit research and seed centres for seed because of the high seed prices, the limited choice they offered (exclusively improved varieties), and the limited availability of seed (Table 4.2). Farmers made similar comments about the formal seed producer even though at points in time he would offer a few local varieties in addition to improved ones (Okry *et al*., 2011). Despite the criticism of seed mixture farmers said they preferred seed from local seed dealers because of the relatively low seed price, the large diversity they offered and the large quantities of seed they usually have available.

Subsequent interviews with local seed dealers revealed that in 2008 none of them had ever collaborated with a seed project even though on average they had spent 14 years selling rice seed. Local seed dealers distributed seed by sale, loan, barter and even as gifts. Their seed price increased from the beginning to the end of the sowing season with an average of US$ 0.50 per kilogram in July–August 2008. About 40% of the local seed dealers were also seed producers (non-formal), the rest were traders. Barter deals involved palm oil and mainly took place in remote areas (e.g. villages of Site 1). Thirty litres of palm oil were exchanged for about 50 kg of seed. Seed loans were only granted to regular customers. Payment was generally made after six months (at harvest) either in cash or in rice. The interest rate varied widely according to the relationship between client and dealer. Seed dealers occasionally gave gifts of seed in cases of misfortune. Local seed dealers also used seed gifts to secure labour for the coming cropping season. Farmers acquired seed through barter, loan or gift only when they have strong ties with seed dealers; those with weak ties can only buy seed. Purity, good germination rate and adaptability of varieties to local environment were the main characteristics sought by farmers. All seed dealers aimed to offer such seed to secure customers: 'Only good quality seed establishes customer loyalty and keeps the seed business going,' dealers said. Good quality seed here refers to seed purity, cleanness and germination rate. Each local seed dealer was linked to several rice growers who, together with their friends and relatives, formed a customer group. Seed dealers therefore entered farmers' networks and sustained their seed business by selling 'good quality seed' in different ways.

Farmers controlled seed dealers through information sharing within their networks. News of any cheating or false information about seed quality or varietal characteristics were said to spread quickly within the farming community and may result in significant loss of customers and even exclusion of suspect seed dealers from the networks. Local seed dealers seemed to be strategic seed suppliers, but their future involvement in seed programmes/interventions will be largely influenced by the perceptions of the various stakeholders.

Table 4.2: External seed sources and preferences of farmers for external seed sources.[†]

	Research centre and seed centre (Kilissi)	Formal seed producer	Local seed dealers at open market	Farmers and local dealers from neighbouring villages
Distance from village to indicated seed source (km)	37	6	19	Varies
Farmers' indication of seed availability	Limited seed availability	Limited seed availability	High seed availability	High seed availability
Seed mixture	Not mixed	Not mixed	Mixed	Fairly mixed
Diversity	Exclusively improved varieties	More improved varieties than local varieties	More local varieties than improved varieties	More local varieties than improved varieties
Average prices (US$/kg) in 2007 and 2008[‡]	1.3	1.3	0.5	0.4
Prices appreciation by farmers	Expensive	Expensive	Affordable	Cheap
Farmers' indication of their preference for an external seed source	Little used seed source	Little used seed source	Important seed source	Important seed source

Source: Group discussion in the village of Dandakhouré in November 2007 (*n* = 22).
[†]External seed sources refer to seed collected from outside the village of Dandakhouré. [‡]Prices in the table are averages of price ranges given by participants. They are consistent with prices recorded during surveys. 1US$ = 3800 Guinean franc.

Conflicting roles and perceptions of stakeholders on one another's roles

Focus group discussions with different stakeholders revealed their diverse perspectives on how the seed sector functions. Research, extension and seed centres tended to blame individual farmers when seed and varieties do not flow as expected (Table 4.3). For researchers, farmers should just use the improved varieties they released. Seed centres thought that farmers do not know the value of 'quality seed' of improved varieties. The extension service believed farmers are incapable of achieving any good development unless under assistance. These views, contrasted against farmers' reasons for using seed of the informal seed distribution channels, reveal poor communication between the actors of the formal seed sector and farmers about the reasons of non-adoption of improved varieties and the limited use of seed from the formal sector. More specifically, the perception of the extension service depicts its top-down vision of seed development showing that the collaboration between extension and farmers (formal seed producers) that occurred during the NGO-led intervention did not alter much the rigid view it held and likely inherited from the training and visit era. It illustrates their negative attitude about farmers' ability to produce and/or sell seed.

While local NGOs saw themselves as the main current extension agencies, the extension service perceived the NGOs as simple 'extension tools' that should be at their disposal. Since the extension service has suffered from financial problems since 2003, they saw NGOs more as competitors. As both have developed expertise in farmer training, institutional arrangements that favour collaboration might increase their impact.

Extension and research denied the existence of local seed dealers (Table 4.3). They regarded seed dealers as paddy traders. This perception illustrates the formal sector's tedious distinction between 'seed' and 'grain'. The scant scientific attention paid to local practices and institutions of seed production, selection and management does not allow a fair appreciation of farmers' capacities to produce and sell seed. It is true that for many crops much remains to be done on quality (purity and sanitary measures) of farmer's seed but one should not deny farmers' capacity to produce and manage seed of self-pollinated crops like rice (Nuijten, 2005). In Guinea, research and extension may not have acknowledged the existence of local seed dealers because dealers operate within the informal seed sector, which is still of less importance to them. This poor interaction between the formal and the informal seed sectors could also explain why some farmers and local seed dealers did not know about the existence of stakeholders of the formal seed sector except for the NGOs – likely because the latter train farmers in many domains, such as animal traction, adult literacy and co-operative management.

Institutional linkages

Key stakeholders at the international level are linked one-way with the Ministry of Agriculture and intermediary stakeholders targeting financial resources and assistance through them. Among international key stakeholders, only AfricaRice provided seed of improved varieties, of which multiplication and dissemination rested mainly within research and extension. AfricaRice also provided technical assistance.

At the national level, seed and varieties moved in two different ways. Research, extension and APEK organized a vertical and one-way seed distribution starting from research centres to farming communities via formal seed producers and farmers' associations. Farmers' association and formal seed producers would therefore link the farming community to the formal seed system. At the community level seed moves more laterally as a result of the relations between farmers, and those between farmers and local seed dealers. In fact, seed and money flows two ways between individual farmers and local seed dealers who are both seed providers and buyers. Seed is also exchanged between them through a wide range of arrangements (cash, loan, gift and barter) while seed exchange occurred only with cash between farmers and formal seed producers. It is however important to note that local seed dealers had the fewest linkages with other stakeholders: they were linked only to rice growers and to some extent had loose relations with money lenders (because of high interest rate applied – 50 to 100%) from whom they get credit in bad years. They have no direct links with stakeholders of the formal seed sector. Nevertheless, through their informal networks, seed dealers would benefit (indirectly) from technical information that extension, NGOs and research disseminated.

Table 4.3: Stakeholders' perceptions of one another's roles in the seed sector, based on focus group discussions and surveys in 2007 and 2008.[†]

	ANPROCA	IRAG	APEK and SARA (NGOs)	Seed centres	Comptoir Agricole (CA)	Local seed dealers	Individual farmers
ANPROCA	-	Partner in seed project elaboration and implementation	Strengthen the extension system. Resources ANPROCA should use	Currently non operational. Their role is partly played by CRAK (IRAG)	0[‡]	They are not seed dealers. They are rather paddy dealers	Incapable of achieving any good development. They constantly need assistance
IRAG	Partner in programme elaboration and implementation	-	Partners (seed dissemination)	Need to be strengthened	Partners in seed distribution	They are not seed dealers. They are rather paddy dealers	Should use improved varieties and seed from the formal seed sector
APEK and SARA (NGOs)	Training partner	Training partner	-	Non-effective	Partner (occasional seed distribution)	Very small-scale business holders	Need to be empowered
Seed centres	Lacks funds to operate properly	Tends to play the role of seed centres	Useful dissemination network	-	Competing stakeholder	Very small-scale business holders Paddy dealers	They do not know the value of 'Quality' seed
Comptoir Agricole (CA)	0	Partners in seed delivery	Partners in seed delivery	Should be closed	-	Competing stakeholder	Customers (commercial relationships)
Local seed dealers	Unknown[§]	Unknown	Unknown	Unknown	Unknown	-	Customers (commercial and trust relationships)
Individual farmers	Non–effective (Absent in the field) Unknown to some farmers	Seed rarely available Unknown to some farmers	Training of farmer's associations. Little attention to non group-members	Frequent seed shortage Unknown to some farmers	Unknown to some farmers	Major seed suppliers	-

[†] In the first column are the respondents. In the top row are the stakeholders on whom the perceptions are expressed. [‡] 0 means there is no perception expressed on that stakeholder. From this it is deduced that there is no tension between them. [§] Unknown means the responding stakeholder does not know the stakeholder or does not know the roles it plays in the rice seed sector.

Comptoir Agricole developed business linkages with individual farmers and from time to time received seed from research (CRAK) when these had surplus seed, and also sold seed to farmers exclusively on a cash basis.

Farmers' associations have a two-way linkage with farmers. Farmers borrowed seed from them and reimbursed at harvest with seed plus an interest. In addition, farmers' associations linked the formal and the informal seed systems in a more direct way: members of an association who benefited from seeds shared them with other farmers and relatives.

Research, extension and APEK developed one-way links with formal seed producers and farmers' associations despite the collaborations they previously had. In fact, farmers' associations and formal seed producers rarely emerged independently. Farmers' associations were established at the request of extension, and currently of NGOs, and evolved under their financial and technical assistance. Formal seed producers were selected, trained and helped financially by the extension service and research. As a result, research, extension and NGOs tended to have patron-client relationships with farmers' associations and formal seed producers.

4.4 DISCUSSION

4.4.1 Learning from past interventions

Seed programmes in the past two decades have used different intervention approaches that have led to different outcomes. The state-led intervention failed mainly because of the unsuitability of the recommended varieties. It regarded farmers as end-users and did not involve them in the choice of varieties. This attitude likely resulted from the influence of the conventional research approach used in the 1980s. The selection of too few varieties for wide dissemination could also be seen as another cause of failure of this intervention. In fact, small-scale farmers operate in diverse environments and seek a range of varieties that match their specific ecologies and needs (Nuijten, 2005; Richards, 1986). The organization of seed distribution during this state intervention also hampered its success. Distributing improved varieties from a few locations (four seed centres) prevented farmers from remote areas such as Bokariya from accessing these varieties unless they paid for transportation resulting in high transaction costs, which are known to hamper farmers' use of improved varieties (Almekinders *et al.*, 1994). Cromwell and Tripp (1994) also remarked that farmers' decisions on new seed acquisitions are often last-minute decisions and require seed to be readily available and nearby.

The NGO-led intervention that followed the state intervention did not involve farmers in variety selection either. But it increased the number of varieties made available to farmers. Our findings showed that 38% of these varieties successfully entered the informal seed system and were cultivated by 7% of the rice farming households a decade later. Those varieties were likely the most suitable among the distributed improved varieties, suggesting that the dissemination of a larger number of varieties, when farmers are not involved in selection processes, increases chance of adoption. Since our surveys covered only Lower Guinea, different figures may emerge for other regions.

The centralized seed dissemination during the state-led intervention did not service farmers from remote areas. The NGO-led intervention improved on that by training small-scale seed producers in order to multiply and decentralize seed distribution points at the community level. As our findings show this organizational setting successfully built on the capacity of the farmers involved, which is essential to sustain the process of professionalizing small-scale seed production and distribution. However, the actual objective of establishing seed enterprises received insufficient attention. With projects buying all the seed, seed producers did not develop the necessary skills and knowledge to properly market seed, e.g. gauging farmers' seed demands, determining farmers' preference for varieties, developing mechanisms of price formation and strategies of advertisement. Other relevant aspects of seed market development, such as packaging and branding, were of less importance in this subsistence rice cultivation. Many formal seed producers saw themselves as service suppliers to the seed projects and quickly left their seed enterprise once projects and inputs subsidies ended. This finding adds to the range of similar experiences across developing countries (Almekinders and Thiele, 2003). Besides, recruitment criteria for formal seed producers (land ownership and literacy) may have led to the selection of betteroff or elite farmers who found better livelihood opportunities than seed production after projects ended. In all, the observed spread of improved varieties through the NGO-led intervention likely resulted from the conjunction of the adaptability of cultivars to farmers' conditions, and the subsequent dissemination through informal channels and to a lesser extent through formal seed producers.

Contrary to the other interventions, the collaborative intervention did involve farmers in variety selection to avoid failure due to the rejection of varieties. The fact that only Nerica varieties were disseminated through this intervention seemed logical since the project was conceived for Nerica dissemination. That our surveys of 2007 and 2008 did not report any use of the varieties introduced via the collaborative intervention could be partly due to the scope of data collection. Extension agents and researchers mentioned that the Nerica varieties were most successful in Forest Guinea and Middle Guinea, rather than in Lower Guinea, even though they were selected in Lower Guinea. In Lower Guinea CRAK is still actively multiplying Nerica varieties for dissemination to other regions of the country. Also the variety naming system at community level may result in different varieties obtaining the same name. Varieties were often named following the person who introduced them or the area where they were first encountered. As such, varieties introduced by this collaborative intervention may have been renamed. Besides, the name 'chinois' systematically given, in the study area, to any unknown improved varieties adds to this complexity. Similar complexities in variety naming have been observed in The Gambia (Nuijten and Almekinders, 2008). A proper tracking of the introduced varieties would require more resources than those available for this study.

Like the NGO-led intervention, the collaborative intervention also formally relied on formal seed producers to multiply and disseminate seed. Here again, the seed produced was entirely bought by projects for large-scale dissemination. To better sustain impacts on the seed sector, projects could have considered enlarging lists of stakeholders to include local seed producers and dealers in addition to the 'promoted' formal seed producers. As our findings show local seed dealers operated independently, without any direct support from the formal seed sector and have developed customer networks that could serve the formal seed sector. Even though training might have made formal seed producers technically better than local seed producers, local seed dealers have a better understanding of the seed market than the newly trained formal seed producers.

Unsupervised seed dissemination results from participation in PVS sessions. Dorward *et al.* (2007) provided evidence on how a small quantity of suitable cultivars acquired by participants in PVS sessions quickly spread among farmers. Further, Marfo *et al.* (2008) showed the usefulness of informal channels in disseminating seed of suitable improved varieties in Ghana. Witcombe *et al.* (1999) specifically highlighted the roles of seed merchants in disseminating seed of varieties selected with PVS in India. Thus, because of the approach used (PVS) the collaborative intervention had the potential to link the formal and the informal seed systems. In practice this potential was not fully utilized. As the study shows, farmers participating in the PVS sessions were not selected on a sound basis, major players in the informal seed system (e.g. local seed dealers) were ignored and seed multiplication systematically given to only the formal seed producers. Unsupervised seed dissemination may add to the efforts of the formal seed sector to supply seed of improved varieties to smallholders. In this regard, we suggest that PVS adapts more to context specificities. In principle, PVS allows flexibility in its implementation like all other participatory approaches. But because of the large geographical coverage (international) projects often use PVS rigidly, not allowing space to adapt to local conditions or be more flexible towards building on local seed systems. In the case of Guinea, proper identification of stakeholders would have revealed the existence of local seed dealers and their involvement at the very beginning of the PVS would have been beneficial. Also, instead of late involvement (only post-harvest) as PVS guidelines often recommend for traders (Dorward *et al.*, 2007), early involvement of local seed dealers would offer opportunities to collect perspectives from their customer networks.

4.4.2 Ways forwards

Getting rid of subsidies for small-scale rice seed enterprises

Since 2004, seed centres have rarely functioned except to supply seed to cope with emergency. Rossignol (2008) argued that they could not run cost-effectively to only cover the seed demand of smallholders and meet their price preferences unless there are subsidies. Even though subsidies are indispensable for large seed industries of self-pollinated and orphan crops, maintaining long-term subsidies for the Guinean seed industry may be too demanding for the government even if this might be an option to consider in the future. In the short run, alternatives that reduce overheads might best fit the current rice production context. With the NGO-led intervention, the formal seed producers were indeed promoted as alternatives to reduce the costs of production of seed of improved varieties. Most of them have left their seed enterprise after subsidies ended. The few remaining formal seed producers offered seed at a price that smallholders could not afford, because of expensive inputs (chemicals) required. The high seed production costs, passed on in the final seed prices, prevent farmers from buying formal seed (see also Almekinders *et al.*, 2007; Ndjeunga, 2002). In addition to the high price of seed from the formal sector, several studies reported farmers' reluctance to pay more than the grain price for quality seed, especially that of self-pollinated crops (Almekinders and Thiele, 2003; Sperling, 2002). However, many African farmers are willing to pay more for quality seed whenever grain market prices are favourable (Van Mele *et al.*, 2011). To Jaffee and Srivastava (1994) only small seed enterprises that carry low overheads are likely to profit from and sustain the production of seed of self-pollinated crops. This view is consistent with the findings by Bentley *et al.* (2001) who reported the development of several successful small rice seed companies in Peru. Success was mainly due to the fact that small seed companies own capital and resources to enter the seed business and most importantly because they had links with farmers that help them market their seed (Bentley *et al.*, 2001). As our findings show, the local seed dealers have developed consistent expertise in the rice seed trade. Strengthening them is an option to consider when developing independent networks of seed distributors. A recent study in nine African countries revealed that all successful small-and medium-scale seed enterprises were able to bridge the formal and informal seed sector, to manage their cash flow and to market their seed (Van Mele *et al.*, 2011).

Bridging the two seed systems

In general the formal seed system fails to serve smallholders (Ndjeunga, 2002; Seboka and Deressa 2000; Wiggens and Cromwell, 1995) and various researchers have explored ways to combine the positive attributes of the formal and informal seed systems (Almekinders and Thiele, 2003; Song, 1998). To integrate both systems, Seboka and Deressa (2000) recommended a redefinition of the role of extension services. They believe that extension services can improve seed supplies by organizing farmers and promoting institutional linkages. David (2004) specifically suggested training of farmers groups to become specialized seed producers who will develop into farmer seed enterprises. Our study revealed that even working with farmers' associations did not guarantee farmers' access to seed. The relations between formal seed producers and seed projects, along with the exclusive membership and managerial problems of farmers' associations, did not allow seed to be effectively distributed to most smallholders. Almekinders and Louwaars (2002) suggested that the formal seed system feeds the informal one with new technologies, e.g. iron resistant or drought tolerant varieties. To them the role of the formal seed system is to produce relatively small but crucial amounts of high quality seed to be injected into the farmer system at suitable moments and places. In our case of Guinea, and consistent with David (2004), farmers' associations and formal seed producers form the current link between the formal and informal seed systems. This might become a functional relation if only government agencies would become more open to and encourage feedback from these actors. Local seed dealers selling both improved and local varieties might also provide a new junction between both seed systems.

Empowering local seed dealers

The extension service in Guinea currently lacks funds to properly function. The few existing local NGOs operate on a relatively small scale. Our findings showed that farmer networks and seed dealers were frequently used channels for information sharing and seed dissemination, as found for many other agro-ecologies and crops (Ndjeunga, 2002; Jones *et al.*, 2001; Tripp and Pal, 2001; Witcombe *et al.*, 1999), although social differentiation and geographical distance could raise barriers to seed dissemination through farmer networks (Almekinders and Thiele, 2003). Our study also showed that local seed dealers improved the availability of seed at the community level thus increasing the chance of adoption and spread of improved varieties. This is particularly important since seed availability is considered a prerequisite to adoption (David *et al.*, 2002; Witcombe *et al.*, 1999). Encouraging farmer-to-farmer seed dissemination might be an option whereby state organizations and NGOs would (in addition to the formal seed producers) train existing local seed producers and dealers in appropriate techniques of seed multiplication and processing while giving them the managerial skills needed to enlarge their enterprises. Similar suggestions were made for pearl millet (Ndjeunga, 2002) and beans (Rubyogo and Sperling, 2009). Local seed dealers and producers would thus provide additional meeting points between the formal and the farmer seed systems. The role of seed projects and research centres would be to introduce new varieties into the farming community via local seed dealers and other agro-dealers, whose capacities they would strengthen to raise the sanitary and physiological quality of the seed they sell. This would reduce seed production and transaction costs rendering seed more affordable to smallholders and leading to the uptake and spread using both formal and informal dissemination channels. But such an approach would function only if cultivars are suitable and their seed available (at least at the beginning), as illustrated in this paper. While seed availability could be somehow solved by political commitment and strong managerial skills, the adaptability of varieties to farmers' conditions has technical aspects and would require careful methodological recommendations that are beyond the scope of this study. A good use of PVS approaches in combination with a careful consideration of the specificities of each agro-ecology are options to further explore.

Speed of seed dissemination also matters for seed interventions. A good exposure of farmers to suitable varieties would speed up seed dissemination, and hence, improve adoption (Witcombe *et al.*, 1996). The recent review of African seed enterprises by Van Mele *et al.* (2011) also reveals that some agro-dealers have begun to take the lead in testing varieties and communicating results with their (potential) clients. Our study in Guinea shows the importance of local seed dealers in supplying seed to farmers and their potential role in improving farmers' exposure to new cultivars. Their involvement, in addition to the formal seed producers, in seed multiplication and dissemination could be considered to speed up dissemination processes. However, current perceptions of research and extension do not favour such collaboration. A move away from the hierarchical relations of state and (sometimes) NGOs would allow more flexible and open decision-making and enhance interaction with other, previously marginalized stakeholders. These shifts in mindsets may happen when formal players experience the benefits of working with people who play significant roles in the informal seed system. Scientists and development workers have much to gain by considering farmers as equal partners, who also have knowledge to share. Farmers not only look for better varieties but are also active agents of crop development (Nuijten *et al.*, 2009; Richards, 1986). Respectful feedback loops between farmers and stakeholders of the formal system are currently lacking.

ACKNOWLEDGMENTS

The Netherlands Organization for International Co-operation in Higher Education (NUFFIC) funded this research. The Africa Rice Center (AfricaRice) provided additional funds for field activities. The Institut de Recherche Agronomique de Guinée (IRAG) and the Association pour la Promotion Economique de Kindia (APEK) assisted in practical organization of the field work. The authors would like to acknowledge the contributions of all those involved in the research, in particular farmers and surveyors. We also thank L. Beavogui, J. D. Reece, A. Sinzogan, B. Teeken, H. Biaou and I. Moumouni Moussa for fruitful discussions; and H. Maat, P. Richards, J. W. Bentley and two anonymous reviewers for their comments on earlier drafts of this paper.

REFERENCES

Almekinders, C. and Thiele, G. (2003). What to do with the seed for small-scale farmers after all? Questions on seed supply strategies for the formal sector, considering PPB successes. *Cultivos Tropicales* 24:5–8.

Almekinders, C. J. M. and Louwaars, N. P. (2002). The importance of the farmers' seed systems in a functional national seed sector. *Journal of New Seeds* 4:15–33.

Almekinders, C. J. M., Thiele, G. and Danial, D. L. (2007). Can cultivars from participatory plant breeding improve seed provision to small-scale farmers? *Euphytica* 153:363–372.

Bam, R. K., Craufurd, P. Q., Dorward, P. T., Asiedu, E. A., Kumaga, F. K. and Ofori, K. (2007). Introducing improved cultivars: understanding farmers' seed drying and storage practices in central Ghana. *Experimental Agriculture* 43:301–317.

Barry, M. B., Pham, J-L., Noyer, J. L., Billot, C., Courtois, B. and Ahmadi, N. (2007). Genetic diversity of the two cultivated rice species (*O. sativa* and *O. glaberrima*) in Maritime Guinea. Evidence for interspecific recombination. *Euphytica* 154:127–137.

Benor, D., Harrison, J. Q. and Braxer, M. (1984). *Agricultural Extension: The Training and Visit System*. Washington DC, World Bank.

Bentley, J. W., Tripp, R. and Delgado de la Flor, R. (2001). Liberalization of Peru's formal seed sector. *Agriculture and Human Values* 18:319–331.

Cromwell, E. and Tripp, R. (1994). Proximity is a plus: the economics of farmers seed production and distribution in developing countries. In *Seed Production by Smallholders Farmers Proceedings of the ILCA/ICARDA Research Planning Workshop on Seed Production by Smallholder Farmers, Addis Ababa (Ethiopia), 13–15 Jun 1994*.

David, S., Mukandala, L. and Mafuru, J. (2002). Seed availability, an ignored factor in crop varietal adoption studies: A case study of beans in Tanzania. *Journal of Sustainable Agriculture* 21:5–20.

David, S. (2004). Farmer seed enterprises: a sustainable approach to seed delivery? *Agricultural and Human Values* 21:387–397.

Dorward, P., Craufurd, P., Marfo, K., Dogbe, W. and Bam, R. (2007). Improving participatory varietal selection processes: participatory varietal selection and the role of informal seed diffusion mechanisms for upland rice in Ghana. *Euphytica* 155:315–327.

Duijndam, F. P., Evenhuis, C. J. and Parlevliet, J. E. (2007). Production and use of maize seed for sowing in Bolivia, Ecuador. *Euphytica* 153:343–351.

IRAG (Institut de Recherche Agronomique de Guinée) (1996). *Rapport annuel d'activités de l'IRAG 1995*.Conakry.

IRAG (Institut de Recherche Agronomique de Guinée) (2000). *L'IRAG de 1997 à 1998*.CIRAD.

Jaffee, S. and Srivastava, J. (1994). The roles of the private and public sectors in enhancing the performance of seed systems. *The World Bank Research Observer* 9:97–117.

Jiggins, J. and Collins, K. (2003). Stakeholders and stake holding in social learning for integrated catchments management and sustainable use of water. *Thematic paper, Social Learning for the Integrated Management*.

Jones, R.B., Audi, P.A. and Tripp, R. (2001). The role of informal seed systems in disseminating modern varieties. The example of pigeonpea from a semi-arid area of Kenya. *Experimental Agriculture* 37:539–548.

Louwaars, N. (2007). *Seeds of confusion: the impact of policies on seed systems*. PhD thesis. Wageningen University, Wageningen, the Netherlands.

MAEF (Ministère de l'Agriculture des Eaux et Forets) (2007a). *Politique Nationale de Développement Agricole Vison 2015. Vol. 1: Bilan Diagnostic de la LPDA 2 (1998–2005)*.Conakry.

MAEF (Ministère de l'Agriculture des Eaux et Forets) (2007b). *Nouvelle Vision de l'Agriculture Guinéenne. Politique Nationale de Développement Agricole vison 2015. Vol. 2: Orientations et axes stratégiques*.Conakry.

Marfo, K. A., Dorward, P. T., Craufurd, P. Q., Ansere-Bioh, F., Haleegoah, J. and Bam, R. (2008). Identifying seed uptake pathways: the spread of *Agya amoah* rice cultivar in southwestern Ghana. *Experimental Agriculture* 44:257–269.

McDonald, M. B. (1998). Seed quality assessment. *Seed Science Research* 8:265–275.

Morris, L. and Bellon, R. (2004). Participatory plant breeding research: opportunities and challenges for the international crop improvement system. *Euphytica* 136:21–35.

Ndjeunga, J. (2002) Local village seed systems and pearl millet seed quality in Niger. *Experimental Agriculture* 38:149–162.

Nuijten, E. and Almekinders, C. J. M. (2008). Mechanisms explaining variety naming by farmers and name consistency of rice varieties in The Gambia. *Economic Botany* 62: 148–160.

Nuijten, E. (2005). *Farmer management of gene flow: the impact of gender and breeding system on genetic diversity and crop improvement in the Gambia*. PhD thesis, Wageningen University, Wageningen, the Netherlands.

Nuijten, E., Van Treuren, R., Struik, P. C., Mokuwa, A., Okry, F., Teeken, B. and Richards, P. (2009). Evidence for the emergence of new rice types of interspecific hybrid origin in West-African farmers' fields. *PLoS ONE* 4:e7335. doi:10.1371/journal.pone.0007335.

Okry, F. (2005). *A socio-technical development of a seed (planting material) system: The case of yam in the Republic of Benin*. MSc thesis, Wageningen University, Wageningen, the Netherlands.

Okry, F., Dalohoun, D. N., Diawara, S., Barry, M. B. and Van Mele, P. (2011). Networks that work. In *African Seed Enterprises: Sowing the Seeds of Food Security* (Eds. P. Van Mele, J. W. Bentley and R. G. Guéi). Wallingford: CABI Publishing.

Richards, P. (1986). *Coping with Hunger: Hazard and Experiment in an African Rice-farming System*. London: Allen and Unwin.

Richards, P. (2009). Knowledge networks and farmer seed systems. In *Farmer First Revisited: Innovation for Agricultural Research and Development*, 233–237 (Eds I. Scoones and J. Thompson). Warwickshire: Practical Action Publishing.

Rossignol, L. (2008). *La problématique de l'approvisionnement en semences de riz en zone de mangrove*. Projet riz Basse Guinée. Conakry.

Rubyogo, J. C. and Sperling, L. (2009). Developing seed systems in Africa. In *Farmer First Revisited: Innovation for Agricultural Research and Development*, 52–57 (Eds I. Scoones and J. Thompson). Warwickshire: Practical Action Publishing.

Seboka, B. and Deressa, A. (2000). Validating the farmers' indigenous social networks for local seed supply in central Rift valley of Ethiopia. *Journal of Agricultural Education and Extension* 6:245–254.

SG2000 (Sassakawa Global 2000). (2005). *Rapport Final 1996–2004*.Conakry.

SNPRV (Service National de la Promotion Rurale et de la Vulgarisation). (2001). *Multiplication and Diffusion of Community-Based Seeds of NERICA Rices Developed by WARDA*.Conakry.

Song, Y. (1998). *"New" Seed in "Old" China: Impact of CIMMYT Collaborative Programme on Maize Breeding in South-Western China*. PhD thesis, Wageningen University, Wageningen, the Netherlands.

Sperling, L. and Cooper, H. D. (2003). Understanding seed systems and seed security. In *Improving the Effectiveness and Sustainability of Seed Relief. Proceedings of a stakeholders' workshop, Rome, 26–28 May*. *Rome*: *Food and Agriculture Organization*.

Sperling, L. (2002). Emergency seed aid in Kenya: some case study insights on lessons learned during the 1990s. *Disasters* 26: 329–342.

Thiele, G. (1999). Informal potato seed systems in the Andes: Why are they important and what should we do with them? *World Development* 27:83–99.

Tripp, R. and Pal, S. (2001). The private delivery of public crop varieties: Rice in Andhra Pradesh. *World Development* 29:103–117.

Tripp, R. (2001). *Seed Provision and Agricultural Development*. Oxford, ODI/James Currey.

Van Mele, P., Bentley, J. W. and Guéi, R. G. (eds) (2011). *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishing.

Vogt, W. P. (1999). *Dictionary of Statistics and Methodology: A Non-technical Guide for the Social Sciences*. London: Sage Publications.

WARDA. (2007). *Africa rice trends: Overview of recent developments in the Sub-Saharan African rice sector*. Cotonou: Africa Rice Center.

Wiggins, S., and Cromwell, E. (1995). NGOs and seed provision to smallholders in developing countries. *World Development* 23: 413–422.

Witcombe, J. R., Joshi, A., Joshi, K. D. and Sthapit, B. R. (1996). Farmer participatory crop improvement. I: Varietal selection and breeding methods and their impact on biodiversity. *Experimental Agriculture* 32: 445–460.

Witcombe, J. R., Petre, R., Jones, S. and Joshi, A. (1999). Farmer participatory crop improvement. IV the spread and impact of a rice variety identified by participatory varietal selection. *Experimental Agriculture* 35:471–487.

CHAPTER 5

ADAPTATION OF THE INFORMAL SEED SYSTEM TO AGRARIAN CHANGE: THE EMERGENCE OF MARKET ORIENTED LOCAL SEED DEALERS IN THE INFORMAL RICE SEED SECTOR IN GUINEA

Okry, F., E. Nuijten, P. Van Mele, P.C. Struik and P. Richards

Journal of Agrarian Change (Under review)

Abstract

This paper examines the rice seed trade within the informal seed system. It analyses changes occurring in the agrarian system of Lower Guinea and describes farmers' strategies to cope with those changes related to seeds. Attention is given to market development strategies in the local seed trade. We found that local seed dealers, contrary to seed traders in the formal seed sector, combined aspects of the market economy with elements of a traditional moral economy grounded on notions that seed is a basic social need. We argue that market oriented seed dealers emerged as an adaptive response of the informal seed system to a rapidly changing agrarian system and to the weaknesses of the formal seed sector. Seed sector interventions should consider and include local dynamics of market development.

Keywords: Guinea, rice, informal seed system, market, seed dealers

5.1 INTRODUCTION

Broadly speaking, two seed systems coexist in most developing countries: the formal seed system and the informal seed system. The latter is also referred to as the local or farmer seed system. Both differ in the way they are organized and function. The formal seed system usually has a centralized mode of organization and generally follows a linear model of seed development in which each stakeholder plays a specific role from breeding and selection to marketing of certified seed (Sperling and Cooper 2003, McGuire 2005, Louwaars 2007). Seed from such centralised systems tends to be uniform in quality, and exchanges always involve cash transactions (David 2004, Louwaars 2007). Parallel to the formal seed system is the informal one, dominated by farmers who actively breed (Harlan 1992, Almekinders et al. 1994), select (Nuijten et al. 2009), test and disseminate plant varieties (Longley 2000, Nuijten et al. 2009, Richards 2009), and produce, store and disseminate seed (Okry et al. 2011a, 2011b). In this system, seed production and crop production are integrated (Almekinders and Louwaars 2002) and dissemination involves seed gifts, seed loans, barter deals and cash transactions (Okry et al. 2011a, Richards 1986).

Seed sector interventions are commonly geared towards the development of a formal seed system, while the informal system receives less attention (Almekinders and Louwaars 2002), even though it is the most active and dynamic source of seed to small-scale farmers in many poorer countries (Sperling and Cooper 2003, David 2004). In West Africa, for example, about 90 per cent of the rice growers in Guinea rely on the informal seed system (SNPRV 2001) and in Ghana less than five per cent of farmers acquire certified cereal seeds from formal sources (Amanor 2011). Yet the dynamics of these local seed systems are not well understood. Formal interventions and development policies often overlook the role of local seed in maintaining food security and underestimate the capacity of local systems to adapt to wider changes in the agrarian system. The emergence of market-oriented local seed dealers within the informal rice seed system (as reported by Okry et al. (2011a) suggests the existence of an interesting local institutional dynamic around which more appropriate seed delivery strategies might be formulated.

This study focuses on seed trade in both African (*Oryza glaberrima*) and Asian rice (*Oryza sativa*) in Lower Guinea. It starts with an analysis of changes occurring in the agrarian system and notes some emerging challenges of seed supply. The organization of the local rice seed trade is examined and seed dealers characterised. The contribution of local seed dealers towards objectives commonly assigned to seed projects, such as raising awareness of and promoting the use of improved varieties, is assessed. Farmer and seed dealer perceptions of seed quality are then compared. The study ends by highlighting dealers' strategies of market development, compared to those pursued in the formal seed system, and considers prospects to involve dealers in formal seed development. The paper shows that the informal seed system is dynamic and adapts to changes in the agrarian system. It argues that in contrast to the formal seed sector local seed dealers have emerged as a response to a number of rapid changes in the agrarian system and that bottom-up design of future seed programmes could provide a more effective response to the changing needs of the small-scale farming sector better than trying to fix the endemic problems of formal seed supply by offering defunct national programmes to international agribusiness.

The study uses evidence derived from fieldwork carried out in southern Lower Guinea. The fieldwork covered three sub-prefectures (local government units): Moussayah, Friguiagbé and Molota, and one municipality, Kindia, the capital of the Kindia region. The informants were mainly Susu. Data were collected in two phases. From June to December 2007 a survey was conducted in ten villages/hamlets and involved 91 rice farming households. The study villages were clustered in three research sites based on proximity and distance to markets. Villages of Site 1: Bokariya (9'20.582N; 12'48.582W; 52.6m asl) and Sangaran (9'20.538N; 12'48.010W; 66.8m asl) were chosen because of relative remoteness to appreciate farmers' seed strategies in the absence of major development project interventions or urban markets. The closest major market was located at Sikhourou (49 kilometres away). Villages of Site 2: Seifan (9’54.136N; 12’47.21W; 78.1m asl) and Dentègueya (9’54.303N; 12’48.204W; 73.1m asl) were selected for their proximity to the national rice breeding centre (5 kilometres) and to the rice seed centre of Kilissi (5 kilometres), in order to assess the influence of formal plant improvement on farmer seed use and distribution. Kindia market (the important market closest to Site 2) was located at 25 kilometres. Villages of Site 3: Kinyaya (9’58.044N; 12’53.591W; 402m asl), Hononkhouré (9’57.143N; 12’53.111W; 429m asl), Tour (9’57.273N; 12’53.25W; 368m asl), Yaya (9’57.491N; 12’54.479W; 436m asl), Dandakhouré (9’56.503N; 12’53.897W; 400m asl) and Sinta (9’57.246N; 12’53.105W; 390m asl) were chosen because of their proximity to Kindia (12 kilometres on average). Kindia is a regional market centre and regional headquarters of governmental agricultural development agencies. At the time of the study the extension services had limited activities in the study area because of shortage of resources. A local NGO APEK (Association pour la Promotion et le développement Economique de Kindia) was operating in Site 1 and to a lesser extent in Site 3.

During the first phase of research data were collected on the rice farming system in order to characterise it and appreciate on-going socio-economic and technical changes. We also assessed farmer awareness of improved varieties, seed[2] sources and seed use, variety use, ways of acquiring seed and perception of seed quality. These data were collected by questionnaire directed to heads of household (mostly male in a strongly Islamic society). Households were randomly selected. Because the survey was conducted during the cropping season, consideration of households’ willingness to participate in the study was taken into account. A few households were replaced and some withdrew because of time constraints. In addition, focus group discussions and informal interviews were conducted to collect data on choice of seed dealers[3] and the nature of relationships between farmers and the seed dealers.

The second phase of research lasted from June to December 2008. A survey was conducted in Kindia, Friguiagbé and Sikhourou-Daffira markets, involving 41 local seed dealers. This survey collected data on the socio-economic status of seed dealers, institutional linkages (relationships with seed projects and rural development organizations), experience in the seed trade[4], sources of seed and varieties, relationships with customers, strategies for market development, perception of seed quality and prospects for involvement in formal seed projects. Friguiagbé, Kindia and Sikhourou-Daffira markets were selected because they were the most frequently cited markets for seed purchases by household heads interviewed in 2007. Seed dealers were identified through use of a snowball sampling technique (Vogt, 1999).

[2] Seed refers to planting material. Differences between seed and grain (or paddy) were considered only from farmers’ point of view and practices. Seed differs from paddy by its time of harvest, techniques of harvest and postharvest manipulations (threshing, drying, conservation and storage).

[3] Seed dealer refers to anyone selling seed as an occupation - coupled or not with another occupation. Seed dealers can be either established at a market place or operating at community level. In the latter case, the dealer will be recognised as such by farmers. Continuous seed sale over years was an important criterion to qualify as a seed dealer. Farmers only occasionally selling seed were not recognised in this study as seed dealers. The objective was to characterise local seed dealers and describe their seed businesses. But in order to avoid subjectivity in selection (especially for part-time dealers operating at community level) this paper purposely focuses on dealers operating at market places.

[4] Seed trade refers to seed commercialisation at a market place. Occasional village seed sales were also observed, and most farmers engaged in these when they had seed surpluses, but these transactions are not included in the present study. This decision made it easier to separate specialised seed dealers from occasional seed dealers.

5.2 ANALYSING THE FARMING SYSTEM: OVERVIEW OF RECENT CHANGES AND NEW CHALLENGES FOR SEED SYSTEMS

5.2.1 Crop Portfolio and Gender

Rice-growing households grew both annual and perennial crops. Perennial crops, i.e. mango trees (Sites 2 and 3) or palm trees (Sites 1 and 3) were the major cash crops in terms of net income for farmers. Only a few farmers owned trees: these were mostly male land owners. The most important annual crops were rice (*Oryza* spp.), fonio (*Digitaria* spp.), groundnut (*Arachis hypogaea*), hot pepper (*Capsicum* spp.) and cassava (*Manihot esculenta*). These are all local food crops, although farmers earned money by selling them.

Apart from rice, cultivated by both men and women, men (in all sites) owned more fonio and cassava fields, whereas women more frequently owned groundnut fields (Table 5.1). Groundnut and cassava were the annual crops farmers most often sold for cash. At the household level, cassava and groundnut fields were managed individually, in contradistinction to the communal management observed for fonio and, particularly, rice. Farmers commonly said: "*groundnut and cassava take care of the rice fields*" to express the importance of money earned from these two crops, and also to indicate how important it is for farmers successfully to cultivate rice. Site 3 had the most diversified crop portfolio. In general men had the more diverse crop portfolio. This reflects the fact that they owned more fields than women.

Table 5.1: Crop type, relative abundance (in percentage) and field ownership (2004-2007)

Crops	Site 1 (N = 32 households)		Site 2 (N = 24 households)		Site 3 (N = 35 households)	
	Female	Male	Female	Male	Female	Male
Perennial crops						
Mango	-	-	0	0.4	0	0.1
Palm	0	0.3	-	-	0	0.1
Annual crops						
Rice	73.8	66.6	49.7	60.3	19.2	50.2
Groundnut	16.3	10.1	46.2	18.7	72.3	10.4
Fonio	9.9	19.1	2.0	15.4	5.4	14.0
Cassava	0	1.3	0	1.8	1.5	13.4
Pepper	0	1.9	0	0.4	0	1.3
Maize	-	-	2.0	2.9	0	1.8
Sweet potato	-	-	-	-	1.5	4.3
Cocoa yam	0	0.3	-	-	-	-
Yam	0	0.5	-	-	-	-
Cucumber	-	-	-	-	0	2.5
Pineapple	-	-	-	-	0	1.6
Total number of fields	141	377	199	272	130	605

Source: Surveys 2007

Notes: -: Crops not grown by the sample households. 0: crop grown in the area but not owned by that category of farmers of the sample. Relative abundances are calculated based on the total number of fields owned per gender per site.

5.2.2 Importance of Rice for Rural Households

At the national level, the per capita rice consumption of Guinea was 69 kg/year between 2001 and 2005 (WARDA 2007). Local supply is outstripped, and rice imports account for 40 per cent of annual consumption (MAEF 2007). Rice consumption by Guineans has deep socio-cultural roots. Guineans commonly say that a dish without rice is not a meal (M. B. Barry, oral communication, Entre Terre et

Mer Symposium, Conakry, December 2008; Sarró 2009). To reduce dependency on rice, a presenter at this same symposium ironically invited Guineans “also to consume other food crops”.

At the local level, farmers ranked rice as the top crop for household food security. It is widely understood in the villages that a "real farmer" should ensure 12 months of rice consumption for his family. Openly buying and consuming imported rice (even though this regularly happens nowadays) is not always perceived positively by villagers. Rice prepared for farm work gangs must be local rice. Farmers say that imported rice is too light and thus quickly digested. Some work gangs even requested exclusively African rice (*O. glaberrima*) when performing the heaviest activities such as field clearing and ploughing. In some cases work gangs accepted local varieties of *O. sativa* but might terminate their performance an hour or two early if they start to feel hungry. So household heads take great care to organize their rice cultivation so as to ensure enough rice of the right kinds to cover annual needs. Each household clears one or several major rice fields on which all household members must work, if they are to eat from family rice supplies. After the major rice fields are established individual household members are permitted to establish private rice fields[5] provided the household has land available. The harvest of these private fields, and also part of the harvest of the main field(s), is sold in local grain markets. Between 2004 and 2007, on average 24 per cent of the rice harvest of the study area was sold and 10 per cent was kept for seed. Household consumption was estimated at 66 per cent of the total harvest. The importance of rice sales differed across sites, being higher for farmers in Site 1 (36 per cent) than for those in Site 2 (24 per cent) and Site 3 (14 per cent).

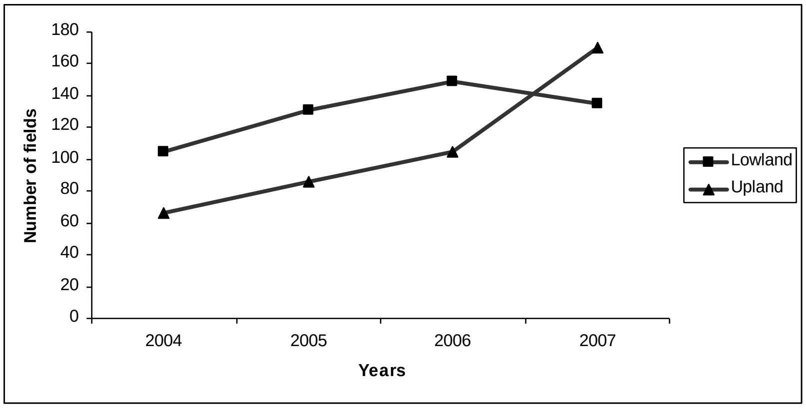
5.2.3 Upland and Lowland: Two Agro-Ecologies Used for Rice Cultivation

Of the four cultivation systems (upland, lowland, mangrove and swamp) encountered in Lower Guinea (Barry et al. 2007), the farmers interviewed for this study practiced only upland and lowland rice cultivation. We found that from 2004 to 2007, upland rice seed represented 60 per cent of the total rice seed used, suggesting that upland rice cultivation dominated in the study area. Seed use varied across sites. From 2004 to 2007, farmers of Sites 1 and 3 steadily increased upland seed use from 61 and 66 per cent to 78 and 82 per cent respectively. Upland seed use increased to a lesser extent in Site 2: from 33 per cent in 2004 to 36 per cent in 2007. These figures indicate greater reliance of farmers in Site 2 on lowland cultivation.

Figure 5.1, based on questionnaire returns, shows the number of rice fields cultivated in both upland and lowland from 2004 to 2007. It is noteworthy that in each year the number of lowland rice fields surpassed the number of upland fields, except for 2007. These figures compared to data on seed use suggest that the lowland fields reported in the questionnaire survey must have been rather small in size, while also indicating an increase from year to year in number of farmers cultivating lowland rice. The intensive labour required to prepare lowland fields helps explain why lowland fields were of small size. The drop in lowland fields in 2007 and the increase observed in upland fields in the same year, may have resulted from build-up of stress factors (especially soil acidity). The drop in lowland fields, however, might be no more than an artefact caused by data collection methods. Data related to number of fields from 2004 to 2006 depended on farmer recall but 2007 were based on the researcher’s own visits to fields.

[5] Farmers said that in the past and up to the 1970s and early 1980s rice fields were owned by the households (managed by the household heads) and collectively cultivated by all members of the households. The possession of private rice fields is thus a recent development in the organization of the households pertaining to the rice farming.

Figure 5.1: Number of rice fields over the years (2004-2007)



Source: Surveys 2007

5.2.4 Land Tenure and Land Management

In Bokariya- Tassen and Sangaran (Site 1) upland farmland belonged to five families: Camara, Yansané, Doumbouya, Diawara and Savané. Among these, only the Camara family originated from the area. According to village elders, the other families migrated from the Kankan region (Upper Guinea) to Site 1 in the 1800s. Hence, the Camara were still the major land owners. The Camara together with elders of the five families formed a governing group of elders managing the land. The land is divided into seven zones. The management group decides each year on which zone to farm, and together with some representatives of farmers, they allocate land to each household. Each year the households submit request for land (number and size of fields) to the elders. Requests are accompanied with a symbolic rent of US$1 or a few cola nuts. Each zone is then cultivated for between 3 and 4 years and followed by a fallow period of 3 to 4 years making a rotation of around 7 years in total. Rice is the first crop in the rotation system and thus comes back to the same field only after seven years. Groundnut and fonio succeed rice in the following two years. Depending on soil fertility, a fourth crop sometimes succeeds fonio, but generally farmers move to another field after three years of cultivation. Women cannot directly request upland fields from the elders' committee, but their requests are included in the overall request of the household head upon whom rests the management of the rice fields subsequently sown. Therefore, women cultivate upland rice fields only when the household heads agree. However, from the second year of the crop rotation (after rice cultivation), women are allowed ready access to upland to grow groundnuts, a so called "women's crop" (Table 5.1), although nowadays it also catches the attention of the men as well because of the income it generates.

Organization around land management is somewhat different in Sites 2 and 3. Land (upland) here belongs to individual families and household heads and there is no element of village management as observed in Site 1. But as in Site 1 women have no direct access to uplands. Here also, they had to request land through their husbands. As in Site 1, women had easier access to uplands from the second year of the crop rotation in order to grow groundnut. In all sites, strangers and migrants had no right to access upland directly.

The land tenure observed for the uplands was absent in the lowlands. In all sites, lowlands were owned by individuals and sometimes families. These wetlands can be rented or sold to any farmer in need. Women had direct access to lowlands (whether through their families or through rent or purchase) and it was here that they established their private rice fields every year. Strangers and migrants also had relatively easy access to rented lowland. It might thus be said that land tenure rules force members of two social categories into swamps. The limited availability of upland resulting from population increase also contributes to the explanation of why more and more farmers cultivate lowlands (Figure 5.1). This ready access by women and migrants to lowland has socio-cultural roots, which are discussed below.

5.2.5 Tasks Division in Rice Farming

Decisions on field location (Sites 2 and 3), field size, and choice of varieties are made by men. Seed processing and storage are mostly women's occupations. Field clearing in uplands is exclusively a task for men. It takes place between March and April each year. From the second half of May, and generally a few days before sowing, or even on the day itself, men "plough" the cleared farm using a narrow-bladed hoe. This is no more than a superficial scratching of the gravelly and sometimes stony soil in order to create a sowing bed for the rice seed. Seed broadcasting, the only crop establishment technique observed in uplands, is performed by an experienced household member in order to ensure a regular planting density. After the broadcast sowing is complete women perform a "patch-and-mend" operation, consisting of the careful ploughing of those parts of the fields mistakenly left out by the men during the ploughing. As this patch-and-mend operation is in progress the women also carefully cover the seed in order to encourage good germination and prevent birds from picking out the seed. This activity, apparently simple, but time consuming, determines the success of the upland rice field.

Farmers said that when the patch- and-mend work is done properly weed invasion is reduced and delayed (eight to ten weeks instead of four to six weeks after sowing), thus saving women from back-breaking weeding. Weeding is also a task for women. Men sometimes help if the burden is too great, but women tend to be wary of men's lack of skill at distinguishing between very young shoots of rice and young weedy grasses. Any time saved from weeding upland rice fields is likely to be invested by a woman in her groundnut fields, and perhaps also to establish a private lowland rice field. Everyone is involved in bird scaring, although women and children tend to predominate. Bird scaring involves working from a specially constructed platform with a sling-shot and pile of stones or mud balls. For children it is as good as a game. Women also play a great part in upland rice harvesting and the post-harvest handling of paddy. The harvest starts in September, but depending on the earliness of the varieties cultivated. Seed selection and seed harvesting are performed by experienced household members, mostly household heads. From this stage onwards, seed handling, including threshing, drying, storage and conservation (when needed), is mainly women's business. In several agro-ecologies, and for several crops, women constitute a skilled work-force (Dolan 2004, Johnston 2007), and they are especially adept at handling seed (Richards 1986, McGuire 2005, Nuijten 2010, F. Okry et al. unpublished) since this requires a fund of patience, dexterity and attentiveness to assure quality. It also remains true that in many situations women take responsibility for many activities not because they are more skilled than men but because they are forced by social norms to take on menial tasks (Dolan 2004, 107, Nuijten 2010). In any case, in Susu villages it is the sole responsibility of the household head to manage the household seed and paddy stocks.

In sum, activities crucial to the success of the upland rice farm rest on women. Therefore, women's involvement in other activities depends on their ability properly to manage their time in order to create slots in the cropping calendar that will not put the all-important rice farm at risk. Left to themselves, women would preferably engage in groundnut and lowland rice cultivation (Tables 5.1 and 5.2). They establish their groundnut fields when men clear and plough upland rice fields; this is a time when women's presence in the rice field is not yet required. Female farmers said the cultivation of late maturing rice varieties and early maturing groundnut varieties allowed them to weed the groundnut fields before starting to weed upland rice fields, as these two activities do not overlap in the cropping calendar. Farmers generally said that the lowland rice cultivation requires less attention than upland rice. They said they felt less weed pressure in the lowlands because water standing in the field reduces weed invasion, giving the farmers extra time to devote to other crops or activities. In addition the rice harvest starts later in the lowlands (December-January) than in the uplands, so leaving some time to lowland rice growers, especially women, properly to finish upland harvesting and essential post-harvest activities.

Ploughing, the most laborious and time consuming activity in lowland rice cultivation (Richards 1986, Mokuwa et al. 2011) is mainly performed manually. But work oxen (re)introduced in the area in the late 1980s are gaining importance (Volpe 2007). Work oxen were mostly used in Site 2 (where lowland cultivation dominated) and only to a lesser extent in Sites 1 and 3. Farmers said the introduction and promotion of oxen helps to reduce the workload of land preparation, a key bottleneck to lowland rice cultivation. Owners of oxen performed land preparation for other farmers on a contractual basis. They charged on average US$7.9 for a working day (of only 4 hours, since the semi-dwarf trypano-tolerant Ndama oxen suffer stress and tiredness easily) although terms might vary depending on the relationships between the oxen owner and farmer.

5.2.6 A Growing Interest in Lowland Rice Cultivation

In 2007, interviewed farmers had spent on average 20 (min 3; max 50) and 19 (min 0; max 50) years in lowland and upland rice cultivation, respectively. Growers' experience in upland cultivation was difficult to evaluate accurately since almost all of them declared that they had cultivated upland rice since their youth. Values are only indicative, therefore. Nevertheless, informants indicated that the development of lowland rice cultivation is recent in Lower Guinea. In fact, prior to the introduction of work oxen (1980s) rice cultivation happened mainly in the uplands. Lowland rice cultivation was perceived as a tedious, “unhealthy” and “humiliating” activity, and therefore reserved to migrants and a landless underclass (in probability the descendants of former slaves). The landless class also includes women, of course, since they have no recognised rights to upland in local custom. In earlier times the entire rice production for household consumption among the freeborn would have been in the uplands. Labour availability, upland soil fertility, climatic conditions and level of domestic rice demand sustained this system. At the time Guinea was a rice exporter (Portères 1966). Since the 1980s increase in domestic demand for rice (due primarily to growth in urban population) has led to an intensification of production, and exacerbated competition for good-quality upland. Guinea is no exception to a wider African pattern in which intensification of production and reliance on markets for inputs and other basic necessities strengthens competition over land and labour (Peters 2004, 292).

The Guinea government, possibly to head off conflict over upland, and committed to national food security, brought lowland cultivation on to the agenda of formal interventions in the post-socialist era (MAEF 2007). Work oxen were re-introduced (the first introduction was in 1915, Volpe 2007) in order to take charge of some of the tedious tasks associated with wetland farming. The Réseau Guinéen pour la Traction Animale et le Développement Intégré (RGTA DI), a local NGO promotes their use in the study area (Starkey 1997, Volpe 2007). Recently, the gap between domestic rice demand and local production has increased further, and reached 40 per cent in 2007 (MAEF 2007). This created additional market opportunities for local rice, especially in recent years when imports have become very expensive as a result of economic instability (2000-2008) and a global food crisis (2007-2008). As a result the government has lost control over food prices (Bush 2010) and a supply of cheap food to Conakry and other urban areas. Being a major food in Guinea, and considering that relatively little of the village harvest is sold, rice has become a financially attractive crop. Existence of outlets for local rice encourages farmers to produce more. The relatively easy access of women and migrants to lowland, together with the advent of work oxen to reduce lowland workloads makes lowland rice an alternative proposition. Autochthonous male farmers also cultivated lowland rice (Table 5.2). They are not immune to its economic attractions. This further explains the increased involvement of farmers in lowland rice cultivation, as shown by Figure 5.1. We found that the type of agro-ecology cultivated was significantly associated with gender (Table 5.2). Within households, women mostly established their rice fields in lowlands while men evenly distributed their fields between uplands and lowlands.

Table 5.2: Distribution of rice fields per agro-ecology and gender (2004 to 2007)

Years	Gender	Number of rice fields	Agro-ecologies		Pearson chi-square (χ^2)
			Percentage of lowland rice fields	Percentage of upland rice fields	
2004	Female	40	85.0	15.0	P< 0.01
	Male	131	54.2	45.8	
	Total	171	61.4	38.6	
2005	Female	53	79.2	20.8	P< 0.01
	Male	164	54.3	45.7	
	Total	217	60.4	39.6	
2006	Female	56	82.1	17.9	P< 0.01
	Male	198	52.0	48.0	
	Total	254	58.7	41.3	
2007	Female	79	68.4	31.6	P< 0.01
	Male	226	35.8	64.2	
	Total	305	44.3	55.7	

Source: Surveys 2007
Notes: Pearson chi-square (χ^2) was performed for each year to test statistical association between gender of the field owners and agro-ecology where the fields were established.

5.2.7 The Arrival of Non-Farming Households in Rice Cultivation

In 2007, 23 per cent of rice growing households surveyed were non-farming households, i.e. those where the head of household derived the bulk of income from non-agricultural activities, such as trade, craft production, driving, civil service employment). In some cases the data also include the households of young urban migrants forced to return home (temporarily) by the crisis in the cities. Food prices, increased in 2007 by 51 per cent on average in developing countries because of the food crisis (HLTF 2008). Guinea was not an exception. This crisis has forced some non-farming households, especially those spending most of their revenue on food products, to diversify into agriculture, either as second source of income or to secure basic subsistence. The highest proportion of non-farming households (31 per cent) was found in Site 3 where rice sales were lowest and crops highly diverse (Table 5.1), suggesting that non-farming households engaged in rice cultivation primarily to increase their rice self-sufficiency, as rice prices were among the prices most affected by the global commodity crisis of 2007-8 (Swan et al. 2010). This fits with general findings by Poulton et al. (2006) and Swan et al. (2010) that households in sub-Saharan Africa rely on a mixture of own produce and the market for their food needs. Hence, depending on local strategies deployed, variations in food prices, whether linked to the international food crisis or to seasonality, would impact households differently.

Our field surveys revealed that non-farming households represented 26 per cent and 30 per cent of rice growing households in upland and lowland farming, respectively. Non-farming households seemed to engage in both agro-ecologies, but had relatively easier access to lowland, as a result of land tenure factors described above. Also, there is a common perception that lowland rice cultivation requires less field time by the farmer (as compared to upland fields), and this encouraged non-farming households to opt to engage in lowland cultivation. In a way, the move of non-farming households into agriculture and the opportunity that lowlands presented to these people, have, we would argue, reduced the dissatisfaction and intensity of protest triggered in Guinea and elsewhere by the 2007-8 food price spike (Bush 2010, Ghosh 2010). Transition of households from one activity to another, and options to forge temporary combinations of activities, as facilitated by local community dynamics rather than by governmental policy, have appeared to play a major part in mitigating effects of the global financial and food crisis at a level of rural households. Yet the local social institutions making such adjustments feasible are neither well understood nor acknowledged when mechanisms mitigating the impact of the food crisis on households have been adumbrated (see FAO 2008, Ghosh 2010).

5.2.8 Challenges for Seed Systems

The changes - some occurring quite rapidly - in Guinean farming systems just sketched raise a number of challenges for seed systems. Among these are the increased demands for seed and suitable varieties to ensure a minimum yield for farmers (some quite inexperienced) operating under their sub-optimal conditions. More extensive cultivation in the lowlands, a relatively unfamiliar agro-ecology, also resulted in increased need for technical advice. These are new challenges for both formal and informal seed systems. This is especially challenging knowing that the extension service lacks resources fully to meet farmers' demands for technical advice –stemming from cuts consequent upon the Structural Adjustment Programs of the 1980s and 1990s − and knowing that the formal seed system covers only 8 per cent of the seed needs (SNPR 2001). It is thus important to understand how the informal seed system coped with these changing realities. Before diving into the responses of the informal seed system to these changes (detailed in the following sections) we first explore farmers' varietal diversity and seed acquisition strategies.

5.3 EXPLORING VARIETAL DIVERSITY AND SEED ACQUISITION STRATEGIES

5.3.1 Cultivated Rice Varieties

There were 38 rice varieties grown in the study area in 2007 (Table 5.3). The largest diversity was encountered in Site 3 (22 varieties) and Site 2 (19 varieties). In all sites lowland and upland varieties were equally represented in the varietal portfolio (Table 5.3). Strict lowland and upland varieties (as classified by farmers) represented 50 and 40 per cent of the total varietal diversity, respectively. About 10 per cent of varieties were cultivated in both lowland and upland. Seed of upland varieties represented 66 per cent of the total amount of rice seed used. In lowland farms five varieties were dominant whereas only two were dominant in upland. Seed of these five lowland varieties represented 80 per cent of total seed used in lowlands and covered 70 per cent of lowland fields. Seed of the two dominant upland varieties represented 80 per cent of total seed used in uplands and covered 65 per cent of the upland fields. The relatively large varietal diversity observed in lowland, a relatively new agro-ecology for farmers, compared to upland, might indicate that lowland farmers were still searching for suitable varieties, and therefore were experimenting with several options. This also explains why most of these varieties were grown at limited scale and by only few farmers (Table 5.3).

Women cultivated 47 per cent of the total varietal diversity (Table 5.3). These varieties were among the dominant in the area (occupying 84 per cent of total fields and representing 90 per cent of total seed use). Of these varieties, 72 per cent were lowland varieties. The four varieties cultivated most by women were all lowland varieties: women controlled 50 per cent or more of lowland fields under cultivation (Table 5.3). These findings confirm that women farmers were more oriented to lowlands than uplands. Men cultivated 97 per cent of the varietal portfolio and (over all three sites) controlled more than 50 per cent of fields planted with each variety. Varieties exclusively cultivated by men (47 per cent of the total number of varieties), were 65 per cent upland varieties. Men were thus more upland oriented. But men had more controlling interest in lowland cultivation than women had in upland cultivation. It could be that because projects encouraged the development of lowland cultivation men took more interest in lowland cultivation, to extend their control over the land. This has been pointed out for modern wet-rice cultivation in The Gambia (Carney 1998).

Only local varieties were grown in uplands, whereas 32 per cent of the strict lowland cultivars were improved varieties. Farmers could not classify three of the strict lowland varieties (Souleimane Malé, Linette and Farana) as either local or improved varieties. The same was true for Conakry (upland), Momodou Malé (upland/lowland) and Three-month (an upland/lowland type). All these varieties were recently introduced varieties known to and cultivated by only a few farmers. A few typical improved lowland varieties, e.g. CK21 and Nankin, were also tried on uplands. The improved varieties represented 21 per cent of the varietal portfolio and 6 per cent of total seed use. CK90 and Nankin were the two most widespread improved varieties. They were possessed by eight and nine per cent of households, respectively. But CK90 and CK21 were the most important improved varieties assessed by total seed use (each accounting for about two per cent of total planted area.

African rice (*O. glaberrima*) represented 13 per cent of the varietal portfolio and 7 per cent of the total seed area planted in 2007. Put another way African rice covers about the same area as improved varieties. Varieties of *O. glaberrima* currently in cultivation are entirely products of farmer agency, as the formal research has devoted little or no effort to their improvement to date (Linares 2002, Richards 2006). Farmers acknowledged *glaberrima* as drought tolerant and weed competitive. A number of researchers have reported also on the apparent ability of *glaberrima* to suppress (or out-compete) weeds and to perform better under harsh conditions than most of the Asian rice varieties (Dingkuhn et al. 1999, Sarla and Swamy 2005, Richards 2006, Futakuchi and Sié 2009). Farmers also said varieties of *O. glaberrima* assure a minimum yield even on poor soils and under fluctuating rainfall. African rice varieties were also thought to be slow digesting as food, helping to improve food security throughout the year, since not so much is eaten at a single sitting. Similar farmer perceptions have been reported also from Togo, Ghana and Sierra Leone (Mohapatra 2010, Teeken et al. 2010) and Guinea Bissau (Temudo 2011). These reasons help explain why farmers in Lower Guinea maintain *O. glaberrima* in the farming system, perhaps mainly as a food security reserve. The varieties Saali and Saali Forê were the most widespread African rices (Sites 2 and 3). These two, with Tombo Bokary, were the most cultivated African rices across all sites: 7 per cent of the total seed used. However, Saali Forê and Tombo Bokary were the most used: 8 and 18 per cent of households cultivated them, respectively. Tombo Bokary clustered at the molecular level with Saali (cf. Nuijten et al. 2009). These two varieties may be genetically identical, carrying different names in different sites.

In sum, compared to lowland, upland farming has a more limited range of varietal diversity, although it has accounts for a greater area of seed use. No improved variety was found in upland. This could be taken to mean that available improved upland varieties do not suit farmers' environment, or that local varieties still outperform improved varieties in sub-optimal upland conditions. It could also be that farmers were not aware of improved upland varieties available at national and international research institutes. Because lowland cultivation is more recent than upland cultivation, it could also be that farmers in lowland were more open to try out new varieties because they were still adapting to an imperfectly known system. Reliance upon African rice (*O. glaberrima*) is about as high in uplands as reliance on improved varieties of Asian rice in lowlands.

5.3.2 Seed Acquisition

Interviews revealed that 70 per cent of the seed used from 2005 to 2007 was farm-saved seed. Farmers said the decision on how much seed to save for the next season was made right after the harvest. However, crop failure (due to changes in rainfall, decline in soil fertility and increase diseases), misfortune (mostly sickness and death) and unplanned events (a birth, or visit of relatives or friends) can result in yield loss or force farmers to eat or sell part of their seed reserve. This often leads to seed shortage at sowing time. In fact, between 2003 and 2007, 44 per cent, 54 per cent and 51 per cent of the rice growing households experienced at least one partial seed shortage in Sites 1, 2 and 3, respectively. In all sites the number of households having experienced at least once seed shortage increased from 4 per cent in 2003 to 9 per cent in 2004 and 2005, 11 per cent in 2006 and 34 per cent in 2007. During those five years, 93 per cent of all reported cases of seed shortage were due to unplanned seed consumption or sale, and only 7 per cent to post-harvest losses.

Table 5.3: Rice varietal portfolio in cultivation in the study area (2007)

Name of varieties	Area of cultivation (Sites)	Agro-ecology of cultivation	Field possession by male (percent)	Field possession by female growers (percent)	Number of fields cultivated with the variety (percent)	Quantity of seed use (percent)	Households cultivating the variety (percent)
Oryza glaberrima ▲							
Tombo Bokary	3	Upland	100	0	5.2	5.9	17.6
Saali Forê	2,3	Upland	100	0	2.1	0.8	7.7
Saali	2,3	Upland	100	0	0.6	0.3	2.2
Saafary	3	Upland	100	0	0.3	0.1	1.1
Siiga	3	Upland	100	0	0.3	0.0	1.1
Farmer hybrids ■							
Wonyonwonyonyin	2,3	Upland	88	13	2.4	0.5	8.8
Kissi Foundégni	1	Upland	100	0	0.3	0.1	1.1
***Oryza sativa* (improved varieties*)**							
Nankin	2,3	Upland/Lowland	56	44	2.7	0.9	8.8
CK90	1,2,3	Lowland	86	14	2.1	2.0	7.7
CK21	3	Upland/Lowland	80	20	1.5	1.6	4.4
Chinois [x]	3	Lowland	100	0	1.5	0.7	4.4
CK801	2	Lowland	50	50	0.6	0.5	2.2
CK4	3	Lowland	100	0	0.3	0.2	1.1
Sengai2	3	Lowland	100	0	0.3	0.1	1.1
Indien	3	Lowland	100	0	0.3	0.1	1.1
***Oryza sativa* (local varieties)**							
Saidou Gbéli	1,2,3	Upland	79	21	24.7	36.3	73.6
Tonsékéréyi	1	Lowland	57	43	10.7	9.1	24.2
Saidou Firê	1,2,3	Upland	88	12	10.4	15.1	36.3
Koba Greffé	2	Lowland	48	52	6.4	6.1	14.3
Koba	2	Lowland	53	47	5.2	4.0	18.7
Samba	1,2	Upland	88	13	4.9	5.9	16.5
Diyan	3	Lowland	90	10	3.0	2.8	8.8
Souleimane Malé [1]	2	Lowland	56	44	2.7	1.9	9.9
Kaolaka	2,3	Lowland	57	43	2.1	0.9	7.7
Momodou Malé [1]	2	Upland/Lowland	67	33	1.8	0.8	5.5
Podê	2,3	Upland	100	0	1.5	0.7	5.5
Foé	1,2	Lowland	50	50	1.2	0.6	4.4
Missilimi	1	Lowland	67	33	0.9	0.5	3.3
Unknown	3	Upland	100	0	0.9	0.5	3.3
Three-month	1	Upland/Lowland	100	0	0.9	0.1	3.3
Gbolomika	2	Lowland	0	100	0.3	0.3	1.1
Sèwa	3	Upland	100	0	0.3	0.3	1.1
Banyounou	1	Lowland	100	0	0.3	0.2	1.1
Farana[1]	3	Lowland	100	0	0.3	0.2	1.1
Soumaila	1	Upland	100	0	0.3	0.2	1.1
Conakry[1]	1	Upland	100	0	0.3	0.1	1.1
Kankoudi	2	Upland	100	0	0.3	0.1	1.1
Linette [1]	3	Lowland	100	0	0.3	0.1	1.1
Footé	2	Lowland	100	0	0.3	0.0	1.1

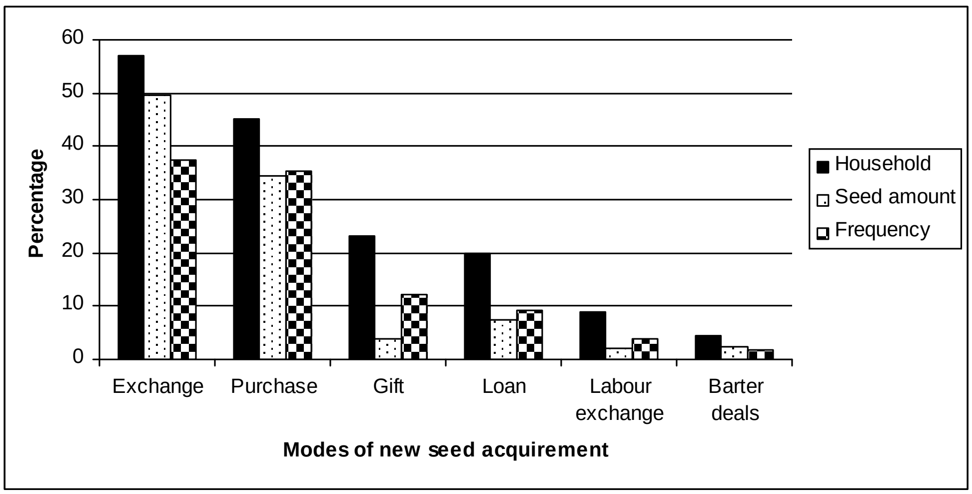
Source: Surveys 2008

Notes: ▲Varieties of *Oryza glaberrima* species (After Nuijten et al. 2009). ■Variety of interspecific origin (*O. sativa* × *O. glaberrima*) as result of hybridisation in farmer fields (After Nuijten et al. 2009). * Improved varieties (we followed farmers' classification of varieties as improved or local varieties). [X] Chinois is a generic name systematically given to unknown improved varieties. 1: varieties farmers were unable to classify as improved or local varieties. Total number of fields: 331. Total number of households studied: 91. Total seed use in 2007: 8598 kg

In the best case, farmers re-acquired seed; if not, they abandoned part of the cleared field (cf. Richards 1986). Besides acquiring new seed to make good shortages (18 per cent of new seed acquired between 2005 and 2007), farmers also obtained new seed for field enlargement purposes (38 per cent), seed renewal because of mixture (3 per cent) and to try a new and desired variety (40 per cent) (Okry et al. 2011a). The recurrent and increasing seed shortages reported by farmers suggest that farmers' seed needs are becoming harder to meet and that specific responses are now needed. Seed relief projects (e.g. FAO/OSRO) have tried to mitigate effects of seed shortages, but their actions were time-bound, being limited to periods following civil unrest in 2007 and 2008. A more structured approach seems to be required.

Farmers in the research sites had several modes of seed acquisition, of which "Exchange" and "Purchase" were the most frequently cited (cf. Richards 1986, 1997, for comparable data for Sierra Leone). These accounted for 50 and 35 per cent of the total quantity of new seed acquired (Figure 5.2).

Figure 5.2: Farmers' strategies of new seed acquisition (2005-2007)



Source: Surveys 2007

Notes: 237 cases of new seed acquisition reported by 91 rice farming households. Total seed acquired (2005-2007) = 6,376 kg.

Frequency: frequency of use of the mode of seed acquisition. Household: number of households having used the mode of seed acquisition. Seed amount: quantity of seed acquired using the mode of seed acquisition. Exchange: exchange of mixed seed, paddy or seed of a variety with pure seed or seed of another variety. Commonly used exchange rate was 1:1. Purchase: seed acquired with cash. Gift: free seed gift and inherited seed. Loan: seed to be reimbursed at harvest or by cash at a defined time period at variable loan rate. Labour exchange: seed acquired in exchange of labour to perform an activity, either in the rice field or not. Barter deals: seed acquired in exchange of other goods e.g. palm oil.

"Purchase" involved a greater number of transactions of smaller average amounts of seed than "Exchange" (Figure 5.2). About 20 per cent of the households obtained new seed through "Gift" and "Loan". Only small quantities of seed flowed through gift giving, though gift exchanges may be important in testing out new varieties, such as farmer selections from in-field crosses (Richards 1995). In terms of seed quantity, gifting ranked as the fourth most important mode of new seed acquisition. "Labour exchange" and "Barter deals" were two other less used ways to acquire new seed (Figure 5.2). Among above listed seed acquisition modes, only seed "exchange" involved farmer-to-farmer transactions. The other main modes ("purchase" and "loan") involved both farmers and seed dealers.

Seed was bought from several agency sources. Of seed purchased with cash (2005-2007), 53 per cent came from relatives, friends and seed dealers living in neighbouring villages, 30 per cent came from occasional seed sales by relatives and friends living in the same village as the purchasing farmers, 15 per cent came from local seed dealers operating in market locations and 1 per cent came from specialised agro-input dealers. At the community level (i.e. same or neighbouring villages) farmers found it difficult to separately identify seed dealers and friends and relatives occasionally selling rice seed. In fact dealers had so many relationships with farmers in their communities (including relationships of kinship and marriage) that it would be artificial for farmers to classify them as “dealers” rather than the affines, friends, and patrons that they undoubtedly were as well. These groups are (perforce) kept together, therefore. A separation between dealer, client and peer was clearer in open market locations.

5.3.3 Understanding the Different Modes of Seed Acquisition

Each mode of seed acquisition served a different purpose in a different context. Farming begins through the acquisition of seed to make a first independent farm. To acquire the first seed as newly independent farmers, farmers relied mainly on seed gifts (e.g. seed from senior male kin or seed that was inherited). This initial gifting of seed marks a young person’s transition from dependency (farming under a head of household or a head wife, to becoming a head of household or wife with a farm of one’s own, and dependents to provide for). It is one of the modalities upon which inter-generational social solidarity is founded in Susu society (cf. Mauss 1950). This kind of inter-generational seed gifting does not show up strongly in the kind of survey reported above since each transaction is rare (a once-in-a-lifetime occurrence) but it would be hard to underestimate the significance of such events for social cohesion as a whole. The success of any modernised or hybrid seed system will depend therefore on the extent to which it takes into account and protects seed exchanges foundational for village social solidarity.

Seed purchase came as second mode of first seed acquisition, thus indicating that seed gift alone cannot meet the entire seed needs of newly independent farmers. Labour exchange, barter and loan were activated equally, both for first and for regular seed acquisition. In a situation of regular seed acquisition (for field enlargement, acquisition of new varieties, seed renewal and acquisition after shortage) barter deals and labour exchange were only rarely used, but seemingly remain current as vestiges of traditional social solidarity. The fact that seed gift ranked as the fourth mode of regular seed acquisition after seed exchange, purchase and loan suggests that farmers were looking for large amounts of seed that could not be acquired as a gift. It also suggests that farmers were keener, in the normal course of events to buy or exchange seed rather than begging seed from fellow farmers or kin. These two findings combined show that, in the study area, there was sufficient "market" demand already present for dealers to address, without risking upsetting of socially-salient seed transactions.

However, it remains true that seed gift consolidates ties. Okry et al. (2011b) reported that some dealers used spontaneous seed gifts to secure labour. Seed gifting has significance in variety dissemination. Richards (1986, 1995, 1997, 2006) links seed gifts to farmer adaptive experimentation. Depending on context, gifted seed conveys consideration, blessing or expression of gratitude between the sender and the receiver. It can also convey the patrimonial power of the sender over the receiver (Okry 2005). However, a seed loan (where a benefactor offers a seed-insecure client the loan of sufficient seed to plant a farm in return for double that amount at harvest) is the more common expression of village patrimonial power (Richards 1986, 1990). Purchased seed, seed obtained by loan, and seed acquisitions through barter deals, labour exchange, and gift need to be distinguished. The first is evidence of the growing importance of a cash nexus upon which market relationships rest. The second type of transaction is linked to a politics of patronage at village level. The third set of transactions bears witness to the continuing functionality of the old village moral economy. The virtue of local seed dealers is that they are deeply embedded within the local context and politics to know some of the risks of confusing these three areas. Formal seed systems operate only with cash, and thus risk unwittingly "dissolving" local social capital without offering anything in return (Okry et al. 2011a). Operators in the informal system are subject to these local constraints of moral economy, at least to a certain extent, and at times can turn knowledge of this system to good account. They can, operate as patrons as well as seed dealers, for instance, and turn a credit sale into a loan agreement on traditional terms, or adjust the costs of a transaction to take account of selective seed gifts (and get a return as labour) (Okry et al. 2011a, Okry et al. 2011b). This means they can develop hybrid and flexible means of payment for cash-strapped clients, thus keeping prices low, and also know accurately how to "price" a range of local risks, such as those associated with seasonal seed credit deals. In short, they are more flexible and resourceful at addressing local needs and affordances than dealers in the formal system ever could hope to be. In effect they bridge between a local system of social solidarity still essential to the functionality of peasant subsistence farming in a high risk environment and an emerging market culture. The market culture as observed within the informal seed system is thus concrete and specific to the local situation, and not based on abstract principles of profit and accountancy deployed in international business environments, and around which formal seed system interventions are generally modelled.

The above findings and arguments add up to the suggestion that the emergence of a market culture for seeds in Lower Guinea is a product of endogenous change consequent changes in local farming system (as above presented). Market-oriented local seed dealers emerged to response to new demands unmet by the formal seed sector. Seed purchase is rarely mentioned as mode of seed procurement in informal seed system (Almekinders and Louwaars 2002). When purchase is cited in the literature, it mostly refers to seed transaction among farmers of the same village or neighbouring villages. Here we have pointed to the existence of a more general market for seeds emergent from the local context, and based around a group of market-oriented seed dealers operating beyond village level, selling seed at market places, and sensitive to the satisfaction of seed needs expressed by their customers. We now introduce these seed dealers and analyse their actual seed trading activities, looking at issues of gender and professional background, seed supply and sources, varietal portfolios, farmer requirements, client characteristics, and relationships between dealers and clients.

5.4 RICE SEED TRADE

5.4.1 The Local Seed Dealers: Profiles and Institutional Linkages

Until recently only households with seed surplus engage in occasional rice seed sales. Nowadays it has become a planned business, at times combined with other occupations. Forty per cent of the studied seed dealers were rice growers selling their own produced seed, sometimes in addition to selling collected seed. Table 5.4 describes the local seed dealers. They were diverse in age (45 years on average) and experience in the seed business (14 years on average). Dealers were mostly illiterate (83 per cent). They had spent on average 1.6 years at school. The most educated (18 years) was an agronomist producing and selling seed in Kindia market. Only a few of the seed dealers had interacted (once or more) with agricultural development organizations (Table 5.4). Dealers thus operate in parallel to formal organizations. Their origins trace to the informal seed system.

Dealers' experience in Kindia and Friguiagbé markets were similar, suggesting that seed business developed in the same period in these two markets, but later in the Sikhourou region (Table 5.4). Strong evidence to show the speed of the development of the rice seed trade is lacking. However, the relatively large proportion of dealers with less than 10 years experience in the seed business, as shown by Figure 5.3, confirms farmers' views that seed purchase from market, and consequently seed trade at market, are recent developments in their area. In fact, farmers acknowledged market as one of their most recent seed source. Although farmers said that seed from the market is often mixed, they continued buying seed from dealers at market, because, compared to the formal seed sector (e.g. Research Centres) dealers at market offer cheaper seed, greater diversity of varieties, and often have large quantities of seed available (Okry et al. 2011a).

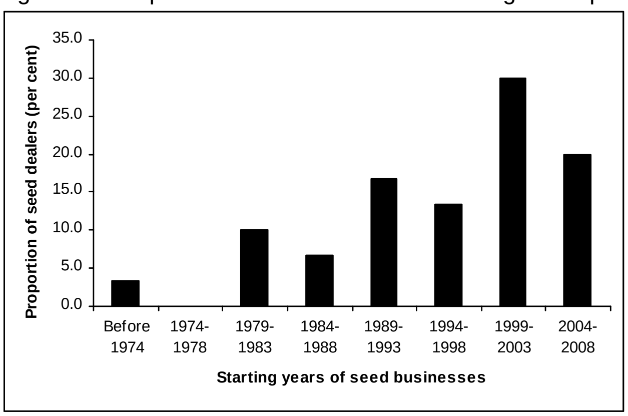
In general, women dominated the seed trade (66 per cent), except in Sikhourou-Daffira where men dominated (Table 5.4). Women had spent relatively more time in the seed business than men, totalling on average 15 years of experience against 11 years for men. Seed dealers had both trading (54 per cent) and agricultural (46 per cent) backgrounds. Male dealers tended to have an agricultural background (57 per cent) whereas female dealers had more often a trading background (63 per cent).

Table 5.4: Profile and formal linkages of the local seed dealers of three markets

	Sikhourou-Daffira (n=14)	Kindia (n=15)	Friguiagbé (n=12)
Age in years: average (min; max)	39 (28; 56)	50 (25; 80)	43 (30; 68)
Years in seed trade: average (min; max)	6 (4; 10)	15 (3; 30)	17 (6; 36)
Education[1] in years (min; max)	2.2 (0; 12)	1.6 (0; 18)	0.8 (0; 9)
Gender in percentage: (female; male)	36; 64	80; 20	83; 17
Initial training			
Farmer in percentage: (female; male)	79 (36; 43)	33 (33; 0)	8 (0; 8)
Trader in percentage: (female; male)	14 (0; 14)	60 (47; 13)	92(83; 8)
Craftsman in percentage: (female; male)	7 (0; 7)	0	0
Agronomist in percentage: (female; male)	0	7 (0; 7)	0
Collaboration with seed projects	0	0	0
Institutional links[2] (percentage)	14	13	17

Source: Surveys 2008
Notes: [1]Number of years spent at school; [2]Percentage seed dealers who interacted at least once with a formal organization in any domain of agricultural development

Figure 5.3: Repartition of seed dealers according to the periods they have started their seed businesses



Source: surveys 2008

Several researchers describe seed management as women's business (Richards 1986, Nuijten 2005). The proportion of female seed traders and their experience in the seed trade are in line with this claim. Men's recent involvement in the seed business could be explained by the growth in outlets for rice seed. Specifically farmers referred to Benna region (consisting of Sikhourou and neighbouring villages) as the major seed providers for the whole of Lower Guinea and neighbouring regions. Already in the 1840s Thomson (1846) reported evidence of seed export from Benna to other regions of Guinea and Sierra Leone. The same trend still prevails. Seed trade in Sikhourou would therefore involve large amounts of seed that only men could easily provide, as they alone have access to upland farm land, the dominant agro-ecology in region at the foot of the Benna hills. The hills themselves are reputed among the Limba of north-western Sierra Leone to be a (magic) source of vegetable seeds. Men in this region also find cash from tree crops (only land owners can cultivate these crops) and have easier access to credit, mostly from local money lenders, who often charge as much as 100 per cent interest for a fixed term loan of six months. Men thus have more resources to invest in the seed fields or to buy seed from farmers to meet the increasing demands. This is a possible explanation why men dominated the seed trade in the particular case of Sikhourou.

The fact that the Benna hills region historically exported seed does not imply that this was an early instance of market development, because rice was a commodity in the interior caravan trade supplying the slave outlets on the coast - a trade firmly controlled by mercantile (monopolist) chiefs (both Susu and Fula). There seem to have been few if any open commodity markets in the region when Thomson visited on his way to Futa Jallon, though it is also pertinent to note that he passed through in the aftermath of several years of devastating locust attack, when some of the chiefly elites lodged in the farm camps presumably to ensure access to food. But the existence of historical seed surpluses implies that the area of Sikhourou-Daffira was a more seed-secured region than the areas to the south where the older seed markets are located. A seed trade based on markets supplying local farmers probably developed in reaction to recent political and economic instability (Table 5.4). Prior to these development rice growers covered their seed needs with their own production, and thus had no need to buy. They supplied seed surplus to agro-input dealers from outside the Benna hills region. For example Comptoir Agricole, an established agro-input dealer at Kindia, collected its rice seed from farmers of the Benna region (see Okry et al. 2011b). But since 2002 successive episodes of social instability in Guinea have threatened seed security in Sikhourou, forcing farmers to sell or eat reserved seed. In addition, Sikhourou and neighbouring villages (Benna region) share borders with Kambia district (North-West Sierra Leone). According to our informants (dealers, farmers and researchers) the return of war-displaced Sierra Leonean farmers to their homeland since 2001 has been followed by a transnational seed flow from Benna to Kambia. Transnational seed flow added to consumption of reserved seed in times of social instabilities threatened local seed security. It is plausible to think that this loss of domestic and community seed security led to the development of seed business supplying local farmers in Sikhourou. If this is a correct inference, then it becomes a plausible hypothesis to suppose that seed trade developed as a response to local seed insecurity, i.e. the domestic moral economy was no longer robust enough to supply all local needs, without institutional innovation. But given the small sample size and scope of the present study further work will be needed before this hypothesis can be tested with requisite thoroughness. It is an aspect to be included in a follow-up study.

5.4.2 Regional Specificities and Influence of Gender and the Background of Dealers on Seed and Variety Supply

Dealers in Kindia and Friguiagbé tended to supply more seed of lowland varieties (53 per cent and 58 per cent respectively) whereas dealers in Sikhourou supplied more seed of upland varieties (80 per cent) (Table 5.5). We also found a significant statistical association between markets and varieties of seed (lowland/upland) offered (χ^2= 6.482, df= 2, p= 0.039) implying a regional specialisation in seed supply. The seeds of varieties offered at a market thus depend on the agro-ecology farmers mainly cultivate in the area where the market is located. Seed programmes intending to involve local dealers in seed distribution should therefore consider agro-ecological specificities.

A relation was less marked between gender of dealers and quantity of seed supplied, although female dealers tended to supply more seed of lowland varieties (56 per cent of their annual sale) compared to male dealers (52 per cent of their annual sale). This same tendency was observed in rice cultivation. In Kindia and Friguiagbé, where women dominated lowland cultivation, female dealers also dominated the seed trade, and supplied mostly seed of lowland rice. It could thus be that the seed trade in Kindia and Friguiagbé emerged primarily to meet women's seed demands for lowland varieties. Women there often sell all the harvest of their private rice fields to meet cash needs and thus may be less seed-secure compared to men who manage seed reserves from the household farm. In Sikhourou, where upland rice cultivation dominated, upland seed also dominated the local seed trade and was sold by both male (79 per cent of annual sales) and female (98 per cent) dealers. It could be concluded that both agro-ecological specificities and gender-based land tenure shape seed supply in the study area. In Kindia and Friguiagbé seed trade would have emerged from an oriented solidarity: women willing to supply seed to women (a group of seed-unsecured farmers investing in a relatively unknown agro-ecology (see above)). In Sikhourou-Daffira seed shortage and regional and transnational seed exchanges would have created an internal seed insecurity motivating the emergence of the local seed trade.

Table 5.5: Seed sales by local seed dealers in 2008: varieties sold, market specificities, gender's influence, clients and pricing

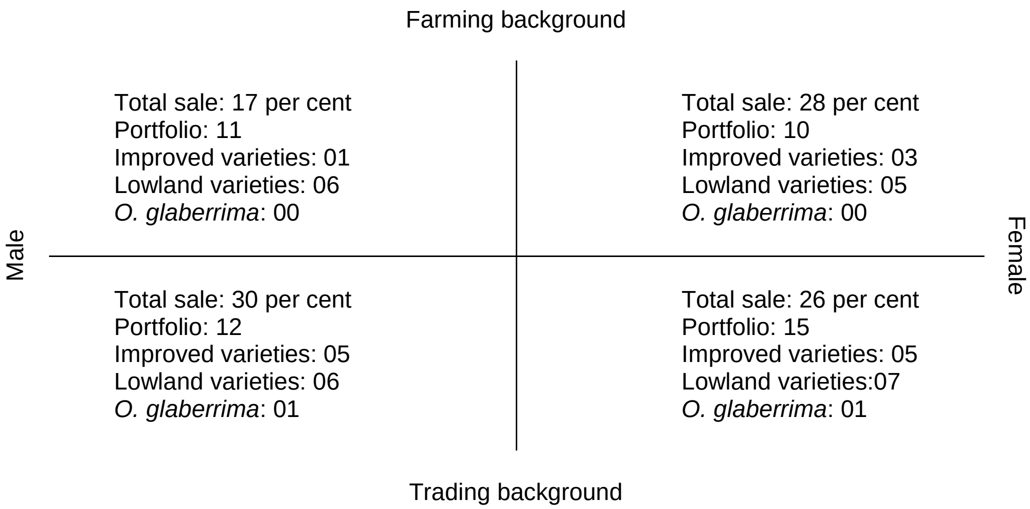
Variety and agro-ecology of cultivation	Markets	Dealers (percent) n=41	Sale 2008 (percent)	Nr Female dealers selling the variety[1] (percent)	Quantity sold by female dealers[2] (percent)	Frequencies of variety supply per group of dealers (percent)				Frequencies of seed demand per group of clients (percent)			Average price (US$ per kilogram)
						FF	FT	MF	MT	All sort of clients	Exp	Wo+NExp	
O. glaberrima													
Saali	F	10	1.1	75	18	0	75	0	25	50	0	50	0.6
***O. sativa* (improved varieties*)**													
CK21[L/U]	F, K	32	13.8	69	58	15	54	23	8	46	23	31	0.5
Chinois[X, L/U]	K	22	12.1	78	52	33	44	00	22	22	11	67	0.4
Coyady[L/U]	K	2	2.8	50	14	0	50	0	50	100	0	0	0.4
Gbotokoly[L/U]	K	2	1.2	0	0	0	0	0	100	100	0	0	0.4
CK90[L]	K	2	0.8	100	100	100	0	0	0	100	0	0	0.2
CK801[L/U]	K	5	***	50	***	0	50	0	50	50	50	0	-
CK4[L]	F	2	***	100	***	0	100	0	0	100	0	0	-
***O. sativa* (local vaieties)**													
Saidou Firê	F, K, S	85	27.3	63	93	26	37	20	17	34	54	11	0.6
Saidou Gbéli	F, K, S	73	14.7	63	56	20	43	23	13	38	53	10	0.5
Samba	F, K, S	59	8.8	58	55	13	46	25	17	38	29	34	0.6
Dalifodé	F, K	10	6.8	75	22	25	50	0	25	50	50	0	0.5
Kaolaka [L]	F, K, S	20	6.6	63	59	13	50	25	13	50	38	13	0.5
Podê	F	12	2.3	60	20	0	60	20	20	40	40	20	0.5
Berber	K	2	0.7	100	100	0	100	0	0	100	0	0	0.2
Moka [L]	S	7	0.6	33	33	33	0	67	0	67	0	33	0.6
Sèwa	F	2	0.2	100	100	0	100	0	0	0	100	0	0.5
Atafodé	S	7	0.1	67	86	67	0	33	0	33	67	0	0.7
Banyounou [L]	S	2	0.1	0	0	0	0	100	0	100	0	0	0.7
Tabounsou [L]	S	2	0.1	0	0	0	0	100	0	100	0	0	0.7
Yaka [L]	F	5	0.1	100	100	0	100	0	0	100	0	0	0.7
Yoni [L]	S	2	0.1	0	0	0	0	100	0	0	100	0	0.6
Total													0.5

Source: Surveys 2008

Notes: * Improved varieties (we followed farmers' classification of varieties as improved or local varieties). 1 US$= 3,800 GNF (Guinean Franc). [X] Chinois is a generic name systematically given to unknown improved varieties. –: Values left out because of sale < 0.1 per cent. [L] varieties cultivated only in lowland. [L/U] varieties farmers cultivated in both lowland and upland. Total seed sale in 2008: 99,462 kg. K: Kindia market. F: Friguiagbé market. S: Sikhourou-Daffira markets. [1] Percentage calculated against number of female seed dealers. [2] Percentage calculated against total amount of seed of the concerned variety. Exp: Experienced rice growers. NExp: Non experienced rice growers. Wo: Women owning private rice fields. FF: Female dealers with farming background. FT: Female dealers with trading background. MF: Male dealers with farming background. MT: Male dealers with trading background.

The four quadrants of Figure 5.4 represent the four groups of seed dealers, taking into account gender and background (see also Table 5.5). The four groups gave similar importance to upland and lowland varieties. Female dealers with a trading background offered the largest total diversity (Table 5.5). Male dealers with a farming background offered the fewest improved varieties.

Figure 5.4: Repartition of the sold varieties per gender and professional background of the seed dealers



Source: surveys 2008

Seed dealers with a trading and farming background offered almost the same number of varieties (16 and 14, respectively). But dealers with trading background (both female and male) supplied 86 per cent of the total range of improved varieties whereas dealers with farming background offered only 43 per cent of them. The influence of the professional background was thus more related to the offered diversity of improved varieties. Eight varieties were sold exclusively by dealers with a trading background (Table 5.5). Among these was Saali (the only *O. glaberrima* represented in the seed trade), four improved varieties and two old varieties. In contrast, among the six varieties exclusively sold by dealers with farming background, only one was an improved variety; the other ones were old local varieties.

These findings show that gender and professional background of dealers influenced the quantity of seed supplied, the types (improved or local, lowland or upland) and the nature (new or old) of the varieties offered. There was a tendency for male dealers to supply old varieties and common varieties, while women seemed more eager to introduce new varieties, including improved ones, in their seed trade. It could be that male dealers sold mainly their own produced seed and household seed surplus after deduction of seed for the new cropping season while female dealers offered in addition to their rice harvest (from lowland farms) seed they purchased from other farmers during harvest. Their use of middlemen to source seed may have made seed collection easier for these women traders, including seed collection from remote areas.

The fact that dealers with a trading background supplied most of the seed (because of the extra investment they made in the seed business) further confirms that not only produced seed was sold but also purchased seed. In short these dealers were (in fact) true traders, with a flair for sourcing the distant, the new, the exotic. Definitely seed dealers, especially those with trading background, require particular attention from policy makers, extension and research as possible partners for seed dissemination. However, if dealers with a trading background come to dominate any hybrid system this might swing towards novelty, but away from quality. Technical collaboration between seed dealers and the formal seed sector for training in quality preservation would then be needed. Any such institutional linkages among seed dealers and organizations of the formal seed system are currently weak (Okry et al. 2011a). For example in 2008, only 15 per cent of seed dealers had interacted, at least once, with a rural development organization (Table 5.4) and none had ever worked with a seed dissemination project. Assuming that these links are strengthened in coming years it may make best sense to incorporate seed dealers with both trading and farming backgrounds, to ensure that quality and novelty gain equal emphasis.

5.4.3 Seed Sourcing and Seed Handling

Seed sold at the local market came from the local rice growers (72 per cent) and dealers' own seed production (19 per cent). F. Okry et al. (unpublished) present a detailed account of farmers' rice seed production and selection in the study area. Minor seed sources were middlemen (8 per cent) collecting seeds from remote areas, farmers' associations (1 per cent) and the research centre (1 per cent). The latter only supplied seed of improved varieties, while the other sources supplied both local varieties and locally accepted improved varieties. Among interviewed seed dealers only female dealers used middlemen to acquire seed, reflecting their trading background.

Seed dealers collect, clean, dry and store seeds at harvest and sell them at sowing time. Seed dealers thus take the risk related to seed storage which is rewarded by the profit they get on seed. In general, no treatment with chemicals takes place. Some dealers, however, used local recipes to repel insects. The role of the research centre (supplying dealers with 1 per cent of seed sold) seemed to be that of injecting improved varieties into the informal seed system via seed dealers. These improved varieties, when they suit farmers, were multiplied by farmers themselves along with local varieties and further distributed by seed dealers. This resonates with David and Sperling (1999) who state that suitable improved varieties sell themselves. A local seed trader received seed from 31.4 (min=0; max=150) kilometres radius and supplied farmers operating in a zone of 17 (min=2; max=157) kilometres average radius. Local seed dealers thus connected locations and helped spread varieties. The fact that dealers source distant supplies of seed and that some seed buyers travel over substantial distance is evidence that the scope and range of the emergent local system of seed trade is sufficient to ensure matching of varieties sold to a range of cultivation contexts. The adaptability and plasticity of the local varieties sold (Mokuwa et al. forthcoming) help reinforce this adaptive potential within the local system.

5.4.4 Traded Seed: Importance, Pricing and Policy Implication

The survey revealed that from 2006 to 2008 the seed dealers studied sold 394.4 tonnes of rice seed. The average annual seed sale was estimated at 2.5 tonnes per local seed dealer. In 2008, dealers sold 99.5 tonnes of seed of which 31 per cent was seed of improved varieties and 1.1 per cent seed of African rice (*O. glaberrima*). A kilogram of seed costs on average US$ 0.50 (sd= 0.20) on the open market at the beginning of the sowing period (May-June). This is more than 50 per cent cheaper than prices in the formal seed sector: US$1.3 (at sowing time in 2007). Seed became more expensive on the open market as the sowing season progressed because seed progressively becomes progressively scarcer (it is being planted!). At sowing time in 2007, the paddy price varied between US$ 0.30 and 0.45 per kilogram. The price difference between paddy and seed is the gross margin dealers get on their investment in seed conservation and storage, in transporting seed to market and in spending time selling. Returns increase as sowing progresses and seed becomes scarce. On open markets improved varieties were cheaper (US$ 0.40) than local varieties (US$ 0.60) ($t= 3.128$, $df= 144$, $p< 0.01$). Newly introduced local varieties were also cheap. This is because demand is currently low. According to dealers prices of improved varieties will increase progressively if farmers accept them. New varieties therefore enter markets relatively cheap due to low current demand. In effect, there is no price barrier in the local seed system to trying new varieties. Prices are then likely to rise in line with demand. In sum, we note two major drivers of adoption; farmers need to have access to the new varieties and they need to be able to experiment with them. The informal seed system in Lower Guinea seems well able to supply the right varieties at the right price.

5.4.5 Analyzing the Traded Varietal Portfolio

Twenty-two varieties were included in the local seed trade in 2008 (Table 5.5). These represented 48 per cent of the total varieties encountered in the study area in 2007 and 2008 (cultivated and sold varieties). Saidou Firê, Saidou Gbéli, Samba and Kaolaka were sold in all studied markets. But Saidou Firê, Saidou Gbéli and CK21 were the ones most often sold, counting for more than 50 per cent of the total sales. These varieties, except CK21, were also the most widely cultivated varieties in the study area (Table 5.3). This suggests that dealers were mainly responding to demand expressed by farmers. Yoni, Yaka, Tabounsou, Banyounou, Sèwa Atafodé and Moka were local old varieties. They were requested by a few farmers, and consequently a few dealers sold them. This may also explain why they were sold only in some markets. Berber, CK90, CK801, CK4, Coyady and Gbotokoly (all improved varieties, except for Berber) were newly introduced varieties still unknown to many farmers, or varieties little demanded because farmers do not like them. They were therefore less present in the seed trade. Saali and Podê, two old varieties well-known to farmers, were not well represented in the seed trade. Farmers said Saali is much easier to acquire through their social networks. Podê is probably the same variety as Dalifodé and Samba, farmers said. So Podê was no little required as Table 5.5 suggests. These observations by farmers agree with findings by Nuijten et al. (2009) that these varieties are closely clustered in molecular analysis.

Lowland and upland varieties were more or less equally represented in the varietal portfolio on sale: accounting for 36 per cent and 41 per cent, respectively. Dealers said 23 per cent of sold varieties (Table 5.5) could be cultivated in either agro-ecology. In terms of quantity of seed sold, upland varieties dominated; they accounted for 62 per cent of the total seed sale. About 60 per cent of sold local varieties were upland varieties. These figures are in accordance with the general trends observed from analysis of varietal diversity cultivated in the study area and patterns of farmer seed use. They show that the seed trade reflects patterns observed in rice cultivation, and therefore that seed dealers were well informed about farmer demand and desire.

Improved varieties represented 32 per cent of the varietal portfolio on sale in 2008. Improved varieties were therefore better represented in the seed trade than cultivated by households in the study. The improved varieties on sale were all lowland varieties. This is also in line with the varietal diversity observed on each agro-ecology. Dealers advised farmers to try most of them (71 per cent) in upland conditions, contrary to their advice in regard to local lowland varieties, recommended exclusively for use in lowlands. We deduce that both farmers and dealers were still testing the suitability of the improved varieties across environments; the local ones are already well known and firmly categorised as lowland or upland varieties on performance grounds. The data on modern varieties shows that more than seed was exchanged between dealers and farmers: discussions during seed transactions trigger farmer experimental behaviour.

5.4.6 Clients of Local Seed Dealers

Seed dealers said their major clients were women and inexperienced rice growers, such as young people or household heads newly engaging in rice cultivation, and non-farming households (traders, craftsmen, civil servants and so on, newly cultivating rice as a second source of income or food). They represented 47 per cent of the clients of the seed dealers. We keep this heterogeneous category of clients together to avoid subjective subdivision, because some dealers classified most of their female clients as "beginners". They said women when purchasing seed often ask many technical questions, as do any of the new rice growers. This may be true in practice, because women were mostly cultivating lowland, a relatively new agro-ecology to most of them, but it might also be an instance of gender stereotyping. These findings clearly show that seed market places are also areas of technical knowledge sharing. Experienced rice growers (household heads with long experience in rice cultivation) came second, representing 34 per cent of all clients. The balance (14 per cent) was made up of clients dealers were not able to classify. They termed this group “All sorts of clients”. “All sort of clients” was also a phrase used by dealers who thought they developed their seed businesses "with all sorts of rice growers". Less frequently cited clients were farmers’ associations collecting seed to start communal rice fields, projects collecting and distributing emergency seed to help affected people start a new cropping season, agro-entrepreneurs (large-scale rice growers), and wholesalers collecting seed to sell in other regions (Figure 5.5).

Comparing the four groups of seed dealers in regard to clients groups, we observe that experienced rice growers were relatively well distributed across the four groups of dealers (Table 5.6), although female dealers with trading background cited them more as clients. Women and non-experienced rice growers, and farmers associations, were more often clients of the female dealers. The only difference is that female dealers with a trading background cited more women and inexperienced growers as clients. Civil servants, wholesalers and projects mostly bought their seed from male dealers.

The fact that non-experienced rice growers and women frequently bought seed from female dealers with trading background (dealers who offer the largest varietal diversity) implies that women and non-experienced growers were looking for more diversity (both local and improved varieties). They also sought technical information on new varieties, since seed purchase was often preceded by technical discussion on the characteristics of varieties, e.g. the ecology, growing cycle, yield indications and so forth. That women and inexperienced growers are unafraid to ask for this kind of technical information means they also acquire technical advice about common local varieties from seniors, friends and neighbours. This might also help explain findings in Table 5.5 showing that women and inexperienced growers also demanded less the popular upland (e.g Saidou Gbéli, Saidou Firê, samba) and lowland (Kaolaka) varieties, all of which are local types. They requested most Chinois (a group of improved varieties) and Saali (*O. glaberrima*) followed by Moka (a local lowland variety), CK21 (an improved lowland variety) and Podê (a local upland variety).

In contrast, experienced rice growers demanded the most common and also the oldest upland (e.g. Sèwa, Dalifodé, and Atafodé) and lowland (Yoni) varieties. They knew precisely what they needed and how to grow it. All that was of interest was whether a dealer could supply, and that the quality was good. No manual was needed; the technical briefing would have been short. Among the seven improved varieties encountered in the seed trade, experienced farmers demanded only CK21 and CK801. But the fact that female dealers with a trading background had more experienced growers as clients (Table 5.6) suggests that experienced farmers also sought a diverse range of varieties. Dealers’ ability to supply a large varietal diversity would thus be a key factor to a successful seed business.

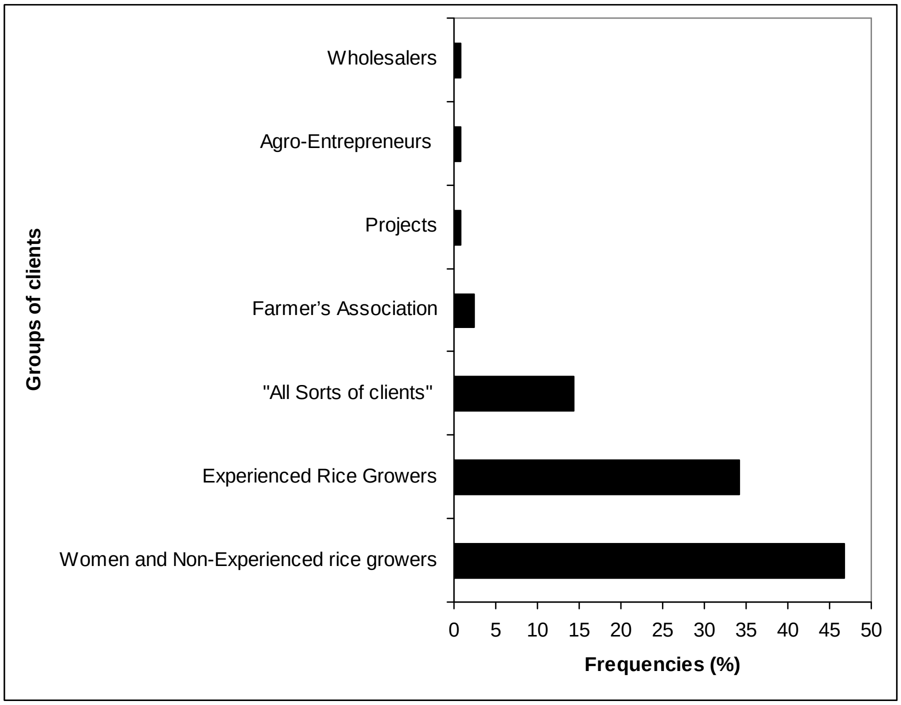
Table 5.6: Proportion of customers cited by the four groups of seed dealers

	Dealers			
	Female-Farming	Female-Trading	Male-Farming	Male-Trading
Women and non-experienced growers	20	58	14	8
Experienced rice growers	28	37	19	16
Farmers’ associations	67	33	0	0
Project	0	0	0	100
Agro-entrepreneurs	0	100	0	0
Wholesalers	0	0	100	0
All sorts of clients	22	6	50	22

Source: Surveys 2008

Notes: N= 41 local seed dealers for 126 responses. Figures in the tables are percentages of citation of a group of clients by a group of dealers.

Figure 5.5: Clients of the local seed dealers



Source: Surveys 2008

Notes: N= 41 seed dealers for 126 answers. The frequencies used in the figure are the number of times seed dealers have cited a group of clients divided by 126 (total answers). Women: women owning private rice fields. Beginners and non-experienced rice growers: youngsters, household heads starting rice cultivation, and non-farming households (traders, craftsmen, civil servants). Experienced rice growers: household heads with long experience in rice cultivation. Projects: e.g seed distribution under FAO project Office of Special Relief Operations (OSRO) in 2007. Agro-entrepreneurs: owners of large farms. Wholesalers: dealers operating at larger scale (e.g regional level) and agro-input dealers. All sorts of clients: a combination of the above listed clients and other unspecified clients.

5.4.7 Strategies of Market Development

Only 15 per cent of the interviewed seed dealers declared that they covered the entire seed demands of their customers every year. Insufficient seed supply was a concern to seed dealers in the study area. As MaYa, a seed dealer in Site 1 expressed it: "*A farmer should never miss seed when coming to a seed dealer… when farmers miss seed once or twice from a dealer they quickly start looking for another seed supplier*". This shows dealer eagerness to meet farmer seed demands. Constant seed availability thus contributes to generating the familiarity and trust essential to keep the seed business going.

The study of strategies developed by seed dealers to cover, as much as possible, their customers' seed demands revealed that about 50 per cent of dealers paid for seed in advance (before harvest) from farmers, or recruited middlemen to collect seed from remote areas. About 33 per cent offered a higher price than for ordinary paddy at the moment of seed collection (harvest time) or lent money to farmers at the beginning of the cropping season (16 per cent) and received payment of the debt in paddy or seed at harvest. The overall objective was to collect as much seed as possible at harvest time. Dealers said unsold seed after sowing was sold as paddy for consumption during the hungry season, so still earning a premium (food prices reach their peak during the hungry season). This made seed dealers less concerned about any potential over-stocking or decline in demand for seed.

In addition to ensuring constant seed supply to build and maintain customer confidence, a second strategy consisted in fostering a relationship with customers. As explained by farmers during group discussions, this concerns the willingness of dealers to assist farmers in situations of misfortune. These might include lack of seed due to sickness or unpredictable events, failure to reimburse previous seed loans because of adversity, or crop failure. Both farmers and dealers openly acknowledged that social modalities of seed acquisition, such as barter deals, seed loans, gifts and seed exchange were important in building close relationships between farmers and dealers. These elements associated with the old village moral economy of seed as a basic need of all farmers are absent in market development strategies found in the formal seed sector. This is a major difference between seed trade developed from above and below.

On the issue of trust between farmers and seed dealers, farmers stated they were looking for quality seed, and seed dealers unanimously said they sought to offer such seed in order to secure their customers: "*Only good quality seed establishes customer loyalty and keeps the seed business going*" one dealer said. "Good quality", in terms of seeds in Lower Guinea, is non-mixed seed of suitable varieties.

5.4.8 Comparing Farmer and Dealer Perceptions of Seed Quality

Farmers claimed they purchased seed from markets only as a last resort, after having gathered what seed they could from fellow farmers in their own or neighbouring villages. This preference for peers was not because the seed was cheaper (Okry et al. 2011a) but because market seed was said often to be mixed. As seed dealers also mentioned seed quality as important to their seed business we compared farmers' and dealers perceptions of seed quality. We found that farmers and seed dealers held different perceptions of seed quality (Table 5.7). From farmer perspectives, they looked for "Filled, big and heavy grains", stressing that the maturity of the grains was the most important indication of quality seed. It was followed by seed purity (varietal purity). Seed cleanness (absence of impurities) was the third desideratum. On the other hand, to dealers a good seed was a "clean and beautiful" (uniform in size and with few or no spotted grains) seed. Indeed, seed composed of grains of different size was also considered by farmers to be a sign of mixing, since it indicated that the seed had been aggregated from different fields or producers. Spotted grains indicate fungal attack or overexposure to intense sunlight. Farmers said that overexposure to sunlight increased the chance of getting broken seed during threshing and consequently poor seed germination. Seed purity came in here also as the second desideratum. Seed dealers (with both farming and trading background) cared less about seed maturity compared to farmers, for whom the seed maturity and absence of mixtures were of prime importance. Farmers are interested in process (how the seed batch was compiled and treated, how it is likely to perform). Dealers are more interested in uniformity of morphotype, perhaps because it is an indicator of pedigree. Dissemination projects based on involvement of local dealers should carefully document and elucidate these differences, and then incorporate them in training packages for dealers.

Table 5.7: Farmers and seed dealers' perceptions of seed quality (in percentage)

Category of seed characteristics	Farmers' perceptions	Seed dealers' perceptions		
		Farming background	Trading background	
Filled + Big + Heavy grains	35	10	7	X^2 = 26.351, df = 8, p= 0.01
Cleaned +Beautiful seed	19	38	67	
Germination	8	5	13	
Purity	24	24	7	Cramer's V= 0.258, p= 0.01
Well dried and free of insects	15	24	7	

Source: surveys 2007- 2008

Notes: Informants listed characteristics of quality seed; we grouped them into categories. Values in the table are frequencies of the characteristics. Percentages are calculated against the total frequency per group of respondents. 84 interviews (25, 24 and 35 from Sites 1, 2 and 3, respectively) were validated out of the 91 interviews carried out. The 84 farmers interviewed gave 162 responses/characteristics (50, 42, 70 from Sites 1, 2 and 3, respectively). 22 dealers with farming background responded and gave 22 characteristics. 15 dealers with trading background responded and gave 15 responses.

5.5 DEALER CONTRIBUTIONS TO RAISING FARMERS' AWARENESS AND USE OF IMPROVED VARIETIES

The contributions of seed dealers to raising farmers' awareness of improved varieties and stimulating their use are now assessed. Interviewed farmers obtained information on improved varieties through three major channels: fellow farmers and local seed dealers (50 per cent), local radio stations (36 per cent) and interaction with seed projects (7 per cent). Information on improved varieties was well spread across sites (Table 5.8). Hence it is possible to claim that local seed dealers and social networks, along with radio, were the most relevant information dissemination channels. Inter-personal interaction between trusted partners is perhaps the most important source, but radio reinforces and speeds up information within and between social networks. We did not separate fellow farmers, community dealers and market dealers as distinct information sources for farmers at community level because seed dealers, as part of the community, were also involved in other relationships that made any such separation confusing and artificial.

Table 5.8: Farmers' awareness and cultivation of improved varieties in 2007

		Site 1 (n=32)	Site 2 (n=24)	Site 3 (n=35)
Have heard at least once of improved varieties (percentage)		97	92	97
Have seen at least once an improved variety (percentage)		66	92	97
Have cultivated at least once an improved variety (percentage)		17	63	91
Currently cultivating an improved variety (percentage)		9	33	51
Number of improved varieties grown		1	3	5+[a]
Total amount of seed of improved varieties used (kg)		24	102	410
Average experience in improved variety cultivation (years)		3	3	6
Experience in improved variety cultivation (percentage)	1-5 years	9	25	37
	6-10 years	0	8	6
	>10 years	0	0	8

Source: Surveys 2007-2008

Notes: [a] At least 5 improved varieties were grown in Site 3. The rest was "Chinois" which might be the same as the improved varieties already listed or might be other ones. Chinois is a generic name systematically given to unknown improved varieties.

About 85 per cent of households had seen an improved variety at least once (exposure to improved varieties). However, exposure to improved varieties differed across sites, the most remote farmers (Site 1) being the least exposed (Table 5.8). Households of Sites 2 and 3 had similar exposure to improved varieties. The proximity of these sites to the rice research centre of Kilissi (CRAK) (Site 2) or to open markets (Site 3) may have contributed to farmers having higher exposure to improved varieties.

With the exception of Site 3, far fewer farmers who had once seen improved varieties had actually cultivated them at least once. The number of farmers having cultivated an improved variety at least once varied across sites, and was highest in Site 3. There were also differences between the proportion of farmers having tried once improved varieties and those currently cultivating them, thus emphasising that long-term cultivation of improved varieties does not always follow from initial experimentation. Farmers abandon any newly introduced variety if and when it does not suit their environment. The proportion of farmers currently cultivating improved varieties also varied across sites, and was highest in Site 3, close to Kindia and Friguiagbé markets. This supports a conclusion that markets, and hence seed dealers, stimulate the cultivation of improved varieties, presumably by making them readily available at affordable prices.

The largest number of improved varieties (five out of the eight found in the area) was cultivated in Site 3, followed by Site 2 (Table 5.3 and Table 5.8). In 2007, 536 kg of seed of improved varieties was planted in the study area of which 76 per cent was planted on farms in Site 3. Farmers currently cultivating improved varieties have been doing so for five years on average (Table 5.8). Those who cultivated improved varieties for more than 10 years were found only in Site 3. These findings confirm that households close to markets are more likely, because of their early and constant exposure to improved varieties, to try them out and thus eventually to adopt them. One might have expected the highest cultivation of improved varieties in Site 2, an area dominated by lowland cultivation, as it is close to CRAK, a source of improved lowland varieties. The fact that farmers in Site 2 cultivated fewer improved varieties than farmers in Site 3 suggests that, apart from the seed price which is higher at the research centre than at market, there may be other barriers to the flow of improved varieties to the farmers of Site 2. The organization of production and dissemination of the improved varieties might be one such barrier. In fact, in Guinea, the formal system of seed production, like in any formal seed production system (see Hossain et al. 2003) assigns specific roles to each actor. The role of the research institute is to supply breeders and foundation seeds. Certified seed production and dissemination are assigned to extension and formal/contract seed producers. Unfortunately none of these actors was fully operating in Site 2. The Participatory Varietal Selection (PVS) approach in use at CRAK aims to improve farmer exposure to improved varieties, but other elements of the necessary system were missing and farmers days were not that frequently organized.

The high uptake of improved varieties at Site 3 may be linked to the fact that this site has the largest number of non-farming households investing mainly in lowland rice cultivation. In fact, these farmers often purchase improved varieties from the markets (Table 5.5). In the following section we explore opportunities that might enable local markets and seed dealers to contribute to seed development through better linkage between the formal and informal seed systems.

5.6 PROSPECTS FOR INVOLVING SEED DEALERS IN SEED PROJECTS

Seed dealers were presented with four hypothetical situations (scenarios) in order to explore their willingness to become involved in seed development projects (Table 5.9). The exercise was set up for dealers as follows: a project wants to involve you in seed dissemination activities. What would your position be if:

Scenario 1: The project gives you free seed and you are requested to sell exclusively the project seed?

Scenario 2: The project sells seed to you and you are requested to sell exclusively the project seed?

Scenario 3: The project sells seed to you and you can sell the project's seed along with your own seed?

Scenario 4: The project gives you free seed and you can sell the project's seed along with your own seed?

Table 5.9: Scenario mapping on seed dealers' willingness to co-operate with seed projects (in percentage)

	An organization/project wants to involve you in seed dissemination activities. What would your position be? (per cent of farmers)			
Response	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Accept	71	56	73	95
Refuse	12	10	12	0
Do not yet know	17	34	15	5

Source: Surveys 2007-2008
Notes: Scenario 1: The project gives you free seed and you are requested to sell exclusively the project seed; Scenario 2: The project sells seed to you and you are requested to sell exclusively the project seed; Scenario 3: The project sells seed to you and you can sell the project's seed along with your own seed; Scenario 4: The project gives you free seed and you can sell the project's seed along with your own seed.

Regardless of scenario, more than 50 per cent of the local seed dealers indicated that they would be willing to become involved in seed projects. Perhaps understandably, Scenario 4, in which a project gives seed at no charge and dealers are free to sell project seed alongside their own, was the most attractive proposal, accepted by 95% of seed dealers. Although this scenario seems an obvious "give away" it was felt worthwhile to include it, since many rural development projects do in fact give away seed, and it is worth asking whether introducing this seed through dealer networks might be a better way to keep it in circulation. Donated seed does not otherwise always stay long in farmer use (A. Mokuwa in preparation). This situation might be reversed if dealers close to farmers actively promoted improved varieties. Scenario 3 was the second most acceptable scenario for dealers. This suggests that seed programmes seeking to promote improved varieties would find it possible to enrol local dealers should they so choose. It also confirms that there is no lack of willingness (in principle) on the part of local dealers to stock and sell improved varieties.

The few who were hesitant to accept Scenario 4 (5 per cent) explained their reserve by the fact that they were not yet sure of the quality of the project seed. This is a very interesting finding, since it underlines the importance dealers place on seed quality, and on the reputation for quality they have built with their clients. Dealers rejecting scenarios 1 and 2 explained that they feared loosing their customers. As one respondent put it: "*I do not want to be seen in my area as the salesman for a project's seed/varieties; the project will cease activities [but] I will have to continue my business*". This statement confirms that some dealers now see the seed business is a long-term occupation in which sustainability is a concern. The perceived link between improved varieties and rural development projects implies that sustainable seed businesses cannot be developed on improved varieties alone. The strategy of formal seed projects often to 'create' their own dealer network around exclusive sale of improved varieties needs to be revisited, in line with Okry et al. (2011b) who report that the few successful formal seed producer dealerships created by seed projects had subsequently introduced local varieties in their varietal portfolio in order to keep their seed business going after the end of project subsidies. Dealers also explained doubts about Scenario 3 in terms of the risks they would incur loosing loyal customers where project varieties not yet well-known to farmers failed to meet their expectations. In all scenarios, hesitant dealers explained a "do not yet know" response by pointing out that they would first prefer to check (in their own fields or through feedback from farmers) whether project varieties were indeed well adapted to the local environment before engaging in selling them. This aligns with findings by Van Mele et al. (2011) that successful seed dealers often test their varieties for sale.

Despite a general willingness to become involved in seed programmes, dealers listed some conditions for any such involvement (Table 5.10). A regular seed supply and 'adaptability of varieties' to local ecologies were the two most important requirements. These related very well with their market development strategies. Other important conditions were 'good seed quality' and a price that allows profit. A price of US$ 0.50/kg, observed as the average for rice seed in open markets in 2008, can be regarded as being an affordable level by most farmers. The condition 'exclusively local varieties' was mentioned across all four scenarios, and this indicates that some seed traders think it important to be able to supply seed of local varieties to farmers. This is in agreement with the findings of this study that the most widely cultivated and widely sold varieties were local varieties. Strikingly, seed quality seemed less important to dealers in Scenarios 1 and 2. They probably assumed that a project requesting exclusive sales would assure seed quality.

Table 5.10: Requirements for collaboration with formal seed projects (in percentage)

Requirements	Scenario 1*	Scenario 2	Scenario 3	Scenario 4
Regular seed provision	35	14	20	58
Adaptability of project's varieties	27	48	10	4
Exclusively local varieties	12	10	20	13
Proven profit	27	29	-	-
Good seed quality	-	-	40	17
Credit	-	-	10	-
Storage facilities	-	-	-	8

Source: Surveys 2007-2008
Notes: *See Table 5.9 for details on scenario. - : requirements not mentioned by dealers under a particular scenario.

5.7 FINAL ARGUMENTS AND CONCLUDING REMARKS

This study has attempted to understand the informal seed trade in Guinea. It has been argued that the emergence of market-oriented seed dealers within the informal seed system is a response of the informal seed system to the rapid changes in rice farming systems in a post-socialist, post-developmental state beset by recent financial crises. Engagement of non-farming households in rice cultivation was triggered by a range of factors. These have been specified as the economic and financial crisis in Guinea, the food crisis of 2007 and 2008, the increasing involvement of women in wetland rice cultivation, a recent change of villager perceptions of lowland farming as a result of the introduction of work oxen and project support for lowland farming. Frequent seed shortage and the sporadic nature of emergency seed distribution then led to an increased seed demand and quest for technical information at the local level. These changes created market opportunities for rice seed. The formal seed sector failed to meet farmer needs. Factors were reduced area coverage (MAEP 2007), centralised organization, limited varietal diversity (only improved varieties), expense, and strict imposition of market rules (cash only terms for acquiring seed, whereas village seed is historically part of a web of socially-embedded credit transactions). The market-oriented local seed dealers within the informal seed system thus filled a gap. They flexibly developed market strategies combining principles of cash based exchange with some elements of the older system of seed solidarity (gift, loan, barter deals, labour exchange for seed, seed and paddy exchange for seed) through which the basic needs of all farmers were met. Dealers also developed a market system that undercut potential formal sector rivals because it could build on social capital and trust already formed by the older village-based seed needs system (Okry et al. 2011b). Dealers thus supplied cheap seed, alleviating the price barriers observed for improved varieties in the formal seed system. This hybrid combination of modern market rules and elements of an older moral economy assuring timely supply of seed to all who needed it seems to have been the driving force behind the emergence of an unprecedented local rice seed trade.

Dealers also developed an interesting system of market intelligence: the seed trade rapidly adapts to specificities of the regions in which dealers operated, so that the most traded varieties corresponded to the most cultivated varieties. This was not the case with the formal system, where the only varieties supplied were improved types. Some of these are unfamiliar to farmers, and sometimes have disadvantages not apparent to breeders, or the enthusiasts who promote them (Richards 1997). Dealers were diverse in their professional background, gender, age, and experience of the seed business. Four categories of dealers (based on background and gender) had somewhat different customer bases and variety portfolios, but together they provide a large range of varieties, including both modern and traditional varieties (of Asian rice, *O. sativa*), and also supply African rice (*O. glaberrima*), something unheard of in the formal sector. Customers were diverse in characteristics and expressed different needs. Experienced rice growers requested mostly older varieties. Dealers with a farming background were the main suppliers of these older varieties. Women and less-experienced male farmers were the main clientele for improved varieties. Dealers with a trading background were the main suppliers of these improved varieties together, while also supplying local varieties.

Several seed dealers said they were unable fully to meet local seed demands. Yet it seems unlikely this demand could be met by international seed companies seen as the "answer" by some governments in the West African region. The data discussed in this paper identifies an opportunity where research and the formal seed sector might intervene to support local dealers' capacity in seed production and reinforce managerial skills. This kind of partnership might also be useful in further improving the quality of traded seed. The low literacy rate of seed dealers, however, would be a drawback for training sessions organized according to conventional extension methods. Moreover, the currently financially weakened extension service in Guinea would simply not be able to train dealers in addition to its usual duties. Video and rural radio have shown to be effective rural learning tools (see Zossou et al. 2009, Van Mele et al. 2010) and are options that could be explored. The governance of any such initiative, however, would be a point of concern, and special steps would be needed to ensure that local seed agents and their customers were placed in charge.

Local seed dealers have developed relationships of trust and inter-dependency with their customers, and so have contributed significantly to the spread of information about improved varieties and stimulated their use. These trust-based relationships induce spontaneous sharing of relevant information and experience in market places between seed dealers and their farmer clients. Seed dealers clearly provide a channel for the distribution of improved varieties, where these are of proven interest to farmers, and thus bridge the formal and the informal seed systems. Furthermore, trust-based relationships reduce the transaction costs known to be a major constraint to further development of the formal seed sector (Cromwell and Tripp 1994, Almekinders et al. 2007). A study in nine African countries revealed that various seed entrepreneurs successfully used television and radio to extend a reputation for trustworthiness beyond their immediate zone of influence (Van Mele et al. 2011). It should be emphasised that seed quality relates to a promise of secure future output, and seed is thus unlike many other market commodities in which a skilled examination suffices to determine quality in relation to price there and then. Trust and reputation matter a great deal to seed dealers. A number of authors have reported on local grain markets as seed sources for farmers (David and Sperling 1999, Sperling and Cooper 2003, Nuijten 2005). The importance of grain markets for seed supply to small-scale farmers varies according to region and crop. While Almekinders and Louwaars (2002) referred to the local grain market as the “last” seed source in the informal seed system in Latin America, Sperling and Cooper (2003) referred to it as the second best bet (after home stocks), in Eastern and Central Africa, where markets keep varieties familiar to farmers in supply. Longley et al. (2001) concluded from a study in southern Somalia that local markets can be a preferred source of seed for small-scale farmers, especially in areas where grain traders invest to obtain “good” quality seed. These case studies clearly referred to grain markets, indicating that seed trade is often organized by grain dealers. This is certainly true for our case study since a clear distinction is not always made between paddy and seed, except that dealers separated seed from paddy just after harvest (in cases where they do not own a separate seed field) and had different post-harvest management practises for seed and grain (Okry et al. unpublished). But a particularity of the Guinea case study is seen in the importance of dealers with an agricultural background. Although perceptions of seed quality differed between farmers and dealers, those dealers with an agricultural background responded better to farmers' requirements for “good seed quality”. A price difference is hardly observed between paddy and seed, especially at the beginning of sowing. A premium over paddy price is seen when the sowing period progresses and seed becomes scarcer. Incentives to take good care of seed in order to maintain a level of seed quality different from (higher than) that of paddy comes from the commitment of dealers to build and maintain a strong relationships with the customers who sustain their seed business, which (to the dealer) has now become a profession.

David (2004) has reported a rather important bean seed trade in local markets in Uganda, with the difference (from the case here described) that farmers rarely purchased seed from each other. The relatively limited development of the rice seed trade in Guinea could be explained by the fact that farmers still primarily buy seed from relatives and fellow farmers. But our study also shows that farmers were eager to buy seed, as opposed to the widespread assumption that small-scale farmers cannot afford to buy seed. This is in accordance with David and Sperling (1999) who report the same finding from case studies in Eastern and Central Africa. These kinds of findings support the presumption that seeds of suitable new varieties will disseminate more rapidly if they meet local standards and enter the local seed market at locally competitive prices.

Rossignol (2008) argued (based on a case study of the Koba seed centre) that rice seed centres could not be run cost effectively, due to excessive overheads. The demand fluctuates unpredictably, and sometimes comes from remote locations. These problems of seed supply, and the inefficiencies they imply, are not unique to Guinea. It seems a general trend in Africa (Tripp and Rorhbach 2001), although some positive changes have been reported over the past decade (Van Mele et al. 2011). In addition, current small-scale organization for agricultural production hardly allows a collective seed demand to emerge because of the diversity of ecologies African small-scale farmers exploit. Support for endogenous capacity (Cromwell and Tripp 1994), such as the seed dealer activity documented in this case study, seems, at least for the time being, to be a rapid and quickly implementable approach to meeting farmer seed needs and demands. Local seed dealers, it has been shown, make a distinctive contribution to the rapidly changing entrepreneurial landscape of African peasant agriculture, by, meeting farmer seed demands in an effective and appropriate manner.

ACKNOWLEDGMENTS

The Netherlands organization for international cooperation in higher education (NUFFIC) funded this research. Africa Rice Center (AfricaRice) provided additional funds for field activities. We thank the Institut de Recherche Agronomique de Guinée (IRAG) and the Association pour la Promotion Economique de Kindia (APEK) for assisting in the practical organization of the field work. The authors also thank N'Famoussa Camara and Foromo Kolié for their assistance in data collection and the farmers and seed dealers for the valuable time they spent answering our endless questions.

REFERENCES

Almekinders, C.J.M. and N.P. Louwaars, 2002. 'The Importance of the Farmers' Seed Systems in a Functional National Seed Sector'. *Journal of New Seeds*, 4: 15-33.

Almekinders, C.J.M., N.P. Louwaars and G. de Bruijn, 1994. 'Local Seed Systems and Their Importance for an Improved Seed supply in Developing Countries'. *Euphytica,* 78: 207-216.

Amanor, S.K., 2011. 'From Farmer Participation to Pro-poor Seed Markets: The Political Economy of Commercial Cereal Seed Networks in Ghana. *IDS Bulletin*, 42 (4): 48-58.

Barry, M.B., J-L Pham, J.L. Noyer, C. Billot, B. Courtois, and N. Ahmadi, 2007. 'Genetic Diversity of the Two Cultivated Rice Species (*O. sativa* & *O. glaberrima*) in Maritime Guinea. Evidence for Interspecific Recombination'. *Euphytica,* 154: 127-137.

Bush, R., 2010. 'Food Riots: Poverty, Power and Protest'. *Journal of Agrarian Change*, 10 (1): 119-129.

Carney, J.A., 1998. 'Women's Land Rights in Gambian Irrigated Rice Schemes: Constraints and Opportunities'. *Agriculture and Human Values*, 15: 325-336.

Cromwell, E. and R. Tripp, 1994. 'Proximity is a Plus: The Economics of Farmers Seed Production and Distribution in Developing Countries'. In *Seed production by smallholders farmers*, ed. J. Hanson. Proceedings of the ILCA/ICARDA.

David, S. and L. Sperling, 1999. 'Improving Technology Delivery Mechanisms: Lessons from Bean Seed Systems Research in Eastern and Central Africa'. *Agriculture and Human Values,* 16: 381-388.

David, S., 2004. 'Farmer Seed Enterprises: A Sustainable Approach to Seed Delivery?' *Agriculture and Human Values,* 21: 387-397.

Dingkuhn, M., D.E. Johnson, A. Sow, and A.Y. Audebert, 1999. 'Relationship Between Upland Rice Canopy Characteristics and Weed Competitiveness'. *Field Crops Research*, 61: 79-95.

Dolan, C.S., 2004. 'On Farm and Packhouse: Employment at the Bottom of a Global Value Chain'. *Rural Sociology*, 69 (1): 99-126.

FAO (United Nations Food and Agriculture Organisation), 2008. Policy measures taken by governments to reduce the impact of soaring prices. Crop Prospects and Food Situation, 5: December 2008. http://www.fao.org/docrep/011/ai476e/ai476e08.htm [accessed on 27 July 2011].

Futakuchi, K. and M. Sié, 2009. 'Better Exploitation of African Rice (*Oryza glaberrima* Steud.) in Varietal Development for Resource-Poor Farmers in West and Central Africa'. *Agricultural Journal*, 4(2): 96-102.

Ghosh, J., 2010. 'The Unnatural Coupling: Food and Global Finance'. *Journal of Agrarian Change*, 10 (1):72-86.

Harlan, J.R., 1992. *Crops and man*. Madison : American Society of Agronomy.

HLTF (United Nations High-Level Task Force on the Global Food Security Crisis), 2008. *Comprehensive Framework for Action*. New York: United Nations.

Hossain, M., A. Janaiah, M. Husain and F. Naher, 2003. *Rice Seed Delivery System and Seed Policy in Bangladesh*. Poster presented at PETRRA Communication Fair. Dhaka, Bangladesh. Accessed on 27 Feb 2011, http://www.cpd-bangladesh.org/publications/cpdiri/poster_2.pdf.

Johnston, D., 2007. 'Who Needs Immigrant Farm Workers? A South African Case Study'. *Journal of Agrarian Change*, 7 (4): 494-525.

Linares, O.F., 2002. 'African Rice (*Oryza glaberrima*): History and Future Potential'. *PNAS*, 99F(25): 16360-16365.

Longley, A.C., 2000. *A social Life of Seeds: Local Management of Crop Variability in North-Western Sierra Leone*. PhD thesis, University College London, London, UK.

Longley, C., R. Jones, M.H. Ahmed and P. Audi, 2001. 'Seed Sector Study of Southern Somalia: Final Report Submitted to the EC Somalia Unit'. London: Overseas Development Institute/International Center for Research in the Semi-Arid Tropics.

Louwaars, N., 2007. *Seeds of Confusion: The Impact of Policies on Seed Systems*. Published PhD thesis. Wageningen University, Wageningen, the Netherlands.

Mauss, M., 1950. *Essay on The Gift: The Form and Reason for Exchange in Archaic Societies*. London, Routledge (trans. W. D. Halls).

McGuire, S., 2005. *Getting Genes: Rethinking Seed System Analysis and Reform for Sorghum in Ethiopia*. Published PhD thesis, Wageningen University, Wageningen, The Netherlands.

Mohapatra, S., 2010. 'Pockets of Gold: Scientists Find a Treasure Trove of Information in Africa's Indegenous Rice That Could Help Breed Better Varieties for Tomorrow's Generation'. *Rice Today*, April-June 32-33.

Mokuwa, A. (in preparation). 'Farmer management of rice seed before, during and beyond low-level insurgency: a case study of Sierra Leone'. PhD Thesis, Wageningen University, Wageningen, The Netherlands.

Mokuwa, A., E. Nuijten, F. Okry, B. Teeken, H. Maat, P. Richards and P.C. Struik, Forthcoming. Robustness and Strategies of Adaptation Within a Large Set of Farmer Varieties of African rice (Oryza glaberrima Steud.) and Asian Rice (Oryza sativa L.) Across West Africa. *Plos One* Submitted.

Mokuwa, E., M. Voors, E. Bulte and P. Richards, 2011. 'Peasant Grievance and Insurgency in Sierra Leone: Judicial Serfdom as a Driver of Conflict'. *African Affairs*, 1–28 doi: 10.1093/afraf/adr019.

Nuijten, E., 2005. *Farmer Management of Gene Flow: The Impact of Gender and Breeding System on Genetic Diversity and Crop Improvement in the Gambia*. Published PhD thesis, Wageningen University, Wageningen, The Netherlands.

Nuijten, E., 2010. 'Gender and Management of Crop Diversity in The Gambia'. *Journal of Political Ecology*, 17:42-58.

Nuijten, E., R. van Treuren, P.C. Struik, A. Mokuwa, F. Okry, B. Teeken and P. Richards, 2009. 'Evidence for the Emergence of New Rice Types of Interspecific Hybrid Origin in West-African Farmer Fields'. *PLoS ONE 4(10):* e7335. doi:10.1371/journal.pone.0007335.

Okry F., 2005. *A Socio-Technical Development of a Seed (planting material) System: The Case of Yam in the Republic of Benin*. Master thesis, Wageningen University, Wageningen, The Netherlands.

Okry F. et al. Unpublished. 'Rice seed production among the Susu in Guinea and Sierra Leone: Local knowledge and farmers' practices'.

Okry, F., D.N. Dalohoun, S. Diawara, M.B. Barry and P. Van Mele, 2011b. 'Networks that Work'. In *African Seed Enterprises: Sowing the Seeds of Food Security*, ed. P. Van Mele, J.W. Bentley and R.G. Guéi, 89-108. CABI Publishing, UK.

Okry, F., P. Van Mele, E. Nuijten, P.C. Struik and R.L. Mongbo, 2011a. 'Organizational Analysis of the Seed Sector of Rice in Guinea: Stakeholders, Perception and Institutional Linkages. *Experimental Agriculture*, 47 (1): 137-157.

Peters, P.E., 2004. 'Inequality and Social Conflict Over Land in Africa'. *Journal of Agrarian Change*, 4 (3): 269-314.

Portères, R., 1966. 'Les Noms des Riz en Guinée'. *Journal d'Agriculture Tropicale et de Botanique Appliquée*, 13 (9): 1–346.

Poulton, C., J. Kydd, S. Wiggins and A. Dorward, 2006. 'State Intervention for Food Price Stabilisation in Africa: Can it Work?' *Food Policy*, 31 (4): 342-356.

Richards, P., 1986. *Coping with Hunger: Hazard and Experiment in an African Rice-farming System*. London: Allen & Unwin.

Richards, P., 1990. 'Local Strategies for Coping With Hunger: Northern Nigeria and Central Sierra Leone Compared'. *African Affairs*, 89: 265-275.

Richards, P., 1995. 'The Versatility of the Poor: Indigenous Wetland Management Systems in Sierra Leone'. *GeoJournal,* 35(2): 197-203.

Richards, P., 1997. 'Towards an African Green Revolution? An Anthropology of Rice Research in Sierra Leone'. In *The Ecology of Practice: Studies of Food Crop Production in Sub-Saharan West Africa,* ed. E. Nyerges, 201-252. Gordon and Breach, Amsterdam.

Richards, P., 2006. 'The History and Future of African Rice: Food Security and Survival in a West African War Zone'. *Afrika Spectrum*, 41(1): 77-93.

Richards, P., 2009. 'Knowledge Networks and Farmer Seed Systems'. In *Farmer First Revisited: Innovation for Agricultural Research and Development*, ed. Ian Scoones, and John Thompson, 233- 237. Warwickshire: Practical Action Publishing, Rugby, UK.

Rossignol, L., 2008. 'La Problématique de l'Approvisionnement en Semences de Riz en Zone de Mangrove'. Projet riz Basse Guinée. Conakry, Guinea.

Sarla, N. and B.P.M. Swamy, 2005. '*Oryza glaberrima*: A Source for the Improvement of *Oryza sativa*'. *Current Science*, 89 (6): 955-963.

Sarró, R., 2009. *The Politics of Religious Change on the Upper Guinea Coast: Iconoclasm Done and Undone*. Edinburgh, Edinburgh University Press Ltd.

SNPRV (Service National de la Promotion Rurale et de la Vulgarisation), 2001. 'Multiplication and Diffusion of Community-Based Seeds of NERICA Rices Developed by WARDA. Conakry.

Sperling, L. and H.D. Cooper, 2003. 'Understanding Seed Systems and Seed Security. In *Improving the Effectiveness and Sustainability of Seed Relief*. Proceedings of a stakeholders' workshop, Rome, 26–28 May 2003. Rome: Food and Agriculture Organization.

Starkey P., 1997. Réseau Guinéen sur la Traction Animale (RGTA): progress, constraints and new possibilities. A summary of discussions following an ACT support mission 6-16 October 1997. http://www.animaltraction.com/StarkeyPapers/Starkey-RGTA-Guinea-1997.pdf [accessed on 27 July 2011].

Swan, S.H., S. Hadley and B. Cichon, 2010. 'Crisis Behind Closed Doors: Global Food Crisis and Local Hunger'. *Journal of Agrarian Change*, 10 (1): 107-118.

Teeken B., E. Nuijten, F. Okry, A. Mokuwa, M. Temudo, P.C. Struik and P. Richards, 2010. 'Advocating the Integration of Socio-Cultural Factors in Models for Variety Dissemination'. Paper Presented at the 28th International Rice Research Conference, 8-12 November 2010, Hanoi, Vietnam.

Temudo, M., 2011. 'Planting Knowledge, Harvesting Agro-Biodiversity: A Case Study of Southern Guinea-Bissau Rice Farming'. *Human Ecology*, DOI 10.1007/s10745-011-9404-0.

Thomson, W.C., 1846. 'Narrative of Mr. William Cooper Thomson's Journey From Sierra Leone to Timbo, Capital of Futah Jallo, in West Africa'. *Journal of the Royal Geographical Society of London*, 16: 106-138.

Tripp, R. and D. Rohrbach, 2001. 'Policies for African Seed Enterprise Development'. *Food Policy*, 26: 147–161.

Van Mele P., J. Wanvoeke and E. Zossou, 2010. 'Enhancing Rural Learning, Linkages, and Institutions: The Rice Videos in Africa. *Development in Practice* 20 (3): 414-421.

Van Mele, P., J.W. Bentley and R.G. Guéi, eds., 2011. *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishing.

Vogt W.P., 1999. *Dictionary of Statistics and Methodology: A non Technical Guide for the Social Sciences*. London: Sage.

Volpe, A. 2007. RGTA DI Réseau Guinéen pour la Traction Animale et le Développement Intégré. http://www.guinee44.fr/spip.php?article94 [accessed on 27 July 2011).

Zossou, E., P. Van Mele, S. Vodouhe and J. Wanvoeke, 2009. 'The Power of Video to Trigger Innovation: Rice Processing in Central Benin'. *International Journal of Agricultural Sustainability*, 7 (2): 119–129.

CHAPTER 6

NETWORKS THAT WORK

Published as: Okry, F., D.N. Dalohoun, S. Diawara, M.B. Barry and P. Van Mele (2011). Guinea: Networks that Work. In *African Seed Enterprises: Sowing the Seeds of Food Security*, eds. P. Van Mele, J.W. Bentley and R.G. Guéi, 89-108. CABI Publishing, UK.

Abstract

For several reasons, of which some have been discussed in the previous chapters of this thesis, attempts to establish seed industries inspired by Western models have largely failed In West Africa. Donors, governments and development agencies continue to invest in developing seed enterprises in the region, often ignoring local success stories because they are not documented. This chapter describes the evolution and strategies of five successful small and medium scale seed entrepreneurs in Guinea that could inspire the design of seed initiatives in support of small scale farmers. Our objective in this chapter is mainly to thoroughly document these success stories.

6.1 INTRODUCTION

6.1.1 Agriculture

Bordered on the north by Senegal and Mali, on the south by Sierra Leone and Liberia, on the east by Côte d'Ivoire and Mali and on the west by the Atlantic Ocean and Guinea Bissau (Figure 6.1), Guinea has one of the most favourable climates for agriculture in West Africa with 6.7 million hectares of cultivable land, of which only 24% are farmed. Although mining (of mainly bauxite, aluminium, gold and diamonds) are the country's major source of foreign exchange, for the 9.7 million citizens agriculture is the major occupation. It contributes to 18.7% of the gross domestic product (2004). Rice, maize, sorghum, millet, cassava and fonio are common food crops, with coffee, rubber, palm, and cocoa as main cash crops. Shifting cultivation is common.

Figure 6.1 : Map of Guinea

Guinea has four natural regions, defined largely by rainfall. Lower Guinea receives 2,800-4,000 mm spread over six months. Upper Guinea is dryer with 1,300 mm of rain over five months. Middle Guinea (Fouta Djallon) is slightly wetter with 1,500 mm per year, whereas Forest Guinea receives 2,000-3,000 mm of rain during nine months.

Rice is the most important food crop and its production is the most organized. In 2000, rice production covered 42% of the total farmed land (about 700,000 hectares) for a total production of 700,000 tonnes of paddy (Barry 2006). Rice is grown in all four natural regions of Guinea. About 65% of rice land is devoted to upland rice, followed by mangrove rice (16%). Lowland and flooded rice are of equal importance. Per capita rice consumption is estimated at 69 kg (WARDA 2007). In 2003, the local rice sector generated about 340 billion Guinean francs (GNF) ($67 million), 5% of the gross domestic product.

Before the 1950s Guinea was the third largest rice producer in Africa, after Egypt and Madagascar (Portères 1966). Guinea was self-sufficient in rice and exported a surplus to other countries in West Africa. In recent years, population growth (3.1% per year) has threatened Guinea's food security. Despite a doubling in production over the past decade, to 1.47 million tonnes in 2009, rice is now imported to meet the rising demand. Imports were estimated at 44% of the national rice demand in 1995, falling to 25% in 2000 and rising again to 40% in 2002 (MAEF 2007a).

To increase food security, the Guinean government plans to introduce rice cultivation on 25,000 more hectares in favourable areas of Lower and Upper Guinea (MAEF 2007b). They want to boost the production to 2.5 million tonnes by 2015. To achieve this, the government collaborates with international partners, invests in roads, bridges, and dikes and supports the dissemination of new technologies, such as improved rice varieties (Nerica and the CK series) and yield-enhancing farming practices.

At a national level, potato is a minor crop but has become increasingly important in the economy of the Fouta region where the climate is favourable to its production. About 16,000 tonnes of potato are produced every year (MAEF 2007a).

6.1.2 Seed systems in Guinea

Informal seed system

The informal seed system supplies the bulk of seed to farmers. From previous harvest, farmers and local seed dealers save seed for the next cropping season, and pass it on through barter, gift or sale. The informal seed system provides inexpensive seed thanks to its low production cost. Seed is produced and stored as part of crop production (Richards 1986). However, a few farmers specialise in seed production (Okry et al. 2011). The informal seed system is more effective at supplying seed of orphan crops (such as fonio, yam and potato) and self-pollinated crops. In Guinea the informal seed system supplies more than 90% of farmers' seed (SNPRV 2001).

Formal seed system

From production to sale, formal seed is broken into discrete activities, done by different stakeholders rather than a single farmer, and it is fully regulated by the government. The Institut de Recherche Agronomique de Guinée (IRAG) conducts breeding for all crops and produces breeder and foundation seed, supported by selected farmers and farmers' associations. The national extension system (Agence Nationale de Promotion et de Conseil Agricole - ANPROCA, ex-SNPRV) then distributes foundation seed to farmer seed producer groups who multiply it into quality seed, under its supervision (only when projects support the activities). Seed producers, some of whom are organized in associations or cooperatives, usually sell the seed themselves. There are only a few retailers in Guinea. The formal seed system focuses exclusively on improved varieties and commercial crops, such as cotton and cocoa.

As the seed production units are located near cities, farmers in remote areas are discouraged to access quality seed. Moreover, many are reluctant to pay more than the grain price to buy seed if they are not sure the source can be trusted or if they are unaware of the added benefits of the quality seed.

6.1.3 Evolution of the formal rice seed sector in Guinea

The first support to the formal seed sector was in 1986, as part of a broader food security programme funded by the World Bank. Four well-equipped seed centres were built in Kilissi, Koba, Guéckédou and Bordo to produce, process, store and package "acceptable seed" under the supervision of the national research system (acceptable seed has followed the standard procedures for seed production, but has not been certified). Two early-maturing and improved varieties, CK 5 and CK 7, were identified to increase national rice production.

The newly created seed centres multiplied foundation seed, processed and packaged resulting seed into five kg bags and developed, in collaboration with SNPRV, technical notes related to the characteristics and use of each variety. SNPRV disseminated the bags free of costs to selected farmers who were trained and expected to diffuse seed and technical information within their community. The programme ended in 1992. Farmers had not accepted the two improved varieties: they were too early-maturing (requiring intensive bird-scaring and delicate post-harvest processes) and too sensitive to weeds.

The seed centres closed in 1997 because of limited impact and lack of funds. They remained government property until the liberalisation of the seed sector in 2004, when they were handed over to private entrepreneurs and farmers' associations (Okry et al. 2011).

In 1997 IRAG and the extension service launched a pilot programme with AfricaRice (ex-WARDA) to accelerate the diffusion of Nerica (varieties created by crossing two rice species: Oryza glaberrima × O. sativa). At first, four of these interspecifics were introduced in Guinea: Nerica 3, Nerica 4, Nerica 6 and IAC 164. Later projects, such as the African Rice Initiative, continued to disseminate Nerica varieties.

Meanwhile, from 1997 to 2003 Sasakawa Global 2000 (SG2000) extended its activities to Guinea, organizing small-scale seed producers. Apart from rice, SG2000 promoted cowpea, maize, soya bean and the cover crop mucuna (velvet bean), to enhance soil fertility (SG2000 2005).

More often, seed components have been part of agricultural development projects that promoted improved varieties and created farmer seed enterprises which collapsed once the projects ended.

6.1.4 Seed legislation in Guinea

Seed law

Guinea, with the FAO, wrote a law on seed and agro-inputs, applicable to all agricultural crops. It sets the norms and aims to stimulate production, marketing and the use of quality seed. It also stipulates who can certify seed and how it should be done. The law was recently approved by parliament and will soon take effect.

Seed certification

The Direction Nationale de l'Agriculture (DNA) should implement national seed policy and seed quality control, but the quality control laboratories are under equipped and non-functional, the national seed committee is still not formed and the seed inventory is not yet completed. Moreover, there is not enough staff trained in seed certification. In reality, there is little proper seed quality control. Most seed producers simply produce at standards acceptable to their clients.

Below we present five seed enterprises in Guinea. They all include rice, the major staple. The first case deals with a traditional rice seed producer and dealer who developed a small seed distribution network in two countries. She produces seed of local rice varieties without agrochemicals. Besides seed, she also sells paddy and palm oil, which at times clients exchange with her for seed. The second case is another one-person seed enterprise that started in the 1980s with project support, but which is still in business five years after the subsidies ended. The third case is an agrodealer who also sells seed of rice, maize, cowpea and vegetables. The last two cases describe enterprises that mainly produce seed potato, followed by rice and maize.

6.2 MAMA ADAMA YANSANÉ

6.2.1 History

Mama Adama Yansané, a 60 year old widow, has been running her rice seed business for over three decades. In the 1970s she started trading rice seed in Bassia, Sierra Leone (Bramaia chiefdom) where she got married. A few years after her husband died she returned home to Bokariya-Tassen in Guinea in the 1990s.

After returning Mama Adama continued running her one-woman seed enterprise, and kept taking seed orders from Bassia and the surrounding area. She married the village imam in her home village. Unlike neighbouring villages, selling seed is forbidden in Bokariya. The imam banned it, citing religious reasons (Box 6.1). Mama Adama's seed business is informal (non-registered) and small, even though it operates in two countries. Her seed business steadily grew until the Sierra Leone civil war started in 1991. Her clients left Bassia to settle elsewhere and farmers from villages across the border in Guinea also began growing less rice, for fear of invasion.

Box 6.1: The unspoken profession

> When we first asked about seed dealers, people said that there were none in their village, because the imam had forbidden it. As we did more interviews, we realised that many farmers buy seed from Mama Adama. One interviewee even requested anonymity if we further discussed Mama Adama's seed business with others.
>
> When we met Mama Adama she readily admitted that she sold rice seed, but added that her clients were mainly from outside the village. She said in the village she sells rice to people, not seed. When we asked "What is the difference between the seed sold to outsiders and the rice sold to Bokariya farmers?" she admitted that there was no difference. Mama Adama was creatively bending her husband's rule to create a seed monopoly.

Mama Adama has always specialised in seed of local rice varieties. Before the war in Sierra Leone ended in 2001 she grew and sold dixi (*O. glaberrima*) and samba (*O. sativa*). However, she abandoned these varieties after their demand dropped. Dixi is a 'heavy variety', meaning that people who eat it feel full for a long time. Dixi was a favourite during the war, but it is sensitive to drought during flowering and its popularity declined. Samba, on the other hand, is a 'light variety' and is mainly eaten by elderly people, given to children at boarding school or sold to people in the cities. After Guinean farmers who had fled the border area returned home, they brought with them a new variety called saidou gbéli (*O. sativa*) named after the person who introduced it, although no one is sure where saidou gbéli came from. It is high yielding, drought-resistant, adapted to the local environment and suitable for both uplands and lowlands. Besides, it can be sown from late May to early September, unlike all other varieties, which have narrower planting windows. Mama Adama now sells only saidou gbéli, as it soon became the most popular variety in her area.

Every year Mama Adama produces a field of rice seed, but she does not keep records of her sales. She has always sold her entire seed production (in 2007 this was 1.5 tonnes from 1.2 hectare). Her seed business prospered after the end of the war, as demand for seed outstripped supply.

Mama Adama says that the demand grows every year as larger areas are planted to rice, while she produces less seed as she gets older. Mama Adama could enlarge her business by letting someone else grow the seed, or by buying seed from other farmers, but she is afraid of compromising quality. She thinks that seed quality, and her reputation, should be preserved by all means.

6.2.2 Structure

Management

Mama Adama's seed business serves neighbouring farmers. She has no contact with external organizations working in seed development, although she took a literacy course from APEK (Association pour la Promotion Economique de Kindia), a local NGO.

Besides rice seed, Mama Adama sells groundnut seed, palm oil and rice paddy. She started trading palm oil and paddy when she started her seed business. These three enterprises are linked because palm oil and paddy are often bartered for rice seed.

Paddy and rice seed are grown, stored and handled separately. Mama Adama grows and processes seed by hand, using no pesticides or botanical products to control storage pests. Seed is stored in a large basket, while paddy is stored in polythene bags.

Land

In Bokariya-Tassen, land is managed communally. Every year a committee of elders allocates land to each household. Allocation within the household rests with the household head, so Mama Adama depends on the imam for land. Once she receives her land from the imam, she selects the best patch to grow seed. She knows that the most fertile land has more shrubs, darker soil and greener vegetation. Her husband usually gives her the land she desires.

Labour

Land preparation, weeding and harvesting are the most labour-intensive tasks in rice farming in Bokariya. Finishing them on time determines the success or failure of one's rice crop. At these crucial times labour is scarce as the demand is high and only people with special relationships with the work crew can hire labour then. Villagers who previously received a gift or a loan of seed from Mama Adama may give her priority when deciding who to work for, out of respect.

Quality control

Mama Adama believes that quality comes from keeping control of her seed production at all times. "The quality of my seed keeps me in the seed business. People come from far away to buy my seed. How can I assure quality if I do not produce my own seed?" She added "I have kept only one variety to avoid seed mixture."

Keeping seed pure requires skill and work. To avoid mixture, Mama Adama does not harvest seed from the edges of her seed field. These areas are harvested as paddy. Since farmers broadcast their seed and rice fields are continuous with no clear borders between neighbouring fields, edges can easily have a mix of varieties. To prevent seed from mixing with other varieties and dirt and to reduce time for scaring away chickens and other rice lovers, Mama Adama dries seed under the sun on tarpaulins in her courtyard.

She tests seed dryness by cracking a few grains between her teeth. The sound of the cracking grains tells her the dryness of the seed. She believes that seed that is harvested on time, well-dried and properly stored has a good germination rate. She does not need to test that.

6.2.3 Cash flow

Apart from selling seed, Mama Adama also buys paddy from farmers just after harvest, stores it and re-sells it as paddy throughout the year. At the beginning of the season seed and paddy cost the same, namely 2000 GNF per kg ($0.50). Quality seed (clean, insect free, unspotted and well-dried) becomes more expensive and can reach up to 3500 GNF per kg ($0.90) towards the end of the planting season. The price of paddy also varies throughout the year, but never reaches this level.

Farmers buy seed or barter for it. Mama Adama may give or loan seed depending on the person involved. Some farmers also trade paddy for seed. The exchange rate is not fixed.

Mama Adama runs her business with her own funds. She could borrow from local money lenders who often charge up to 100% interest, but she believes that no credit service will give her a loan since she is too old.

Mama Adama produces seed without agro-chemicals thus reducing her costs. All farm tasks are done by hand, for which she hires labour.

6.2.4 Marketing

Most of Mama Adama's customers are rice growers, informal dealers and occasionally farmers' associations (Table 6.1). Her seed network expands through her kinship ties. For example, Samba Yansané, one of her nephews living in Bassia, Sierra Leone, takes seed orders before the sowing season from nearby villages: Siakhaya, Kabaya, Sabuya, Surumaya, Fadugu, Sogbaya, Yaya and Sulemania. Samba´s father used to take the rice orders, before he died. Samba, only 22 years old, travels to Bokariya, crossing the Great Scarcies River on the border to get seed from Mama Adama. Samba collects transportation fees and receives a commission from farmers. In Guinea, customers come from Kaff (7 km), Sangaran (1.5 km), Konkoya (1.5 km), Boubouya (4 km), Salamou (4 km) and Kondedara (5 km). Although Mama Adama occasionally used to take seed to her relatives, now most customers come to her house to get seed.

Mama Adama only has so much flexibility. She has a fixed capacity to produce seed and produces none off-season. The seed she sells is from the year before and as she fears enlarging the enterprise, the quantities have not really changed. Once her seed is sold she never buys paddy to sell as seed.

Mama Adama does not pack her seed before selling it. Customers come with their own containers, mostly plastic sacks, or a piece of cloth and a bowl for small quantities.

6.3 IBRAHIMA SHERIF

6.3.1 History

Sherif, 66 years old and a driver by profession, was born in Samoukiry, Lower Guinea. In the 1980s he migrated to Foulaya where he started farming. He was growing avocado trees, vegetables and a bit of upland rice when a delegation from the World Bank visited his village with government extension agents to monitor one of their projects in 1984. He must have made a good impression because soon after the visit the director general of the extension service allowed him to get a lease-to-own for a water pump to increase his production. The charges amounted to 500,000 GNF ($130). With the new equipment, Sherif increased his production and became a model farmer, regularly receiving and impressing official visitors.

When donors changed their policy on agricultural extension in the 1990s and group approaches came into vogue, the local NGO APEK started grouping farmers into associations and unions. Sherif was elected chair of the union of cereal producer groups of Kindia. In this role Sherif negotiated a tractor for the union, but of course he could use the tractor too, and so he increased his production and with the surplus bought fertilisers, herbicides and pesticides.

In the early 1990s Sherif produced seed of local varieties, such as sewa, an upland O. sativa variety, but in 1996 he abandoned it to produce seed of improved varieties of rice, soya bean and mucuna with support from SG2000.

Over the years, he has collaborated with several projects. One day the former President, the late Lansana Conté, visited Sherif's farm and soon after he received a tractor for his own farm from the Ministry of Agriculture, and a water pump from SG2000. However, in 2004 SG2000 left Guinea, ending the subsidies for Sherif's seed business. After that he bought all his own inputs, although in smaller amounts.

Sherif has tried growing seed of the upland rice Nerica 4 in 2003, 2004 and 2006, but abandoned it because threshing was tedious. Ideally, Nerica 4 should be threshed the same day it is harvested. When the bundles remain in the field for a couple of days, it has to be threshed by machine. Sherif focuses on seed of improved lowland varieties, such as CK 90, CK 21 and CK 801 (Table 6.2). Occasionally, he grows Nankin. All these are improved lowland rice varieties. Nankin was introduced by Koreans, while the CK series were bred by the national rice breeding unit at the Kilissi station. These varieties have yield potentials of five to six tonnes per hectare and are all found in the local seed trade.

In 2008, Sherif decided to include dia, a local rice variety for seed production. He grew three tonnes of dia in 2009 and plans to include more local varieties in 2010. Sherif began growing local rice varieties when he had to produce seed without subsidies and also to meet smallholder farmers' explicit demands.

Table 6.1: Clients of Mama Adama Yansané

	1995	2000	2005	2009	2015
Individual farmers	1	1	1	1	1
Local dealers	2	2	2	2	2
Groups and cooperatives	-	-	-	3	3
Projects and NGOs	-	-	-	-	4

*Ranking assessment by senior management of seed enterprise, 1 being the most important

Table 6.2: Rice seed produced (tonnes), I. Sherif

	2005	2006	2007	2008	2009
CK 90	0.3	5.0	15.0	-	-
CK 21	5.1	5.0	9.0	2.0	1.0
CK 801	0.1	1.0	5.0	1.0	5.0
Dia	-	-	-	-	3.0

6.3.2 Structure

Management

Like Mama Adama Yansané, Sherif runs a one-man seed enterprise, but unlike her he has collaborated with several seed projects that led him to produce improved varieties, besides giving him much valuable equipment.

Besides rice seed, Sherif has produced smaller amounts of seed of maize (since 1997), cowpea (since 2000), soya bean (2000) and mucuna (1997-2003), as requested by SG2000. But he stopped producing mucuna seed because of the limited demand. For years, mucuna was promoted as a miracle crop to restore soil fertility, but farmers never took it up because, as they correctly say, it occupies cultivable land and it is not edible. After he stopped receiving subsidies he reduced the area grown, cut down on the use of agro-chemicals and included local rice varieties in his portfolio.

Land, equipment and labour

Sherif owns about 46 hectares, of which 44 hectares are lowlands and two hectares upland. Only 41% of the land is exploited. Upland fields are used for maize seed (one hectare) and cowpea seed production (one hectare). About 17 hectares of lowlands are devoted to lowland rice seed production. Seed fields of different varieties are far away from paddy fields and separated from one another by dikes to reduce the chances of seed mixture by flood.

Since 2003 Sherif owns a tractor which is still running. He also has a pair of cows for ploughing and two water pumps for irrigating occasional off-season seed.

Sherif has limited household labour. He hires labour for land preparation, building dikes, transplanting, harvesting and threshing. The household labour takes care of other crops like fonio and vegetables.

Links and quality control

Sherif has extensive relationships with rural development organizations. For many years, research and extension have used Sherif as a model farmer.

Sherif receives no external quality control for his seed farm. He has participated in several trainings on seed production in Guinea and Senegal. These courses and follow-up sessions from research and extension have helped Sherif to do his own quality control.

6.3.3 Cash flow

Since SG2000 left in 2004, Sherif has run his seed business on his own funds. The equipment he obtained from SG2000 and the Ministry of Agriculture helped. However, Sherif realised that he cannot keep producing only seed of improved rice varieties which he once sold mainly to projects and farmers' unions. To stay in business and reduce production costs he also started producing local rice varieties in 2008.

To individual rice growers, Sherif sells seed on average at 3,500 GNF ($0.90) per kg, but the price can reach 5,000 GNF ($1.30). Unlike many seed dealers in Guinea, Sherif no longer accepts loans, gifts or barters. "Some farmers reimbursed their loan with mixed seed and some even did not reimburse me at all," he said.

Customers referred by the Chamber of Agriculture (Chambre d'Agriculture) bought seed at 2,500 GNF ($0.70) per kg. Sherif said the Chamber of Agriculture helped him acquire inputs and equipment, so he gives them a special price because he wants to keep good relations with them.

Sherif said he sells rice seed for just 2,000 GNF ($0.50) per kg to farmer groups and unions as an expression of solidarity with them, even though he is no longer the chair of the farmers' association, and to show commitment to the groups' efforts to raise revenues of other farmers. Sherif also uses the farmers' union to develop his seed distribution network. He believes that by offering a discount to groups he will encourage individuals to try improved varieties.

6.3.4 Marketing

Sherif's clients have changed a lot over time, as he gradually started to build his network after projects came to an end (Table 6.3). Local dealers are likely to play a stronger role in the future.

Up to 2004, customers were mainly referred by the Chamber of Agriculture (50%), followed by individual rice growers (30%) and farmers' unions (20%). The Chamber of Agriculture did not put official orders for its own use, but directed seed orders from projects, state farms and NGOs to Sherif as a faithful, recognised seed producer.

Seed is sold at Sherif's store. The discount Sheriff gives to associations is part of his marketing strategy, as individual farmers get to know him through this. If off-season seed production is abundant, Sherif advertises at the local radio station before farmers start sowing. Advertisement usually takes four weeks and starts about two weeks before the sowing period. The radio spot explains the importance of improved varieties, and says that Sherif produces and sells the seed, and that he can be reached at his village, or through farmer's associations, researchers and extension agents. The advertisements helped Sherif build his popularity and reputation in the area.

Table 6.3: Clients of Ibrahima Sherif

	1995	**2000**	**2005**	**2009**	**2015**
State farms	2	2	2	1	4
Individual farmers	-	3	3	2	1
Groups and cooperatives	-	4	4	3	2
Research institute	-	6	6	4	6
Local dealers	-	5	4	5	3
Projects and NGOs	1	1	1	6	5

*Ranking assessment by senior management of seed enterprise, 1 being the most important

6.4 COMPTOIR AGRICOLE

6.4.1 History

In the early 1990s the Belgian NGO ACT (now called TRIAS) invested heavily in training farmers and building roads to improve farmers' access to markets. It noticed that farmers of Bangouya village, near Kindia, could make better use of their lowlands if they had vegetable seed, which ACT helped them acquire.

In 1994, before ACT stopped its intervention in Guinea, it decided to organize Bangouya's farmers in a cooperative called CCIAK (Cooperative de Commercialisation des Intrants Agricoles de Kindia) to obtain vegetable seed and agro-input supplies. It was led by former ACT staff. Incofin, a Belgian social investment company focusing on microfinance, provided financial support to CCIAK and helped them import vegetable seed from Belgium. CCIAK rapidly enlarged its activities and started a store in Kindia.

Also in 1994, Comptoir Agricole was created and registered as a private company to distribute agricultural inputs (seed, agrochemicals and farm equipment) and food (such as paddy). CCIAK and Comptoir Agricole thus shared the seed market.

CCIAK cooperated with Incofin until 2000, when the latter stopped working in Guinea. However, until 2003 Incofin linked CCIAK to Belgian and Dutch seed companies, allowing CCIAK to import vegetable seed for sale.

In the Guinea's financial crisis of 2003 the Guinean Franc lost value and CCIAK nearly went bankrupt. It stopped importing vegetable seed and adjusted by engaging in local seed supply. Due to the harsh financial crisis, CCIAK could not survive alone and merged with Comptoir Agricole in 2004, retaining Comptoir Agricole as its official name.

In addition to farm inputs, Comptoir Agricole sells up to 100 tonnes of rice seed per year, although it does not produce any of the seed itself (Table 6.4). It also sells seed of maize, groundnut and resumed its former trade in vegetable seeds (tomato, pepper, cucumber and onion). The amount of seed sold per year largely depends on the money available to import vegetable seed and the amount of good local seed that its scouts can source.

In 2008 and 2009 Comptoir was hit by the global financial crisis. To reduce overhead costs it got rid of salaries by handing over its seven shops to its employees. Currently, it supplies the shops with inputs. After sale, Comptoir deducts the capital and leaves the profits to the employees, who now earn money only if they sell.

Individual rice growers from Madina Oula, near the southern border with Sierra Leone, supply Comptoir Agricole with seed of both local and improved varieties. Some seed comes from government employees who farm their own land part-time. Occasionally Comptoir Agricole sells seed of improved varieties produced by the national rice breeding unit at the Kilissi Research Centre (Table 6.5).

The rice varieties sold include saidou firê (local variety), saidou gbéli (local variety), kaolaka (local variety), Nankin (improved variety), Nerica 4 (interspecific), CK 21 and CK 90 (improved varieties). Saidou firê and saidou gbéli are the most popular upland varieties grown in Kindia region, where Comptoir Agricole's has its headquarters.

Table 6.4: Seed sales (tonnes), Comptoir Agricole

	2007	**2008**	**2009**
Rice	98	78	67
Maize	5	7	6
Groundnut	40	3	2
Vegetables	0.3	0.7	0.5

*Data from 2007; includes both seed sold and emergency seed distributed under the FAO project Office of Special Relief Operations (OSRO)

Table 6.5: Rice seed supplied to Comptoir Agricole

Supplier	**Variety supplied**	**Quantity (tonnes)***
Formal seed producer from Labe	Nerica 4	6
Kilissi Research Centre	CK21, CK90	50
Rice growers	Nankin, *kaolaka*, *saidou gbéli*, *saidou firê*	80
Sunday farmers (loan reimbursement)	Diverse	1.5

6.4.2 Structure

Comptoir Agricole was created by a group of former civil servants and registered as a private company. Comptoir Agricole has seven shops located in Lower Guinea (Kindia, Dubreka and Forecariah), and Middle Guinea (Dalaba and Labé). Comptoir Agricole covers the entire country when contracted to distribute emergency seed by projects (such as OSRO) or by humanitarian and international organizations, such as FAO and the World Food Programme (WFP).

Links

Comptoir Agricole is a member of professional associations, including the national Association des Producteurs Importateurs Distributeurs d'intrants Agricole (APiDIA) and the international African Seed Trade Association (AFSTA).

At the local level, however, Comptoir Agricole is poorly linked with formal seed producers except for one seed producer trained by SG2000 who sold them six tonnes of Nerica in 2007. According to its director Mr Hamidou Diallo "seed projects and local NGOs have helped a lot in training formal seed producers, but after the training, the formal seed producers served exclusively the projects and NGOs involved. These seed growers were not allowed to diversify their clients. The projects and NGOs are trainers, suppliers of foundation seed and buyers of the produced seed."

6.4.3 Cash flow

Comptoir Agricole sells agro-chemicals, paddy and seed of various crops. It is a seed retailer, but does not produce seed. Comptoir Agricole collects seed at harvest, stores it and sells it at planting season. It does not process seed. Young people who work part-time for Comptoir visit the seed-producing villages on motorbikes and advise the company when the seed is ready. Over the years these young people have built up their social networks. They know exactly which farmers produce good quality seed. Comptoir then goes to the villages, collects the seed and pays cash at 1,000 GNF ($0.25) per kg. Comptoir only sells seed on credit to civil servants farming their own land part-time. Interest rates vary according to the person involved and other chemicals bought.

6.4.4 Marketing

Farmers make up 65% of Comptoir's customers. Others are projects and Sunday farmers who are part-time farmers. Comptoir Agricole reaches its customers mainly by participating in fairs and distributing booklets presenting its products. Since its creation in 1994, it has advertised only once on the local radio station in 1994. Farmers are their main customers, which is unlikely to change in the future. As various efforts currently aim at strengthening groups and cooperatives (in terms of organization, training and land management) these will likely become more important clients (Table 6.6).

Table 6.6: Clients of Comptoir Agricole

	1995	2000	2005	2009	2015
Individual farmers	1	1	1	1	1
Sunday farmers	2	2	2	2	3
Projects and NGOs	-	-	3	3	4
Groups and cooperatives	-	-	4	4	2
Local dealers	-	-	-	-	-

*Ranking assessment by senior management of seed enterprise, 1 being the most important

Table 6.7: Seed produced, Cereal and Potato Seed Producers' Union

	2007	2008	2009
Cultivated area (hectares)			
Potato	5	14	22
Maize	3	6	10
Rice	2	8	12
Net production - sold as seed (tonnes)			
Potato	17.5	55	96
Maize	4.5	12	18
Rice	4	16	36

6.5 CEREAL AND POTATO SEED PRODUCERS' UNION

6.5.1 History

After many years of experience in working with farmers, as extension officers, four agricultural engineers and two agricultural technicians decided to set up an organization to produce seeds in the Fouta region, in middle Guinea. Although they still receive their basic salaries, the government barely provides an operational budget for extension. Tired of being idle, they looked for an opportunity to make best use of their time and expertise. One of the agronomists noticed that investing in agriculture is profitable but that seed production is even more so. Knowing that good seed improves yields and crop quality, the agronomist discussed the idea with some colleagues and farmers and they decided to join the existing farmers' associations as a seed enterprise.

In 2006, nineteen farmers (including the six extension agents) and ten cooperatives growing cereals, ware potatoes and vegetables founded a union (Union des Coopératives pour la Production des Semences de Céréales et Tubercules). It was officially registered at Labé, the regional capital of the Fouta.

The start-up capital of the Union came from membership subscriptions. But this was not enough to start the business. Then, in 2006 a CFC (Common Fund for Commodities) project provided seed potato as a loan to the Union. After its first harvest, the Union reimbursed double the amount of seed potato. Profits from the first activities were kept and used to expand production.

The Union has rapidly increased its seed production (Table 6.7). Net production is just the part of the harvest that is selected for seed. The rest is eaten or sold as food. Production increased because: fertile land is available for expansion; the Union hosts many cooperatives (giving them a large customer base); the Union has a good marketing strategy; and because the Union's managers are extension agents who easily convince farmers about the importance of using quality seed. Apart from their agricultural skills, extension agents can often bank in on the social networks built up during their life time, both with the farming community as with research and source seed suppliers.

6.5.2 Structure

Management and staff

The Union is composed of ten cooperatives, each with 30 members, of which 80% are women. The cooperatives were set up by women to create income generating activities. They invited some men to join. The leaders of the Union are male agronomists who are still paid as government extensionists. Alpha Oumar Balde, who is the regional director of the extension service for the Fouta region, is the president of the Union. The other three agronomists are each responsible for one of the three crops (potato, maize and rice). Two technicians help members and ensure strict adherence to the technical itinerary. None of the management staff is paid by the Union. They think that if the activity develops they may request a salary in the future, but so far they do not charge the Union, since they still draw a government salary and they do not want to burden the Union to allow it to grow. Though the Union has the required technical capacities, most women are illiterate, and need skill strengthening.

Production

The Union operates on part of a vast lowland of about 7,000 hectares, at an altitude of 1,002-1,115 meters. The main crop is dry season potato. After the potato harvest, rice is planted on the lower, wetter part of the area, while maize is sown on the upper part.

Seed potato is imported from France, the Netherlands and Belgium by Sica, a private company based in Labé. Five varieties dominate: Nicola, Spunta, Anova, Kaon and Désirée. At harvest, the Union members select the smallest or medium size tubers as seed. They renew their foundation seed for potato, maize and rice every three years. For maize they isolate the farm, on land where they used to produce potato so no other field of maize is near it.

Activities are organized by gender. The men build the fences to protect the seed crops from goats and cattle, while the women do everything else. Traditional wooden fencing costs about five million GNF ($1,000) per hectare. The second year, maintenance expenses are about 10% of the construction costs. The third year, there is a need to replace the fence. Using modern materials (mostly wire) the fence costs 14 million GNF ($2,750), but lasts for 20 years.

Each cooperative chooses one crop, often the one they were growing before for food. No group can produce seeds for two different crops. This is to balance the supply and demand of seed. If everybody produced seed of the same crop, some crops would be under-served.

Specialising in one crop is a good arrangement for members. If seed potato is more profitable, growing it demands more work. Specialisation allows each actor to master the crop and become a real professional.

It is easy for the Union leaders to identify each member's needs for new skills, so that when training opportunities occur or are created, it is easier to designate participants.

Other activities

Each cooperative of the Union produces seed on collective land assigned for seed production, and the Union sells the seed. On individual plots each member of the cooperative has other activities including raising crops to feed their families, animal husbandry, food processing for people and animals. Cattle raising is the most common activity for Foullah (Fulani). Animals eat rice straw and maize stalks and fertilise the soil with their dung.

Equipment

The Union has limited equipment and infrastructure. For seed storage, it hires space from big traders of the region. It owns two motor-pumps and a few animal-drawn implements. In 2009, the Union started using the tractor ploughing services of a Frenchman to expand production.

Links and partnership

The Union has strong ties with extension and research thanks to its management. It has also developed partnerships with projects, NGOs and government bodies whom it supplies with seeds. Other farmers not in the Union are important as potential clients. The Union is trying to strengthen relationships with them and create new ones.

Quality control

The Union works under the strict control of agricultural engineers and technicians, but without certification; the seeds can be sold only in Guinea, but the Union sells all the seed it produces.

6.5.3 Cash flow

Cooperatives or individual members of the Union access some credit from small, local private credit agencies (établissement) at an exorbitant interest rate (4.75% per month). Fortunately the Union members need little credit, mainly for foundation seed, which they reimburse quickly. The fertile soils need little fertiliser.

Cereal seed production is rewarding, but profit from seed potato is higher. First category potato seed has a vegetative cycle of 75 days and second category one of 90 days. Sica supplies the first category at 10,000 GNF ($2.0) per kg and the second category at 6,500 GNF ($1.3). The CFC project also imports potato seed and supplies it at 8,000GNF ($1.6). Ordinary farm-saved seed costs 7,000 GNF ($1.4). Ware potato costs on average 3,500 GNF ($0.7) per kg.

Reinvesting profits into the enterprise has been a key to success of various other enterprises presented by Van Mele et al. 2011a, ranging from the farmer seed producer groups in Northern Cameroon who applied revolving funds (see Silué et al. 2011) to NASECO, one of Uganda's leading companies (see Van Mele et al. 2011b). But operational budgets based on membership fees and profits are often not enough. Governments and donors have a role to play in strengthening the financial sector to support rural entrepreneurs.

6.5.4 Marketing

The Union assesses the seed demands of its members, based on the areas they intend to devote to each crop. The management of the Union approaches some NGOs, projects and other government bodies that usually buy seed from them and assess their interest in seed for the upcoming season.

The first clients of the Union are its members, who buy up to 40% of the seed produced. The rest is sold to organizations and projects, but mostly to individual farmers. The Union gives technical assistance to the members through rigorous follow up programmes organized by its agricultural technicians, to make sure that the members produce the seed well. This helps producers to get expected results.

Each individual member brings at least one new customer every year, a personalised marketing strategy that banks in on farmers' social networks. The Union is also getting ready to use community radios to advertise.

There were demands for potato and rice seed from Senegal and efforts were made to meet them. Unfortunately, the attempt was unsuccessful for lack of certification. So far, there is no authorised body that certifies seed in Guinea.

6.6 EL-HADJ TAFSIR SOW

6.6.1 History

From importer to seed grower

El-Hadj Tafsir Sow was a prosperous importer of sugar, wheat flour and other foodstuffs from France. On a business trip to France in 1987, he decided to visit farms and see how wheat grows. Among other crops, he saw sugar beet, maize and potato. He was most impressed by the yields and quality of the maize and potato. He realised that good seed is important. He was amazed because he used to produce maize and potato for his family's table, but he could never imagine achieving the results he saw in France. For El-Hadj Sow this new discovery had to be shared with farmers in the Fouta (the Middle Guinea region).

Sow noticed that without quality seed and other inputs, farmers get meagre results. Once back in Guinea, he approached the research and extension service to know more about seed and to understand how it is produced. The long and demanding process requires more care and equipment, and specific technical and managerial skills and knowledge about production, harvest and post-harvest.

El-Hadj Sow worked with extensionists and helped researchers set up experiments on his farm to study the behaviour of many crop varieties. They also did livestock experiments. These trials became a sort of field school where he learned about seed production and farm management.

Despite all the barriers to a newcomer in the seed industry, El-Hadj Tafsir Sow was determined to take the lead in producing and distributing seed. But when he shared his new vision with people, they told him that he could not succeed with seed production in the Fouta. But he refused to go down without a fight. So he requested Nerica rice seed from the extension service and received 29.5 kg. Today, El-Hadj Sow is happy and proud to have transformed this into more than 50 tonnes of rice seed.

Portfolio

El-Hadj Sow produces seed for the main crops of his region, namely potato, rice, maize and cowpea (Table 6.8). Though he started in 2000 with Nerica rice seed production, he could only provide figures for the last three years. His cultivated land remained the same in 2007 and 2008, but increased by one hectare in 2009. The areas devoted to seed potato, cowpea and rice seed fluctuated while maize increased. El-Hadj Sow explained that he has more land and could farm more of it but his tractor broke down and the spare parts are not available in Guinea to fix it.

Table 6.8: Seed produced, El-Hadj Sow

	2007	**2008**	**2009**
Cultivated area (hectares)			
Potato	10	8	9
Rice	7	8	5
Maize	3	4	6
Cowpea	2	2	3
Net production - sold as seed (tonnes)			
Potato	25	17	20
Rice	18	19	10
Maize	2	4	9
Cowpea	0.6	0.5	0.8

Table 6.9: Clients of El-Hadj Sow

	2000	**2005**	**2009**	**2015**
Individual farmers	1	1	1	1
State farms	2	2	2	2
Export in region	-	-	-	3
Projects and NGOs	-	-	-	4

*Ranking assessment by senior management of seed enterprise, 1 being the most important

6.6.2 Structure

Management

Except for occasional labourers, El-Hadj Sow does all the farm work with his household. One of his sons, a fourth-year agronomy student at university, gives him technical advice. He is open to new technologies and eager to transform them into innovations.

Besides crop production, El-Hadj Sow expanded to livestock. When he started his seed business, he added to his stock of cattle (as a Fulani he always has something in his corral) because he believed that crop production would be more successful when associated with animals, who can turn crop residues into manure.

Land and equipment

El-Hadj Sow owns 29 hectares of land. He inherited four hectares and bought 25. His strategy was to start by renting three to five hectares from a landlord. After farming it for two to three years he earned enough money from seed to buy the land. He now has two motor-pumps and garden hoses for irrigation, and rents many buildings to store seed and other farm products.

Links and external relations

El-Hadj Sow has close ties with researchers and extension officers who do experiments on his farms and sell him foundation seed. When he has a technical problem he cannot solve, Sow calls upon these experts, and they always come. He has excellent relations with farmers who buy his seed. He advises his clients on how best to treat improved crop varieties. He has little or no interaction with other seed producers. Foundation seed potato importers are his suppliers.

6.6.3 Cash flow

This family farmer has more vision and ambition than capital, but no banks make agricultural loans in Guinea. This is in sharp contrast with Mali, where the government supports the Banque Nationale de Développement Agricole (BNDA) to provide farmers agricultural loans at an annual interest rate of 12% (Dalohoun et al. 2011).

El-Hadj Sow said that there are some small financial establishments but the biggest loans they give are much lower than the minimum he would need. Worst of all, they charge exorbitant interest rates, and the first payment has to be made just a month after taking the loan, long before one could harvest the crop and begin selling the seed to repay the debt.

6.6.4 Marketing

El-Hadj Sow is the first large-scale seed producer in his region. He is known for his insistence on quality seed and for strictly following the technical production itinerary. He regularly visits his clients to encourage them and learn about their ever-changing demands.

His main customers include farmers from Labé district and state farms directed by the Chamber of Agriculture (Table 6.9).

Official orders for rice seed arrived at the Ministry of Agriculture from the embassies of The Gambia, Mali and Guinea Bissau in 2005 and 2006. As there is no certification, the seed could not be sold directly, but for this special request from one government to another, quality seed was sourced from El-Hadj Sow (see above). There are still opportunities for exporting seeds to neighbouring countries, but he cannot respond to them because of lack of certification.

6.7 CHALLENGES AND STRENGTHS OF THE SEED ENTERPRISES

The formal seed sector in Guinea is still fragile. The seed laws are not enforced and regulation and certification agencies are weak. Most seed is informal, supplied by individual seed producers, farmers' associations or cooperatives. A few of them are formally registered. Seed entrepreneurs mostly supply good quality seed rather than certified seed.

Over time, the seed enterprises described above have learned about their markets and how to adapt to a changing environment with small and unpredictable seed demands, no subsidies, lack of credit, and farmers who are often reluctant to pay extra for improved seed (e.g. because they do not know the variety, are unsure about the quality or believe they can save seed of a similar or even better quality). Thus production costs largely determine viability of seed enterprises. Sherif used to receive subsidised inputs, but now pays full costs. To stay in business he also produces local varieties that perform without use of fertilisers.

Unlike Sherif, Mama Adama has no relationship with rural development organizations and produces exclusively local varieties without any agrochemicals, thus reducing her production costs. Comptoir Agricole prefers buying seed from farmers and the research centre to minimise the risks of seed production. Although both enterprises have acquired a reputation among their clients, they differ fundamentally: while Mama Adama capitalises on her social network to sell her seed, Comptoir Agricole relies on the social networks of young people who scout the area for quality seed at the time of harvest.

About 80% of the members of the Cereal and Potato Seed Producers' Union are women, eager to earn an income and feed their families. The Union has access to plenty of fertile land on the Fouta Plateau, as well as access to foundation seed and technical expertise through its management. As all are extension agents who have worked their entire lives with farmers; they have a vast network, deep respect and sound knowledge of farmers' needs.

El-Hadj Sow was inspired by a visit to France in the late 1980s, after which he developed strong institutional relations and still receives technical advice from research and extension. However his client network is strong; he regularly visits his clients to support them and learn about their changing demands. He hardly sells to outside markets because of the lack of certification. The sustainability and reputation of Sow's seed enterprise rests on his entrepreneurial spirit, his solid management skills and his dedication to quality.

Besides the lack of subsidies and credit, rice seed producers face other challenges, especially scarce labour, which is in high demand during ploughing, weeding and harvest. Rice seed is produced at the same time as all the rest of the rice and during the growing season most households prefer to work first on their own farm, to assure their staple food supply. Paid labour becomes scarce and more expensive, making it difficult to expand seed enterprises.

Several seed enterprises in Guinea lack functional links with formal institutions, and make a business from selling quality seed of local varieties. Their networks and reputation are their major assets.

Various enterprises like the ones presented in this chapter survive without access to credit, which does not mean, however, that they would not benefit from more accessible and customer-friendly rural financial products and services. The Government of Mali has done just that (Dalohoun et al. 2011).

Many publications on entrepreneurship in developing countries have argued that social networks are essential for entrepreneurial success. However, based on a study in Madagascar, Fafchamps and Minten (2002) stressed the need to distinguish different components of social networks, e.g. relations with other traders and with potential lenders increased transaction productivity, whereas extended family relations reduced it. Egbert (2009) came to the same conclusion, namely that African entrepreneurs in Tanzania financially support the extended families despite the trouble it causes for their business. However, the case of Mama Adama described in this chapter (Section 6.2) shows how extended family ties can have a long-lasting positive effect on seed trade. Social networks are indeed complex and context-specific; no doubt they can be supportive and functional, as well as parasitic.

ACKNOWLEDGEMENTS

The authors would like to thank A. Kaboré, M. Soumah, L. Béavogui and the technical staff of the Association pour la Promotion Economique de Kindia (APEK) for their assistance in data collection. The authors also thank anonymous reviewers for their comments on earlier drafts of this paper.

REFERENCES

Barry, Billo M. 2006 *Diversité et dynamique des variétés locales de riz (*O. sativa *&* O. glaberrima*) en Guinée. Conséquences pour la conservation des ressources génétiques*. PhD thesis. Rennes : Ecole Nationale Supérieure Agronomique de Rennes.

Dalohoun N. Daniel, Paul Van Mele, Eva Weltzien, Dioukamady Diallo, Hamidou Guindo and Kirsten Vom Brocke 2011 “Mali: When governement gives entrepreneurs room to grow”. In P. Van Mele, Bentley, J.W and Guéi, R.G. (Eds.) *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishin, pp 65-88.

Egbert, Henrik 2009 “Business Success through Social Networks? A Comment on Social Networks and Business Success.” *American Journal of Economics and Sociology* 68(3):665-677.

Fafchamps, Marcel & Bart Minten 2002 “Returns to Social Network Capital among Traders.” *Oxford Economic Papers* 54(2):173-206.

MAEF 2007a *Politique nationale de développement agricole vision 2015. Vol. 1* Bilan-Diagnostic de la LPDA2 (1998-2005). Conakry: Ministère de l’Agriculture des Eaux et Forêts.

MAEF 2007b *Nouvelle vision de l’agriculture Guinéenne. Politique nationale de développement agricole vision 2015. Vol. 2 : Orientations et axes strategiques*. Conakry: Ministère de l’Agriculture des Eaux et Forêts.

Okry, Florent, Paul Van Mele, Edwin Nuijten, P.C. Struik & M.L. Roch 2011 “Organizational analysis of the seed sector of rice in Guinea: stakeholders, perception and institutional linkages,” *Experimental Agriculture*, 47(1):137-157.

Portères, Roland 1966 “Les noms des riz en Guinée,” *Journal d’Agriculture Tropicale et de Botanique Appliqué* 13:346 pp.

Richards, Paul 1986 *Coping with Hunger: Hazard and Experiment in an African Rice-farming System.* London: Allen & Unwin.

SG2000 2005 *Rapport Final 1996-2004*. Conakry: Sasakawa Global 2000.

Silué Drissa, Abdoulaye Barra and Robert G Guéi 2011 “Cameroon: Revolving funds make a difference”. In P. Van Mele, Bentley, J.W and Guéi, R.G. (Eds.) *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishin, pp 25-37.

SNPRV 2001 *Multiplication and Diffusion of Community-Based Seeds of NERICA Rices Developed by WARDA*. Conakry: Agence Nationale de Promotion et de Conseil Agricole.

Van Mele Paul, Michael A. Ugen, David Wanyama, Robert Anyang, Jean Claude Rubyogo and Louise Sperling 2011b “Uganda: Dreams of starting a company”. In P. Van Mele, Bentley, J.W and Guéi, R.G. (Eds.) *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishin, pp 156-180.

Van Mele, P., Bentley, J.W and Guéi, R.G. (Eds.) 2011a. *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishing, 236p.

WARDA 2007 *Africa Rice Trends: Overview of Recent Developments in the Sub-Saharan African Rice Sector*. Cotonou: Africa Rice Center.

CHAPTER 7

RICE SEED PRODUCTION AMONG THE SUSU IN GUINEA AND SIERRA LEONE: LOCAL KNOWLEDGE AND FARMERS' PRACTICES

Okry, F., E. Nuijten, P. Van Mele, P. Richards and P.C. Struik

Abstract

This paper analyses rice seed production and selection by a cross border ethnic group, Susu farmers of Guinea and Sierra Leone. Data were collected in 2007-8 in the Kindia region (Lower Guinea) and Kambia district (North-West Sierra Leone). Data were collected using a combination of research methods including group discussions, surveys, informal interviews and participant observation (from the social sciences) and field measurement, germination tests, determination of seed rate and field mixtures (from the biological sciences). Farmers' seed production and selection are part of their crop production systems and are best understood when considering farmers' objectives of production and the wider socio-economic conditions they live in. We argue that knowledge is not a major limiting factor for Susu small-scale farmers' seed production, but socio-economic and political factors are. These factors often force farmers to alter their initial plans for seed production and search for contingencies planning that can assure them a certain quality of seed in their given conditions. Hence, farmer seed production is not and cannot be regarded as a pre-determined design. Consequently, recommendations for its improvement cannot be limited to a series of planned actions to be implemented by a set of actors as the formal seed system often conceives it. Interventions should not narrowly focus on knowledge. It is necessary to understand that farmers have to succeed even under extremely harsh conditions in order to protect their food security. A sustainable improvement of the formal seed system should consider integrating farmers' coping strategies.

Keywords: *Oryza* spp.; farmers' seed production; formal seed system; informal seed system; Susu; Guinea and Sierra Leone.

7.1 INTRODUCTION

West-African rice consumption has steadily increased in recent years but domestic production is still far from meeting the local demand. In Guinea, for example, the annual per capita consumption was estimated at 69 kg (2001-2005) (WARDA, 2007), but the country's rice self-sufficiency was only 60% (MAEF, 2007). Guinea shifted from being a rice exporter in the 1950s (Portères, 1966) to being a rice importer at present (MAEF, 2007). The same gap between rice production and consumption is also found in Sierra Leone (WARDA, 2007).

Much rice in Guinea and Sierra Leone is produced for subsistence, and, as in many other developing countries, subsistence rice growers rely on farm-saved seed (SNPRV, 2001; Okry et al., 2011a). Throughout the 1980s and early 1990s both countries went through structural adjustment programmes resulting in a weakened extension system. In addition, Sierra Leone underwent a long civil war (1991-2002) that seriously damaged social relations and affected the formal and informal seed systems.

Several programmes designed to strengthen seed supply have focused solely on the formal seed system. They often lacked follow up action once projects came to an end. For the past two decades local seed dealers have emerged within local farming communities partly to fill a gap resulting from an unprofitable and contracted formal seed sector. Local dealers sell their own produced seed as well as seed produced by other farmers and by official seed producers (Okry et al., 2011a, 2011b). Building on such dynamics in the informal seed system could improve seed supply to smallholder farmers and contribute to better linkage between the formal and informal seed systems.

Although by far the major seed supplier to small-scale farmers (Almekinders and Louwaars, 2002; Ndjeunga, 2002; Almekinders et al., 2007), the informal seed system has had scant attention from the scientific community (Louwaars, 2007). Scientific investigation has more often focused on the formal seed sector and consequently development efforts have been oriented in this direction as well (Louwaars, 2007; Okry et al., 2011a). However, a few projects have developed activities focusing on the informal seed system, or have attempted to develop an intermediate seed system merging formal and informal seed systems. For example the Community Based Seed System (CBSS) implemented by Africa Rice Center (AfricaRice) in various sub-Saharan African countries aims to combine elements of formal and informal seed systems (see Bèye et al., 1997, Bèye et al., 2005). Efforts to valorise the informal seed system, on the other hand, have more often been based on theoretical reflections than on actual data, partly because the system in itself is not well known (Thiele, 1999). This study highlights some of these principles.

Researchers and development policy makers have tended to question farmers' ability to select varieties, produce and conserve seed, and preserve seed quality. Surprisingly, few data exist on the actual quality of farmer-saved seed (Rubyogo et al., 2009). This helps explain why donors seem reluctant to invest in farmer' seed systems. In rice production, farmer' seed is often mentioned as a presumed major weakness, whereas the epitome of good quality seed are the improved varieties obtained from accredited formal sources (Hossain et al., 2003, Tin et al., 2010). Taking an informed position in such a debate, however, requires a clear understanding of the functioning of farmer seed systems: variety creation and selection, seed production and seed dissemination.

Dorward et al. (2007) and Okry et al. (2011a, 2011b) investigated seed dissemination and identified several scenarios (reflecting local social networking and systems of trust) for seed dissemination activity by small-scale farmers. These studies also note that the farmer seed system is capable of producing new seed types. Barry et al. (2007) and Nuijten et al. (2009) demonstrated that these new varieties emerged as a result of variety and field management by farmers. Farmers' agronomic practices bring to bear a range of selection pressures on their crop genetic resources distinct both from those applied in formal breeding programmes (Nuijten et al., 2009) and those of natural selection (Cleveland and Soleri, 2007, Mercer and Perales, 2010). In addition to agronomic practices, socio-economic, cultural and historical factors can also act as selection pressures (Nuijten et al., 2009; Nuijten et al., 2010; Teeken et al. 2010). In contrast to the emphasis put on planning in farming by extension and research, Richards (1989) argued that because of unforeseen events and changes in socio-economic context farmers often have to improvise. As such, farmer' seed selection and production is perhaps more a product of good performance (seasonal adjustment of farming practices to unforeseen constraints and opportunities) than good planning. It has also been noted, for rice, that farmer seed management practices can vary from year to year depending on the socio-economic context (Nuijten, 2005; Longley, 2000).

The research reported in this paper covers the seed production and selection practices of Susu rice farmers in Guinea and Sierra Leone. As a self-pollinating crop, rice seed production poses fewer problems to farmers than cross-pollinating crops such as maize. Hence farmers often use farm-saved seed. This typically amounts 70% of annual seed needs for rice farmers in Guinea (Okry et al., 2011a). Moreover, compared to beans and groundnuts, rice has much lower levels of protein and oil, which makes it much easier to store. Rice seed is stored for six to nine months and then planted. Hence, farmers do not face the problem of loss of germination ability due to long periods of storage.

The paper assesses commonly accepted seed quality standards, social organisation of farming activities in relation to availability of resources (mostly labour). The aim of the study is to (i) document farmers' knowledge and practices of seed production and selection; (ii) describe important principles and mechanisms shaping farmer seed production and selection; and (iii) suggest domains where cooperation with the formal research system could strengthen farmer seed production and selection practices, and vice versa. The following research questions will be discussed:

1- How do farmers select and produce seed? Is knowledge a limiting factor to farmer seed selection and production?

2- Do farmers' standards for quality seed differ from those of the formal seed system?

3- To what extent can the formal seed sector strengthen the farmers' seed system (and vice versa)?

7.2 METHODOLOGY

7.2.1 The study area

The study was conducted from June 2007 to December 2008. Eleven villages/hamlets in Kindia region in Lower Guinea and neighbouring Kambia district in north- western Sierra Leone were selected for primary data collection. Based on proximity the villages/hamlets were grouped into four research sites (Figure 7.1). Villages of Site 1: Bokariya (9'20.582N; 12'48.582W; 52.6m asl) and Sangaran (9'20.538N; 12'48.010W; 66.8m asl) were selected because of remoteness from cities. Villages of Site 2: Seifan (9'54.136N; 12'47.21W; 78.1m asl) and Dentègueya (9'54.303N; 12'48.204W; 73.1m asl) were selected because of proximity to the national rice research institute (CRA Kilissi). Villages of Site 3: Kinyaya (9'58.044N; 12'53.591W; 402m asl), Hononkhouré (9'57.143N; 12'53.111W; 429m asl), Tour (9'57.273N; 12'53.25W; 368m asl), Yaya (9'57.491N; 12'54.479W; 436m asl), Dandakhouré (9'56.503N; 12'53.897W; 400m asl) and Sinta (9'57.246N; 12'53.105W; 390m asl) were selected because of proximity to Kindia, the urban headquarters of the region. In Sierra Leone, the village of Bassia (09'16.854N; 12'48.304W; 226m asl) hereafter referred to as Site 4 was selected as an outlier, in order to gain knowledge of the possible influence of the different politico-administrative systems of Guinea and Sierra Leone on farmers' seed production practices. Additionally, the villages Bassia, Bokariya and Sangaran are involved, historically, in trans-boundary seed exchanges, since Guinean Susu farmers have kin and affines in Bassia on the other side of the Great Scarcies River, which here acts as a natural border between the two countries. Sites 1 and 4 are located towards the foot of the Benna hills, opposed to Sites 2 and 3.

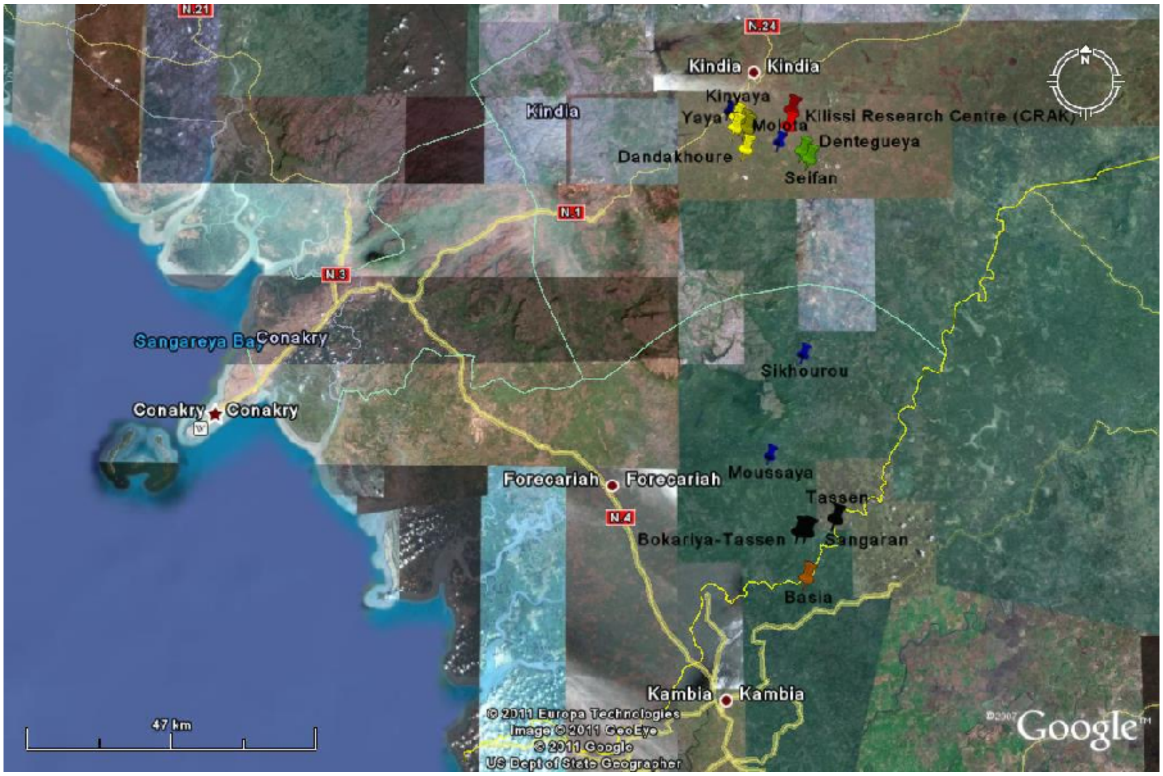


Figure 7.1: Study area. Black, green, yellow and brown pinpushs indicate villages studied in Sites 1, 2, 3 and 4, respectively.

Lower Guinea and Kambia district enjoy a six-month rainy season from May to November and a dry season also of six months. The average annual rainfall ranges from 2800 to 4000 mm.

The study focuses on rice, a self-pollinated crop. In these villages rice is cultivated mainly for household consumption. Only 30% is sold at local markets (Okry et al., forthcoming). Rice is consumed daily in all households. This is part of the historical rice zone in West Africa, based on domestication of African rice (*Oryza glaberrima*), though today more Asian than African rice is grown. In rural areas, farmers often say that a real farmer entirely covers the rice needs of his household. Hence all households aim to produce enough rice to cover annual requirements, even though some fall short. Farmers used mainly farm-saved seed. New seed acquisitions cover, on average, 30% of annual seed needs (Okry et al., 2011a) but these acquisitions - from traders and other farmers - are often farm-saved seeds as well. Only 8% of seed is supplied by the formal seed system, in the case of Guinea (SNPRV, 2001). In Sierra Leone, the formal seed system is still under re-construction after the civil war, but probably supplies even less, except in areas where humanitarian agencies have been very active in post-war rehabilitation of farmers (Richards, 2006). Farmers cultivate both lowland and upland rice. The upland agro-ecology includes hilly areas (e.g. adjoining the Bena Hills), flat and non-inundated areas, forest zones, and so on. Lowlands include the moist foot slopes of hills and mountains and inland valley swamps, as well as the costal mangrove zone.

7.2.2 Data collection

The study used a combination of research tools reflecting both social and biological sciences methods to collect primary data.

Social science methods

First, we used focus group discussions with farmers and extension agents to collect information on farmers' practices of seed production and selection, farmers' attitude towards seed mixture and information on formal seed producers (contract farmers) operating in the area. At the end of each discussion we collected samples of varieties from farmers. Second, we used structured interviews with 113 households (32, 24, 35 and 22 selected from sites 1, 2, 3 and 4, respectively) to deepen insights on techniques of seed production (sowing, weeding, harvesting methods and periods, drying, threshing), techniques of seed conservation, practices of seed selection, local innovations and farmers' perception of seed quality. Three specialised seed producers were also interviewed. Specialised seed producers belonged to two groups: the formal seed producers trained in techniques of seed production under seed projects such as Projet Semencier National (now closed), SG 2000 (now closed) and the African Rice Initiative (on-going) and the traditional or local seed producers/dealers who have never experienced formal training (Okry et al., 2011a). About 19% of the seed sold at local markets was produced by the traditional producers/dealers themselves (Okry et al., 2011a, Okry et al., forthcoming).

Among two dozen formal seed producers and extension agents listed as being trained and accredited in the Kindia region, we visited six still living in the study area. Only two of them were still producing seed at the time of the study. They were located in Sites 2 and 3. A female traditional seed producer was identified in Site 1. The study reports on her activity as part of an in-depth case study of traditional seed production (Okry et al 2011b). Information about this traditional dealer was complemented by information given by local seed dealers identified at open markets (periodic markets) but who did not live in the study villages. No specialised seed producer was identified in Site 4, probably because this village, like many other Sierra Leonean villages, was still recovering from the war that had badly disrupted agricultural production. As recently as 2000 the Sierra Leone rebels and the Guinean troop contingent in the international peace keeping force were fighting across this section of the border, and most villagers had fled. Even som it is worth noting that the traditional seed producer in Site 1 had an extensive seed business with farmers of Site 4, based on pre-war contacts but now strongly revived. Third, informal interviews and participant observation helped to triangulate results and further probe farmers' knowledge. For all interviews and questionnaires, interviewees were selected at random. Because the study was carried out during the cropping season, some interviewees had to be replaced when they lacked time to participate in the study.

Biological science methods

We conducted germination tests and estimated field mixtures to cross-check information gathered through interviews.

Germination test

Fifty-six samples of 36 rice varieties were collected from farmers from July to August 2007 during group discussions. Farmers were requested to publicly show samples of listed varieties. Samples were both lowland (31) and upland (25) varieties. From collected seed samples 150 grains were selected and subdivided into three equal lots. Each seed lot was labelled, put in a perforated plastic bag and soaked in ordinary water. After 24 hours, plastic bags were removed and the water drained. Plastic bags were covered with cloths creating a warm environment for 48 hours. Germinated grains were counted 72 hours after soaking, instead of seven days as commonly used, in order to align our methodology to that of a collaborating rice research team from the Foulaya research centre of IRAG (Institut de Recherche Agronomique de Guinée).

Estimation of field mixture

Measurements took place at maturity in 64 fields (26, 3 and 35 fields from Sites 1, 2 and 3 respectively) selected randomly from 49 households (23, 3 and 23 from Sites 1, 2 and 3 respectively). Estimate of field mixture was not conducted in Site 4 because of contingencies. For the same reasons only three fields were visited in Site 2 for this exercise. Measurements were made along the diagonal of the field using observation plots of 1 m^2. Taking into account the fact that extremity of the field (bordering with other fields) is often mixed we left 10 m from the extremity of the diagonal and set the first observation plot. The second observation plot was set 10 m from the first and a third 10 m from the second, along the same diagonal. Observation plots were set along the second diagonal of the field only when the size of the field did not allow three observation plots on the same diagonal.

Panicles were harvested from each plot, and in collaboration with field owners, panicles were sorted in groups by variety. The mixture rate was determined as the proportion of panicles of varieties other than the ones the field owner intended to plant.

When the determination of mixture happened prior to harvest time (Sites 1 and 3), the degree of mixture was determined by counting the number of off-types against the total number of plants in the observation plot.

Field Mixture rate (%) = $100\, N_2\, (N_1+N_2)^{-1}$

N_1 = number of panicles or plants of the sown varieties

N_2 = number of panicles or plants of other varieties (non intended)

Measurement of actual field size and seed rate (quantity of seed used per hectare)

The tracking function of a GPS device was used to determine the size of rice fields. A total of 136 fields (57, 17 and 62 from Sites 1, 2, and 3, respectively) were measured. These fields belonged to 85 households. Eight household heads (6 and 2 from Sites 1 and 3 respectively) who were not involved in the surveys showed interest in the study during the period of field measurements. Their 13 fields (8 and 5 fields form Sites 1 and 3 respectively) were measured and information related to field management (varieties sown, quantity of seed used, date of sowing etc.) recorded. Only the size of upland fields was measured and used to determine the seed rate. We did not measure rice fields in Site 4 because of contingencies (defective GPS).

Two methods were used for determining the seed quantities used by farmers. Where the researcher was available during sowing the seed used by farmers was weighted. In other cases recollection methods were used. Farmers measure seed for sowing volumetrically, and have pretty clear recall (Richards, 1995; 1997).

Secondary data were also collected through literature reviews and archive searches. Secondary data gathered in this way related to the formal seed production schemes and the Community Based Seed System (CBSS).

7.2.3 Data analysis

We used ordinary data analysis tools to provide general descriptions. Descriptive statistics (averages, standard deviation and percentages) and Chi-square tests with and without Cramer's V were performed to analyse relations and indicate strength of relations.

7.3 RESULTS

7.3.1 Farmers' seed production

Farmers rarely owned special rice seed fields in the study area. Hence, seed production by farmers consisted in a careful seed selection from paddy field or from paddy (rice from the general harvest). Actual seed selection began at harvest time and could be broadly divided into two stages: harvest practices and post-harvest practices.

Harvest practices

Period of seed selection

Generally knowledge in the study area (as expressed at village meetings) is that seed harvest from paddy fields should start once the field reaches maturity and when two thirds of the panicles are dried. The rationale of this practice was that harvested panicles would continue to dry in the shade preventing seeds from being over-dry and cracking during threshing. Seed cracking threatens seed germination. Seed harvesting at this stage implies that seed should be harvested before the harvest of paddy. In practice a range of harvest periods was observed (Table 7.1a). Overall, there was a relationship between the research sites and the period farmers harvested seed (Cramer's $V = 0.25$, $p < 0.05$). This suggests that farmers, from the studied sites, did not harvest their seed in the same period. Seed harvest before the paddy harvest was observed in all sites, but mostly in Sites 1 and 4 (Table 7.1a), two sites located 10 km away from each other as the bird flies. Harvesting seed after the paddy harvest, mentioned only in Sites 2 and 3, seemed a rather marginal practice in general (7%) although not negligible in Site 3 (18%). These findings show similarities between Sites 1 and 4 on the one hand and Sites 2 and 3 on the other hand concerning the periods of seed harvest. Their proximity to each other might explain this similarity. About 53% of farmers coupled their seed harvest period with their paddy harvest. In this case seed panicles were either (i) harvested while the paddy harvest was in progress, as illustrated by Photos 7.1a and 7.1b (9% of the studied households selected seed in this way), or (ii) selected from bundles (13% of the households), or (iii) seed grain was selected from the threshed paddy (31% of the households). This last practice increased the chances of seed mixture as farmers harvested the entire field, threshed, dried and winnowed the harvest, and then collected part of it as seed. In some cases only left over (grains) after annual household consumption was used as seed. Seed selection form harvested panicles consisted in a sorting of harvested bundles for off-types and diseased panicles. During this process farmers often selected less mixed bundles and removed off-types and diseased panicles. When the bundles were highly mixed farmers preferred to select panicles of desired varieties from the mixed bundles.

Area selection for seed harvest

About half of the interviewed households (51%) selected seed from *anywhere in the field* (Table 7.1b). This group includes farmers selecting seed from harvested paddy and/or harvesting seed panicle by panicle all around the field. Other farmers selected seed from specific areas of the field (Table 7.1b). They harvested seed mostly from any *productive area* of the field or specifically from *Non mixed but productive areas* (Table 7.1b) stressing that plant vigour (impacting grain formation and robustness) and seed purity were two important factors determining the area to be selected for seed. There were, however, differences between sites on area selection for seed harvest (Cramer's $V= 0.34$, $p< 0.01$). For example seed selection from *any part of the paddy field except borders* (14%), seed selection from the *middle of the field* (11%) and seed selection from *first sown areas* (4%) were only observed in Site 1. According to farmers of Site 1, *first sown areas* of the rice field have the most vigorous plants and most matured panicles. Seed harvesting from the *central part* of the rice field or from *anywhere except borders* was justified by the fact that the borders often have less vigorous plants and were generally mixed compared to the inner parts. This confirms information reported for Mende farmers in Sierra Leone by Squire (1943). All upland rice fields were found clustered in a single location, sharing common boundaries, rather than isolated at separate points in the village territory in Site 1. It is logical that seed broadcasting in adjacent plots and seed washed down from farm to farm by sheet flood renders the borders of the fields highly mixed up. This could well explain why farmers of Site 1 selected seed from several parts of the field to reduce the likelihood of seed mixing. The three other sites showed a lot of similarities in the ways farmers selected areas for seed harvest. In these other sites, fields were also clustered to some extent, but the clusters were much smaller and contained fewer separate plots, when compared to Site 1.

Table 7.1 (a, b, c): Farmer practices of harvesting rice seed (when, where and how) at four different sites in the study area, 2007-2008

	Respondents (%)					
	Site 1 (n = 28)	Site 2 (n = 20)	Site 3 (n = 33)	Site 4 (n = 19)	Study area (n = 100)	Test[1]
			a) Harvest period			
Before paddy harvest	54	30	30	47	40	
Seed selected during and from paddy harvest	46	65	52	53	53	V = 0.25*
After paddy harvest	0	5	18	0	7	
			b) Area selected for seed			
Anywhere in the field	54	50	49	53	51	
Anywhere except borders	14	0	0	0	4	
First sown area	4	0	0	0	1	V= 0.34**
Middle of the field	11	0	0	0	3	
Non mixed productive area	18	25	15	5	16	
Productive area	0	25	36	42	25	
			c) Seed harvest method			
Panicle by panicle (with knife)	7	10	3	11	7	
Selected plot (with sickle)	54	40	46	37	45	NS
Entire field (with sickle)	39	50	52	53	48	

Source: Fieldwork 2007 [1]Test conducted was Chi-square with Cramer's V to indicate strength of relation; **: significant at 0.01 level; * significant at 0.05 level; NS: not significant. NB. The table synthesises information from all the interviewed farmers.

Methods of harvesting seed

Based on the tools used to harvest seed it is possible to distinguish in the study area a sickle- harvest (93%) and a knife- harvest (7%). Combining the usage of the harvest tools and the ways farmers grasped the plants to be harvested for seed, three methods of seed harvest could be distinguished: seed harvesting plant by plant or panicle by panicle using a knife (hereafter referred to as seed harvest panicle by panicle), harvesting of a selected plot for seed by bunch using a sickle, and harvesting of the entire field by bunch with sickle (Table 7.1c). The first method of harvesting allows the harvester to select by quality of panicle, and although labour intensive is preferred in many parts of central and eastern Sierra Leone. The sickle is more common in north-western Sierra Leone and Guinea.

No significant difference was observed across sites concerning the proportions of each method of seed harvest. Farmers said that harvesting seed panicle by panicle (Photo 7.1) allows selection of robust and healthy panicles for desired varieties and is therefore compulsory when one's field is highly mixed or infected by diseases. In case of lack of labour to harvest seed (from a mixed field) and to avoid panicles becoming over-dry in the field, farmers said they will then harvest the entire rice field, and sort seed rice from the harvest (as described above). It happened sometimes that due to unforeseen events farmers failed to sort seed from harvested bundles and thus proceeded immediately to the threshing of a mixed harvest. In this case, farmers said they exchanged a portion of the (mixed) harvest with fellow farmers possessing pure seeds to spare. This type of exchange works on the basis that the farmer with seed to spare has reserved seed already and would otherwise simply eat the seed that is exchanged. Sometimes women (who clean the rice) complain about mixed batches, especially where grains of *O. glaberrima* are mixed in, since this species is generally harder to clean.

When a selected plot is harvested for seed using a sickle (45%), off-types and desired varieties were harvested together. Likewise, diseased panicles were gathered with the harvested seed. Here also farmers spent some time to sort the seed bundles as described above. No significant association was found between the area where farmers selected seed and the harvest method they used. This suggests that the methods of seed harvest farmers adopted did not significantly influence their area selection for seed and vice versa (Table 7.2a).

After harvest, the seed bundles were kept upright (panicle up) lodged on felled tree stumps in the farm or piled or on top of platforms but preferably in the shadow of trees for one to seven days. This period of time allows grains to continue drying and gives households time to prepare a threshing floor and/or plan for threshing. Farmers covered the bundles with straws to protect the seed from dew and direct sunshine.

Table 7.2: Interactions between harvest method and area selected for seed harvest and interactions between harvest method and type of labour used

	Seed harvest methods (% of respondents)			
	Panicle by panicle (with knife)	**Selected plot (with sickle)**	**Entire field (with sickle)**	**Total**
	a) Interaction: "Seed harvest methods" and "Seed harvest areas"			
Anywhere	2	5	44	52
Anywhere except borders	0	3	0	3
First sown area	0	1	0	1
Middle of the field	0	2	0	2
Non mixed productive area	2	12	0	14
Productive area	3	25	0	28
n = 99 Households				
	b) Interaction: "Seed Harvest Methods" and "Labour used for harvest"			
Assigned household members	1	3	8	12
Head household	4	43	17	64
Work gang	0	4	19	24
n = 89 Households				
	χ^2 *(Labour Used vs. Seed Harvest Methods) p < 0.01*			

Source: Fieldwork 2007

Harvest labour

Seed was harvested mainly by specific members of the household (76%). Seed was either harvested by household heads (64%) or by any experienced household member delegated by the household head (12%). When lacking household labour to perform the harvest, farmers (24%) relied on a work gang (Photo 7.2) that carried the harvest under the supervision of the field owner or his representative. In this case, the entire field was often harvested and seed selected from the entire harvest. Richards (1986) reports that in Sierra Leone the harvesting gang is often accompanied by elderly kinsfolk, who may have helped earlier in preparing the farm, and that sometimes a portion is delimited for them to receive "payment" for this help.

Seed harvest methods, whether "panicle by panicle" or from "selected plots", were mainly applied by household members, mostly by household heads (Table 7.2b). The methods of seed harvest adopted by households largely depended on type of labour available by the time of the harvest (F= 16.83, df=

3, $p < 0.01$). Sickle harvesting is quicker but less selective. It is also sometimes less preferred (or less effective) when a field is heavily inter-cropped with other important food crops such as millet, sorghum, maize, sesame, pepper etc. (see also Richards, 1986).

Gleaning

Gleaning is a sort of “second harvest” consisting of collecting panicles left behind during the harvest. Gleaning always follows the harvest when it is performed by a work gang. Farmers said labour is scarce during the harvest time. To be able to perform several harvests on the same day, work gangs work fast and frequently leave some rice plants un-harvested. The field owner or anyone in the family (often old women) performs the gleaning within one or two weeks of the first harvest. Panicles harvested during the gleaning were also often highly valued as seed.

Post-harvest practices

Threshing

Unlike paddy threshing, which was done by beating bundles with sticks (Photo 7.3), about 57% of the interviewed households used their feet to thresh the seed. Feet-threshing consisted of walking repetitively on the bundles (Photo 7.4). Feet-threshing, farmers mentioned, prevents seed cracking and seed mixing as grains cannot easily jump out. However, farmers said when there is a lot of seed to thresh or when labour is scarce, stick-threshing is preferred as it is quicker. Seed threshing was carried out by both men and women. Winnowing complemented threshing. It was performed exclusively by women using a special flat basket (woven form raphia and known as a fanner) or any other ‘modern’ equivalent.

About 48% of the households threshed seed before paddy threshing, 11% after paddy threshing and 20% did so before the paddy harvest. Farmers said the different periods of seed threshing all aimed to reduce the chances of mixing varieties, as often the same threshing floor was used to thresh seed and paddy. Threshing was done (where possible) on a concrete threshing floor (Photo 7.5), a tarpaulin (Photos 7.6 and 7.7) or on the ground (Photo 7.3). When concrete threshing floors (often donated by NGOs or rehabilitation programmes) exist (e.g. in Sites 3 and 4), they belonged to the community and were managed by community leaders. Each household could thresh and dry according to established rules. Better-off farmers used their own tarpaulin (in all sites) as a threshing and drying floor. The majority of farmers threshed on the ground. In Site 2 farmers innovated and constructed their own threshing floor using clay from termite hills (Box 7.1).

Drying

Additional seed drying after threshing happened only when farmers felt seed was not sufficiently dried after the bundles had remained in the field for a few days. Also, farmers dried threshed seed when the threshing happened just after the harvest. In this case seed drying lasted for 7 (+/- 3) days on average. Longer seed drying periods were observed for early maturing varieties, since they ripen during the wet season. Children and elderly people take care of seed during the drying. They scared away chicken, birds, goats and so forth. According to farmers, seed drying after threshing increases the chance of seed mixture unless a good supervision is provided.

Storage and preservation

Farmers stored their seed threshed. Only one farmer stored seed un-threshed. Polythene sacks were the most frequently used containers (92%) followed by baskets (4%). Wooden boxes and sealed PVC containers were also used but to a lesser extent (2% each). Seed sacks and baskets were kept on platforms either at home in farmers’ room (94%) or in the village stores (6%) where they existed and functioned.

Photos 7.1a and 7.b: Mr. N'Famoussa harvesting seed panicle by panicle (with a knife) from his mixed rice field. His son immediately follows for the bulk paddy harvest with sickle. Photos by F. Okry

Photo 7.2: Members of a work gang of Hononkhouré happily pose after completion of a manual ploughing. They had a lunch made of African rice (*O. Glaberrima*). Photo by F. Okry

Photo 7.3: Mrs Fodelay Camara threshes paddy with a stick. This method is used for seed, but only when labour is scarce (Hononkhouré). Photo by F. Okry

Photo 7.4: Feet threshing is the preferred method for seed as it prevents seed cracking and seed mixing (Dandakhouré). Photo by F. Okry

Photo 7.5: Khabiatu Kamara poses in front of a communal threshing and drying floor (Bassia). Several households dry there their seed of different varieties. Photo by F. Okry

Photo 7.6: Mrs Fodé Sory Naité dries her domestic seed reserve (Bokariya). Photo by F. Okry

Photo 7.7: Mama Adama Yansané (right), a traditional seed producer, dries her commercial seed in her backyard and receives visit of two field researchers (Bokariya). Photo by P. Van Mele

Seed storage lasts six to nine months, up to the sowing of the next season in fact. Longer storage (up to 24 months) was observed only in the case of one seventy year-old farmer who wanted to keep a variety secure for diversity conservation purpose. He said that he did not trust the ability of any of the young farmers properly to cultivate and keep that particular variety of African rice (*O. glaberrima*). He therefore cultivated it every two years and conserved the seed (un-threshed) in paper; the package hanging on a stick of the ceiling of his room.

Damage in storage reported was mainly caused by rats (68% of farmers reporting) and insects (19%). A few farmers (11%) reported combined damage by rats and insects. Reports of fungal damage were negligible.

Box 7.1: Building a personal threshing floor from clay of a termite hill.

In Site 2 farmers often look for termite hills when establishing their rice fields. When no termite hill is located in the rice field, farmers look for nearby hills. The main reason is that clay of the termite hill is used as raw material in building a private threshing floor. Such a floor is similar to a concrete floor but does not last long; the rains of the next season wash it away.

The clay threshing floor is built by women assisted by children (see photos below). Children often dig the termite hill and women build the floor. Informants gave several reasons for building their own clay-threshing floor in absence of a tarpaulin. First, they said the clay threshing floor prevents seed mixture as several varieties are often consecutively threshed on the same floor: the clay threshing floor makes it easier to collect the grains after threshing using an ordinary broom. Second, farmers said it helps avoid impurities (stones, straw and so forth) that are frequently incorporated with seed and paddy when threshed directly on the ground: women said it helps to avoid tedious sorting before cooking. Another reason farmers gave was that a private threshing floor prevents conflicts that often arise among farmers concerning the management of a communal concrete threshing floor. Last, it helps keeping discretion over one's harvest. It is easier to be discreet about the total rice harvested, and avoid later claims for help by farmers with less successful harvests.

Khadiathou (left) and Sekhou dig the termite hill to collect clay.

Khadiathou mixes the collected clay with water and builds her own threshing floor.

Building a clay threshing floor takes several days and requires commitment especially when the harvest is large. Women prefer to build the clay threshing floor to preserve seed and paddy quality (exempted from impurities and stones).

The clay threshing floor is ready. Khadiatou prepares to start threshing the family harvest.

Photos by F. Okry

In general farmers do not use insecticide to preserve seed. According to them well-dried seed is not attacked by insects and fungi. Nevertheless, some farmers (14%) added whole or powdered hot pepper (*Capsicum* spp.) to their seed to prevent insect damage. In addition to the use of pepper, a farmer said he pre-soaked polythene sacks in a solution made of powdered leaves and kernels of neem (*Azadirachta indica)* before filling them with seed. Many other local recipes to repel local insects were known and used in the study area.

Seed management and seed shortages

Farmers selecting seed from their field (69%) systematically reserved seed after the harvest. Other farmers (31%) selected seed from threshed paddy just after threshing or kept grains and seed together till the next sowing. In this last case left over paddy is used as seed, but often there is none, where food demands have been unexpectedly high during the year - when, for example, a member of the household has to be buried (see Richards 1986).

From 2003 to 2007, 48% of the interviewed farmers experienced seed shortage at least once. In the study area, seed shortage was showing an upward trend (from 4% in 2003 to 11% in 2006. A sudden increase (34%) was then experienced in 2007. The same trends were observed in each of the four study sites. The high seed shortage observed in 2007 in all sites can be linked to the civil unrest Guinea experienced in February and March 2007, following the international food crisis of 2007. Bush (2010) has argued that these episodes of civil unrests - even though social and sometimes military in manifestation - were directly linked to food price rises in the same period. Farmers were in some ways forced to sell or eat most of their paddy and even their seed reserve, e.g. by having to cater for urban kin. This civil unrest also indirectly affected farmers of Site 4 (Sierra Leone) who still partly depended on farmers of Site 1 for seed (Okry et al., 2011 b). About 47% of seed shortages between 2003 and 2007 were caused by entire consumption of the harvest, leaving farmers seedless at sowing time. This was mainly the case for those households who did not separate seed from the bulk harvest of paddy. Other situations leading to seed consumption or sale, and hence to seed shortage, were crop failure (18%), misfortune (e.g. sickness, death of a family member, or non-reimbursement of a seed loan to a fellow farmer) causing 17% of seed shortages and wrong predictions about seed needs (12%). About 7% of seed shortages were caused by post-harvest losses and poor seed quality forcing farmers to re-sow. In sum, 76% of seed shortages were due to socio-economic and political factors influencing farmers' management of seed stock, 18% to crop failure and 7% due to farmers' inability to properly conserve and preserve their seed (for a similar account for central Sierra Leone, but showing a different pattern of causality see Richards (1986)).

Seed quality and seed mixture

Farmers' perceptions regarding seed quality

Farmers listed and ranked a number of characteristics they used to assess seed quality. These characteristics were classed into several groups following the median ranking (Table 7.3). Within sites, the nonparametric test (Kruskal-Wallis) performed did not reveal any significant difference among groups of characteristics suggesting that within sites, every characteristic was, to farmers, as important as every other characteristic. However, the importance given to the seed characteristics significantly varied across sites ($\chi^2 = 29.167$; df= 12; $p < 0.01$). Farmers of Sites 1 and 4 were similar in the way they ranked the listed characteristics. They put more emphasis on seed purity compared to farmers in Sites 2 and 3. This is in accordance with the finding in Table 7.1 that farmers in Site 1 take special care to select seed from several areas of their fields to ensure seed purity. Proximity between Sites 1 and 4 might explain the fact that farmers in both sites have similar perceptions of the importance of seed purity despite being in two different countries (Guinea and Sierra Leone). In contrast, farmers in Sites 2 and 3 put more emphasis on visual maturity-related characteristics such as filled, big, heavy grains and less on seed purity (conformity to a single morphotype). Seemingly, evidence of vigour or success is more important than pedigree, to these farmers. In the specific case of Site 3 seed purity came third after maturity related characteristics and presentational aspects of seed (cleaned and beautiful seed). Farmers' ranking of seed characteristics in Sites 2 and 3 is similar to that of seed dealers (Okry et al., forthcoming). It is likely that farmer seed management in Sites 2 and 3 and dealers' seed management have the same origin. Either seed dealers inherited their perceptions on seed quality from interactions with farmers from Sites 2 and 3 or vice versa. The seed trade being recent in the study area (Okry et al., forthcoming) it seems the former is more likely. Possibly, seed dealers originated from the general area including Sites 2 and 3 since this is the area where the seed trade developed first.

The germination ability of seed was mentioned in all sites. Again, there were differences between Sites 2 and 3 on the one hand and 1 and 4 on the other. Farmers in Sites 1 and 4 emphasised the germination factor more strongly. This difference needs to be explained since our estimate of germination rate was 73±14% in 2007 (73±15%, 75±13% and 73±13% for Sites 1, 2 and 3, respectively). Germination ability was not significantly different at 0.05 level across all three sites. This means that, in practice, farmers maintain seed with similar germination rates in all three sites. So differences in the ranking of perceived importance in "germination ability" as a characteristic of seed quality is associated not with seed but with the local knowledge system. In Sites 2 and 3, where germination ability was less emphasised, farmers focused on maturity related characteristics, expressed in terms such as 'filled, big and heavy grain', as visual predictors of seed germination capability. In Site 1 (there are no data on this topic for Site 4) farmers appear to rely more on morphotype (and thus pedigree) as a guarantor of quality. This could be linked to different levels of plasticity and niche specificity in the varieties characteristic of different sites (Mokuwa et al. forthcoming). A precise morphotype may be especially important as an indicator of performance for some highly niche-adapted varieties, such as the japonica group of Asian rices important in Sierra Leone (Mokuwa et al. forthcoming). More work will now be needed to relate farmer perceptions of seed quality to specific varieties in local seed repertoires.

Taking the study area as a whole, maturity-related characteristics, seed purity and seed appearance expressed as "cleaned (exempt of impurities) and beautiful seed (similar size and non-spotted seed)" were highly rated (Table 7.3), and from a farmer perspective the major characteristics of good quality seed (Kruskal-Wallis Test, $H = 15.106$, $df= 4$, $p < 0.01$).

Seed mixing: discourse and reality

It needs also to be pointed out that norms and practice are at variance in Susu rice farming. At village meetings only a few farmers publicly acknowledged that at times their rice fields were mixed (due to presence of varieties not consciously planted, also referred to as off-types). These farmers were quickly qualified as "little rice growers" by their peers. For example, farmers at Site 1 said at a village meeting that "real rice growers would never mix seed, and should avoid seed mixing by all means". This discourse of farmers is only partly consistent with their various practices of seed selection and perceptions of seed quality. In practice intentional and non-intentional seed mixtures frequently occurred.[6] For example, over half the farmers from Site 1, so adamant that seed should never mix, also admitted that unintentional mixing did actually occur (see below).

The issue may have a historical context, linked to the sensitive issue of slavery. In the 18th century, Susu ruling families were heavily involved in the Atlantic slave trade, and managed large rice plantations to supply the slave vessels. The preferred food for victualing these ships was "red rice" (presumably *O. glaberrima*). It was the food the slaves were familiar with, and was considered more nutritious than Asian rice. Despite the cruelties of the trade, slavers were very keen to land slaves in a fit and healthy condition, since this affected the profits of the voyage. At the end of the 18th century the British colony of Sierra Leone, founded as a bulwark against slavery, promoted "white rice"

[6] Note that percentages presented in the sections Intentional seed mixing, Non intentional seed mixing and Mixture in farmers' fields are calculated against the number of respondents shown in Table 7.4.

(presumably Asian rice, sub sp. japonica) as a possible export crop. This white rice was promoted among the Susu landlords of the "Northern Rivers" (now Guinee Maritime or Lower Guinea), to encourage supply to Sierra Leone. Keeping "white rice" pure became a subject of diplomatic endeavour between the new colony and its Susu neighbours to the north. Under guidance from Sierra Leone the Susu nobility grew "pure" rice on large plantations, while other farmers and former slaves (the new peasant classes) presumably planted whatever (mixed) seed they could get on their own subsistence plots, concerned more with performance than pedigree (Mouser et al., 2011).

Intentional seed mixing. During individual interviews 15% of household heads (10%, 13%, 20% and 17% in Sites 1, 2, 3 and 4, respectively) declared that they sometimes intentionally mixed seed at sowing. About 75% of these farmers often mixed two varieties; 18% mixed three varieties and 6% (one farmer) mixed four varieties (Table 7.4). Farmers said only varieties of the same growth duration are mixed to avoid rice ripening at different times, hampering the normal performance of other farming activities. Fields where varieties of different crop duration are mixed required more intensive and longer periods of bird scaring farmers said. Apart from this general rule for intentional variety mixing, some farmers gave specific reasons for intentional seed mixing. About 38% said they mixed slow-digesting (heavy) varieties (often varieties of *O. glaberrima,* or Saidou Gbéli (*O. sativa))* with quickly-digesting (light) varieties (only *O. sativa*) (Table 7.4). By doing so, these farmers explained they increase their chances of meeting the annual rice needs for consumption. According to farmers, the light varieties are the most delicious and therefore would otherwise be quickly consumed after the harvest. The heavy varieties are often kept to feed the work gang during the cropping season and to feed the household during the hungry season. A mixture of both in the harvest, farmers said, prevents quick depletion of the light varieties. Mixture of light and heavy varieties could also be done at cooking (a common practice in the study area). But the farmers intentionally mixing varieties said they preferred to mix them at sowing, so that the women will no longer have the option to cook the light varieties first (the harvest would already be mixed). It was also noted during fieldwork that some farmers mixed varieties of *O. glaberrima*, so presumably had a different rationale, since *O. glaberrima* varieties are all generally considered "heavy", but there are no measured data on this (Table 7.4). The greatest number of farmers mixing light and heavy varieties at sowing was found in Site 3 (Table 7.4). Some informants (19% of households mixing varieties) also believed that the mixture of high and low yielding varieties improved the total average yield. This finding is consistent with observation by Longley and Richards (1993) and Jusu (1999). Farmers also explained that, for example, when *O. sativa* and *O. glaberrima* are mixed, *O. sativa* at complete maturity supports *O. glaberrima,* reducing its propensity to lodge. This helped to limit yield loss for *glaberrima*, especially when farmers lacked labour for timely harvest. Only 30% of farmers purposely mixing varieties used a specific mixing ratio. The average ratio for mixture of two varieties was estimated at 0.7. Often the light varieties dominated the mixture.

Non-intentional seed mixing. About 30% of interviewees (58%, 9% and 65% of interviewees at Sites 1, 3 and 4, respectively) acknowledged non-intentional seed mixing. No farmers at Site 2 acknowledged unintentional seed mixing. For 35% of farmers the non-intentional seed mixing occurs at sowing because the rice fields are clustered and seed is broadcast. Some broadcasting at the edges of a plot must end up in the neighbouring farm plot, separated by nothing more than a rough "fence" of branches from felled vegetation. Unintentional mixing also happens at harvest (8%), when seed is not properly selected from the paddy field, and also at threshing (31%) and drying (10%), when seed is threshed and dried on a communal floor inadequately cleaned from previous use. About 26% of farmers acknowledged non-intentional mixing but did not know its cause. Some attributed it to an "invisible hand" as seed very often gets mixed no matter how much precaution farmers take. All causes of non-intentional seed mixing enumerated above were present at Site 2. The fact that no farmers in Site 2 and only a few from Site 3 acknowledged non-intentional seed mixture might indicate that seed mixture occurred mostly with the farmers of Sites 1 and 4, or that farmers in Sites 1 and 4 paid closer attention to their fields than their peers in Sites 2 and 3. But it should also be recalled that

Table 7.3: Characteristics of quality seed and ranking across sites

	Site1						Site 2						Site 3						Site 4						Study area	
	%	Rank					**%**	Rank					**%**	Rank					**%**	Rank					%	**Med**
		1	**2**	**3**	**4**	**med**		**1**	**2**	**3**	**4**	**med**		**1**	**2**	**3**	**4**	**med**		**1**	**2**	**3**	**4**	**med**		
Filled, big and heavy grains	22	5	4	1	1	1	52	14	7	1	0	1	34	14	6	3	1	1	21	5	3	1	1	1	32	1
Cleaned and beautiful seed	16	6	2	0	0	1	12	2	2	1	0	2	24	8	8	1	0	1	17	7	1	0	0	3	18	1
Germination	16	4	2	1	1	2	2	0	1	0	0	2	6	1	0	3	0	3	27	2	9	2	0	2	12	2
Purity	30	9	4	2	0	1	19	6	1	1	0	1	21	8	6	1	0	1	27	6	6	1	0	2	24	1
Well dried and conserved; free from insects and fungi	16	1	4	3	0	2	14	2	3	0	1	2	14	4	4	2	0	2	8	1	1	1	1	3	13	2
Total		25	16	7	2			24	14	3	1			35	24	10	1			21	20	5	2			

Source: Survey 2007. %: frequency of appearance of the characteristic. Percentages are calculated against the total number of responses obtained per site. In total 105 farmers (25, 24, 25 and 21 from Sites 1, 2, 3, 4 respectively) gave 210 responses (50, 42, 70 and 48 from sites 1, 2, 3 and 4 respectively). Rank: 1= highest importance. Med: result of the median ranking of each characteristic.

farmers in Site 2 were especially adamant that seed mixing was bad. In short, they care more about seed mixing, on normative grounds, than other farmers.

Two possible explanations (both already noted) could be advanced to explain the difference in degrees of concern for seed mixing - the old discourse of variety purity dating from the aftermath of slave trade, and the agronomic need to keep a specific set of niche adapted varieties separate. The two explanations might reinforce each other, since the niche adapted varieties might be descended from the "white" (thus possibly japonica) varieties introduced from Sierra Leone, but at present we have no data specifically to test either of these hypotheses. But as triangulation, actual field mixtures were measured in 2007. The following section reports on the observed degrees of mixture in fields.

Table 7.4: Farmers declaration of intentional variety mixing: importance per site, varieties mixed, mixing ratio and reasons for mixing varieties

	Code Household	Mixed Varieties		Rice Species	Mixing Ratio	Reasons giving by farmers to mix varieties
Site 1 n=31	102	1	Tonsékéréyi	*O. sativa*	60	Same crop duration/High yielding/Swell/Light/Not tasty/Hard shortly after cooking
		2	Dama	*O. glaberrima*	40	Same crop duration/Tasty/Swell/Heavy
	110	1	Dama	*O. glaberrima*	-	Same crop duration/Look alike
		2	Missilimi	*O. sativa*	-	Same crop duration/Look alike
		3	Tonsékéréyi	*O. sativa*	-	Same crop duration/Look alike
	205	1	Saidou Firê	*O. sativa*	5	Same crop duration
		2	Saidou Gbéli	*O. sativa*	10	Same crop duration
Site 2 n= 23	312	1	Saidou Firê	*O. sativa*	1	Same crop duration/Heavy
		2	Podê	*O. sativa*	1	Same crop duration/Light
	315	2	Saidou Gbéli	*O. sativa*	1	Same crop duration
		1	Saidou Firê	*O. sativa*	1	Same crop duration
	403	1	Saidou Firê	*O. sativa*	-	Same crop duration
		2	Saidou Gbéli	*O. sativa*	-	Same crop duration
Site 3 n= 35	502	1	Saidou Gbéli	*O. sativa*	-	Same crop duration
		2	Saali	*O. glaberrima*	-	Same crop duration
	504	1	Dalifodé	*O. sativa*	66	Same crop duration/High yielding/Light
		2	Tombo Bokary	*O. glaberrima*	33	Same crop duration/Heavy
	513	1	Saidou Gbéli	*O. sativa*	-	Same crop duration
		2	Tombo Bokary	*O. glaberrima*	-	Same crop duration
	519	1	Samba	*O. sativa*	-	Same crop duration/High yielding/Light
		2	Saali	*O. glaberrima*	-	Same crop duration/Low yield/Heavy
		3	Tombo Bokary	*O. glaberrima*	-	Same crop duration/Low yield/Heavy
		4	Dixi	*O. glaberrima*	-	Same crop duration/Low yield/Heavy
	609	1	Tombo Bokary	*O. glaberrima*	-	Same crop duration/Same ecology
		2	Podê	*O. sativa*	-	Same crop duration/Same ecology
		3	Saali Forê	*O. glaberrima*	-	Same crop duration/Same ecology
	610	1	Saidou Gbéli	*O. sativa*	-	Same crop duration/Heavy
		2	Saidou Firê	*O. sativa*	-	Same crop duration/Light
	612	1	Saali Forê	*O. glaberrima*	-	Same crop duration/Heavy
		2	Dalifodé	*O. sativa*	-	Same crop duration/Heavy
		3	Tombo Bokary	*O. glaberrima*	-	Same crop duration/Heavy
Site 4 n= 17	714	1	Samba	*O. sativa*	-	Same crop duration
		2	Saidou Gbéli	*O. sativa*	-	Same crop duration
	715	1	Samba	*O. sativa*	-	Same crop duration
		2	Saidou Gbéli	*O. sativa*	-	Same crop duration
	716	1	Samba	*O. sativa*	-	Same crop duration
		2	Saidou Gbéli	*O. sativa*	-	Same crop duration

Source: Fieldwork 2007-2008. - = no specific ratio given

Mixtures in farmers' fields. Counting of off-types showed that almost all the rice fields visited were mixed in all sites, though to a varying degree. The rate of field mixture was estimated at 7% (min= 0; max= 17), 41% (min= 6, max= 76) and 11% (min= 0, max= 47) in Sites 1, 2 and 3, respectively[7]. On average, two (min= 1; max= 4) additional varieties were found in the rice fields surveyed, resulting in two to five varieties co-existing in the same field, despite farmers varying protestations concerning the need for seed purity.

Farmers at Site 1 assessed seed purity as being the major characteristic of a good batch of seed. Compared to other sites, farmers at Site 1 also showed the most diverse methods of area selection to obtain pure seed. The fact that the lowest rate of field mixture was observed in Site 1 aligns with farmer discourse about practice. These farmers try harder to maintain seed purity, though field mixtures still occur. In Sites 2 and 3 farmers did not rate seed purity as the top characteristic of seed quality. Besides, their area selection practices for harvesting seed were not as diversified as those observed in Site 1. These differences in practices and perceptions among sites were also reflected in the degree of field mixture. The higher rates of field mixture observed in Sites 2 and 3 match with the finding that seed purity was less important to these farmers, even although their discourse clearly mentions seed purity as an objective. The fact that many farmers in Sites 2 and 3 did not acknowledge any accidental mixture in their fields prior to the determination of the level of field mixture further supports the idea that a distinctive set of seed quality norms, tolerant of mixture, has emerged in the area including Sites 2 and 3, and that it may be subject to further spread through association with emergent seed trading networks (Okry et al., forthcoming).

However, it should also be added that farmers in all sites showed little disappointment when we discovered varietal mixtures in their fields. Farmers clearly stated that field mixture becomes a practical problem only when varieties of different crop duration become mixed, since this affects harvesting labour demands. For some, mixed seed allows variety selection: "Mixed seed acquired from elsewhere, especially from the market place, brings in new diversity" said AY, a successful rice grower in Site 3. In 2007 AY was very glad to re-select Sèwa, a variety already extinct in the area, from his mixed field planted with the variety Saidou Firê; the seed of which he had acquired from Kindia market. ISh, the formal seed producer in Site 3 said he wanted to introduce Sèwa in his varietal portfolio to help sustain his seed business. He was pleased to hear that AY could once again offer seed of this variety in coming years. If concern for rice purity reflects old status differences between slave and free then practical necessity and the onward march of market forces are presumably fast eroding such distinctions. On the other hand, if concern for pedigree reflects an agronomic factor (niche adaptation) some farmers may be at a disadvantage if the more relaxed standards of Sites 2 and 3 become the regional norm. Further research linking farmer seed choice to some of the issues of varietal robustness and plasticity assessed by Mokuwa et al. (forthcoming; Chapter 3 of this thesis) is now needed.

7.3.2 Rice seed production by traditional seed producers

Local seed producers did not use any pesticides or mineral fertilizers. Their seed production system comprises a series of measures to guarantee grain maturity and prevent varietal mixture. Differences in practices of cultivating a seed field and a paddy field appeared at sowing, weed control and harvest. Below we describe these differences, drawing upon information from interviews with seed traders who produced their own seed, and a case from Site 1 for in-depth insights.

Period of sowing, labour management and seed rate

Labour availability (which depends on the size and composition of the household, affiliation of the household to a work gang, ability to mobilise kin and/or capability to negotiate and hire a work gang) determines sowing date. Farmers sowed their paddy fields, with minor differences depending on the site and climatic conditions, from the end of May to the second half of July. Farmers mentioned that they could extend the sowing period up to the end of August, but this incurs a risk of drought at booting and flowering stages, causing a yield drop. Such flexibility is absent in seed fields. Local seed dealers and producers said a seed field should be established from the end of May until mid-July at the latest. A delay in sowing, they said, could impact on seed maturity and cause yield to drop, especially in a year of erratic rainfall. They also mentioned that early-sown plants had more chance to mature properly than late-sown plants. Ordinary rice growers also acknowledged this. Another commonly-shared item of knowledge in the study area was that, compared to normal and late sowing, early sowing requires less seed. According to farmers, early sown rice plants can develop more tillers, thus compensating for reduced plant density. For this same reason, and because of the risk incurred

[7] Rate of seed mixture was not estimated in Site 4 because of contingencies

when sowing late, ordinary rice growers also aimed to establish their fields at the beginning of the cropping season, as shown in Table 7.5. Hence there is competition between rice growers and seed producers for labour at sowing time. Strategies of seed producers to secure labour varied. These included:

1 Premium payment for labour: the seed producers paid more than the normal rate to assure that the work gang visits them first.

2 Spontaneous seed gifts to less seed secure farmers (relatives and non-relatives) to facilitate labour arrangements at a later stage, e.g. locking up individual contracts at low rates, or through advancing position on the waiting list for a work gang.

3 Work group membership: seed producers made sure at least one dependent or affiliated member of their household is part of a work gang.

Comparing seed rates used in the study area, it was observed that the seed rate used by the traditional seed producer of our case study (53 kg ha^{-1}) did not differ (t-test) at 0.05 level from seed rates used in upland paddy fields. The average seed rate in upland fields was estimated at 56 kg ha^{-1} (sd= 32; n= 123) in 2007, not significantly different at 0.05 level from the formal (extension) recommendation (60 kg ha^{-1}).

Throughout the rainy season, seed rates differed per period of sowing (F= 2.132, df= 8, p= 0.038). Referring both to farmer knowledge on sowing windows (see above) to observed sowing periods in 2007 (Table 7.5) it can be concluded that sowings from the last third of July onwards are late sowings: 16% of rice fields owned by 13% of households were sown in that period. Farmers who sowed in this period gave several reasons to explain late sowing - lack of household labour, lack of resources at the beginning of the sowing period to hire and feed a work gang, lack of seed to sow, misfortune (e.g. sickness or death of a family member at the beginning of the sowing period), and so on. Such events are examples of circumstances that deviated farmers from their initial plans and forced them to adopt contingency coping strategies to assure a minimum of food production. Some of these farmers mentioned that some varieties permit late sowing. These were Saidou Gbéli, the most widely cultivated variety in the study area, Wonyonwonyonyin, a farmer interspecific hybrid (Nuijten et al., 2009), and Saali and Tombo Bokary (*O. glaberrima*). To stay consistent with their declared knowledge, it might be expected that farmers would increase their seed rates when planting was delayed, but this was not the case (Table 7.5). Other factors like the perceived risk attached to a late sowing (e.g crop failure due to drought) might have influenced farmers' decision on the seed rate to use in cases of delay. It seems unlikely that delayed farmers would greatly increase seed rates, even if they had wished to, given that seed reserves would be eaten, in order to feed the family during the period of delay.

The majority of the fields (84%) were sown from June to the second third of July. Within this overall interval seed rates varied when decades (ten day periods) are compared (F= 3.186, df= 4, p= 0.017). The second third of July showed a higher seed rate (75 kg ha^{-1}) than the average seed rate (53 kg $ha^{-1)}$ for the four preceding decades, (during which seed rates did not vary). Farmer practices are thus in conformity with the local knowledge that late-sowing (i.e. the last decade of the regular sowing period) requires more seed to compensate for limited tillering in a late crop. Seed rates were then reduced for extremely late sowing (third decade of July onwards) because of the likelihood that declining rain would adversely affect booting and flowering stages.

Table 7.5: Rice sowing periods and seed rates (upland fields)

Sowing periods	% fields sown	Seed rate (kg ha^{-1}) (Average ± Std deviation)
First decade of June	7	53 ±16
Second decade June	11	68 ±44
Third decade June	18	52 ±18
First decade of July	31	48 ±19
Second decade July	19	75 ±51
Third decade July	11	49 ±16
First decade of August	2	43 ±13
Second decade August	2	29 ±10
First decade of September	1	48
Total	100	56 ±32

Source: Fieldwork 2007. N= 123 upland rice fields owned by 76 households

Techniques of sowing

In upland paddy fields broadcasting was the only crop establishment technique, whereas in lowland paddy fields farmers transplanted (71%), broadcast (1%), or interchangeably used seedling transplantation and seed broadcasting (28%) depending on circumstances. Farmers explained that seed is broadcast in lowlands only when the field owner lacks labour and is delayed in sowing. In case of delay, seed is broadcast before water establishes in the field. According to farmers when seed is broadcast in lowlands extra manpower is required for hand weeding and thinning. So farmers often preferred good field preparation and seedling transplantation in lowland ecologies. According to seed producers seedling transplantation is essential in seed fields.

Weed control

Weeding strategies (undertaken by women and children) did not differ between paddy fields and seed fields, except that weeding was done on average once in paddy fields and twice in seed fields. According to informants a properly managed rice field requires three weedings. Farmers' ability to control weeds largely depended on the availability of and access to women's labour. In uplands, weed control consisted of hand weeding. In lowlands, farmers used a hoe. Manual and back-breaking weed control represented the most tedious activity in the rice field. But it also requires care. Rice and other emergent grasses are at times hard to distinguish, and women often feel that many men have neither the knowledge nor patience to perform the task well (Richards 1986). Because of the care weeding requires, it was primarily performed with women and children of the household, supplemented by informal collaboration among neighbours. But seed producers said they often also used paid non-household labour to supplement household labour. Ordinary rice growers did this as well, but not to the same extent.

Harvesting practices

The borders of the seed fields were often avoided during harvest to reduce chances of mixing, as explained above. In fact, seed fields were not isolated from paddy fields. Fields are demarcated with wooden sticks laid horizontally. Non-intentional mixing in seed fields, was caused by seed broadcasting and sheet wash draining seeds from one field to another. Seed producers rogued off-types before harvest to reduce chances of incorporating off-types into the seed supplies.

7.3.3 Seed production by formal seed producers

At field level, the use of chemicals (e.g. herbicides, fertilisers, fumigants and insecticides at recommended doses or affordable rates), machinery (e.g. tractor and plough), and work oxen (where available) marked out the major difference between traditional seed production and formal seed production. Apart from differences in inputs and equipment, formal seed producers received or were supposed to receive the visits of field staff from extension and seed inspection services to check seed quality and compliance with international standards defining requirements for seed production fields. In principle the history of the field, required distance between seed field and other fields, techniques of seed production, phytosanitary measures, techniques of harvesting, storage, conservation and packaging are all under scrutiny (Bèye et al., 2005). But the inspection service was non operational due to lack of equipment and resources. Efforts at revival were ongoing. Nor were seed laws and regulations enforced at the time of the study (Okry et al., 2011b). Box 7.2 summarises stages of seed production as recommended by the formal seed sector (extension and research). Formal seed producers (contract farmers) are involved at Stage 4 for certified seed production and at Stage 5 for seed sale to farmers. These stages of seed production are similar to those observed in most developing countries. They apply to the production of seed of improved varieties only.

Box 7.2. Formal seed production scheme (actors, tasks division and time frame)

Stage	Actors	Task description	Produces obtained	Required time
1	Research (Breeders)	Variety development and release	G0	From variety release
2	Public seed centres and seed inspection service	Production of breeder seed and certification	G1 → G2 → G3	1^{st} to 3^{rd} years
3	Research Extension Public seed centres Seed inspection service	Production of foundation seed and certification	Foundation seed (G4)	4^{th} year
4	Formal seed producers Extension Seed inspection service	Seed production, certification and commercialisation	Certified seed R1 & R2	5^{th} and 6^{th} years
5	Seed stores Seed centres		Seeds	7^{th} year

Source: Fieldwork 2007 (Focus group discussions with researchers, extension officers and NGOs)

7.3.4 The Community Based Seed System (CBSS)

The formal seed production is often criticised for being too long drawn out (Bèye et al., 1997). It requires on average seven years for a released variety to reach farmers. Additionally, the formal system promotes only "improved varieties" (i.e. products of formal plant breeding) hence the criticism of many farmers that the formal seed system offers only limited varietal diversity (Okry et al., 2011a). Nor does it emphasise farmer participation (Bèye et al., 2005). To improve the formal system, several participatory approaches to variety selection and seed production have been developed. These include participatory varietal selection (PVS) to improve the efficiency of the formal seed system (Witcombe et al., 1996). PVS has been implemented in Guinea since the late 1990s, and the CBSS was designed specifically to engage farmers in formal seed multiplication and diffusion activities (Bèye et al., 2005; Guéi et al., 2008). The CBSS was implemented in Guinea from 1998 to 2004, after which it was halted due to lack of funds. The CBSS is described here since it specifically deals with seed production (the aim of this study) and is a model continued in other West-African countries, e.g., Cote d'Ivoire (A.M. Bèye, personal communication). In Box 7.3 we summarise the stages of seed production of the CBSS.

Box 7.3: CBSS seed production scheme (actors, tasks division and time frame)

Stage	Actors	Tasks description	Produces obtained	Required time
1	Research (Breeders)	Variety development and release	Breeder seed G0	1st year
2	Public seed centres Seed inspection services	Production and certification of breeder seed	G1, G2	2nd and 3rd years
3	Farmer cooperatives, Privates seed producers, NGOs, Formal seed producers	Seed production	Non-certified foundation seed	4th year
4	Formal seed producers, Farmer cooperatives and Extension (technicians)	Organise the renewal of foundation seed, record farmers' seed needs, produce seed in collaboration with technicians who monitor harvesting and post-harvesting processes (seed purity and germination)	Seed of acceptable quality*	From the 4th year

Source: Bèye et al., 2005; * Seed of acceptable quality is defined as uncertified seed with more than 80% germination rate and more than 90% varietal purity.

The CBSS aimed to promote on-farm production of quality seed through training farmer groups (Guéi et al., 2008). It was designed to draw upon farmers' practices and local knowledge, and to act as an alternative seed supply mechanism for smallholder farmers. The CBSS thus aimed to strengthen farmers' capacities in seed production and conservation techniques and link them to the market (Bèye et al., 2005). In West Africa, the CBSS is the first ever seed production scheme, with a focus on rice, that pledged to easing formal standards and procedures of seed production and to involve farmers fully in the process. It is not in conception limited to improved varieties but this was how it worked in practice in Guinea.

The CBSS was recommended for implementation at national level (Bèye et al., 2005) with establishment of a nation "observatory" and involvement of researchers, extension officers and the private seed sector. The official mission of the observatory is to ascertain farmers' needs for seed and varieties, per community, and to monitor the quantities of seed to be produced. A major well known weakness of the formal seed sector has been its inability to inventory the seed needed by farmers and to supply it in a timely way in the right places. A problem here is that farmer's decisions to acquire new seed are often last minute decisions and require seed to be readily available at a local level (Richards, 1989; Cromwell and Tripp, 1994). Consequently, the national observatory idea needs reformulation. A more decentralised approach is needed, perhaps run by farmers and local seed producers themselves (Richards et al., 2009) or by small to medium-scale private entrepreneurs who may operate at a slightly larger geographical scale (Van Mele et al. 2011).

7.4 DISCUSSION

7.4.1 Seeds and contingencies

The findings above reveal a gap between what farmers stated as their practices of seed production and what they actually did. Additionally, farmer practices of seed production varied from year to year (Nuijten, 2005; Longley, 2000). For example, contrary to general techniques described during village meetings and group discussions, farmers individually developed and used a range of methods of area selection and techniques of seed harvest, and dealt differently with post-harvest activities. This gap between statement and practice is not, in fact, surprising, since it is well known among anthropologists that West African village consultations produce political consensus, reflecting the interests of ruling elites, and not statements of fact, as they would be understood in science (Murphy, 1990). The type of labour available most determined actual farmers' practices. In situations where there is lack of household labour to harvest seed as required and to avoid losses (from over dried panicles, or through lodging and shattering) farmers often turned to work gangs. The latter were more concerned with completing a job quickly than with preserving the quality of the harvested seed. Hence farmers developed other ways of gathering quality seed in such circumstances. The low proportion of households currently harvesting seed panicle by panicle (preferring instead to use the labour-efficient sickle) despite a high observed rate of mixed fields, and the general wish of Susu farmers to obtain pure seed, is a good instance of where farmers norms and practice are at variance.

Jusu (1999), comparing seed production/selection practices of three ethnic groups from Northern Sierra Leone, reported that Temne and Limba farmers were more inclined to prioritise seed purity and therefore rogued more frequently than Susu farmers. Roguing is a type of negative selection, involving removal of off-types from a mixed field before or during harvesting. In situations where rice fields are scattered about the bush, rather than being clustered in a single communally cleared area, with the result that there is less field mixing caused by seed broadcasting and sheet wash, and in cases where farmers predominantly select their seed from threshed paddy, roguing probably confer a good enough degree of purity to seed. But in areas where fields are clustered (e.g Site 1) and in situations where fields are highly mixed, farmers reject roguing in favour of positive mass selection, consisting of harvesting plants of desired varieties (as described above) to maintain seed purity. Roguing and seed harvesting panicle by panicle lead to the same end: maintaining seed purity. Jusu (1999) offered a cultural explanation for the variation in roguing practices among Susu, Limba and Temne. Longley (1999) suggested, in addition to a cultural explanation that shortages of household labour might also force Susu farmers to adopt practices that do not prevent accidental variety mixing. In fact, Susu farmers of Longley's research area (Northern Sierra Leone) were also involved in trade. Hence the household labour was primarily used in trade-related activities. Nuijten (2005) also mentioned socio-economic factors (in particular labour shortage) to explain the gap between norm and practice in the seed production activities of Mandinka and Jola farmers in The Gambia. In other rice cultivation systems (e.g. in Vietnam) roguing is also reported as a time consuming and labour intensive activity (Tin et al., 2008).

The limited availability of or access to labour among Susu farmers, especially in Sites 2 and 3, where out-migration to the cities is a factor, might also prevent farmers from using labour-intensive practices such as roguing and panicle harvesting that preserve seed purity. In the past these activities were common in the study area (A. Pendessa, personal communication). More generally, labour scarcity at crucial periods of the cropping season force farmers to abandon carefully-considered initial plans and adapt to contingencies at peak periods, such as sowing, weeding and particularly harvesting, when households are generally unable to cope on their own. As Richards (1986, 1989) reported for Kpa-Mende rice farmers in south-central Sierra Leone, farmers know that successful seed and paddy production requires good command over labour supply throughout the cropping season. Only the wealthiest farmers are in a position to exercise such control. Others improvise. In sum, it is not knowledge alone that shapes farmer practices of seed selection and production. Local coping strategies assure that a majority of households, by ingenious or sometimes desperate means, get just enough seed from an environment in which a large number of physical, socio-cultural, economic and political constraints interplay. Farmer seed management is thus, in most cases, the product of adapting to contingencies. This is common across West Africa (Richards, 1985; 1986; 1989; Nuijten, 2005).

7.4.2 How does coping with contingencies fit with CBSS and formal seed interventions?

Within the formal seed system and the CBSS variant (see Boxes 7.2 and 7.3) seed production and distribution are divided among a set of actors following strict procedures. In contrast, farmer seed production (product of adapting to contingencies as above showed) and acquisition are integrated with the food production system (McGuire, 2005; Richards, 2009). This results in certain seed-oriented “ritualisation processes” that maintain social cohesion as well as flow and circulation of seeds (Richards, 2010). A separation of seed and food production would be artificial, and possibly damaging to local norms of cooperation.

A common weakness of the formal seed system and some intermediate seed systems (e.g. the CBSS) is that they overlook these performative dimensions to farming practice. They think instead in terms of “plans”, and give advice to farmers as “planned actions” to be implemented. The real challenge for these seed system remains how to link technical advice to the daily performance of farmers addressing contingency. The development of the seed sector, it is here argued, needs to go beyond the introduction of technological packages. In addition to valorisation of existing knowledge and technologies formal interventions (e.g governmental programmes) should also try better to understand and improve the global context (physical, social, economic) in which farmers operate and which constrains them to certain decisions making repertoires, as shown by Teeken et al. (2010), Tin et al. (2010) and Sambodo and Nuthall (2010).

7.4.3 Understanding seed standards from small scale farmer’s perspectives

Germination rate

The observed germination rate (73±14%) of farmers’ seeds was not too far below the 80% used as reference figure by the rice researchers of IRAG (N. Bourouno, personal communication) and also officially recommended (see Bèye et al., 2005; Somado et al., 2008) as an acceptable rate of germination. The fact that farmers’ seed rate (56±32 kg ha^{-1}) was not significantly different (at 0.05) from the formal recommendation (60 kg ha^{-1}) further confirms that the germination rate of farmer seeds was good. Tin (2009) also showed that farmers’ rice seed generally has a good germination capacity. However, the large variance in the Guinea case indicates that Susu farmer practices of seed conservation did not always successfully maintain high seed germination levels, although farmers themselves reported only 7% of seed losses due to inappropriate conservation practices. Here is a domain where farmers may lack knowledge and resources, and where training might pay dividends. The dominance of polythene sacks as storage materials instead of air tight storage materials (e.g. PVC containers) further compounds the problem. A better germination rate would surely lead to significant reductions of seed rates, as Chowdhury et al. (2011) have reported from Bangladesh.

Seed purity

Intentional and non-intentional seed mixing were both observed. The former has its roots in the socio-economic situation of a specific category of farmers. Causes of non-intentional seed mixture, e.g. through clustering of fields, seed broadcasting and seed translocation through sheet wash were beyond farmers’ control. These aforementioned causes of non-intentional seed mixtures, to which must be added the communal use of threshing and drying floors and the stick threshing that often causes seed to scatter, indicate that an objective of 96-100% seed purity, as suggested by the formal seed system, is an unrealistic objective for most low resource farmers in Guinea and Sierra Leone.

Farmers knew the factors that undermine seed quality. Local practices and innovations such as seed threshing after or before paddy harvest, threshing by foot to reduce numbers of cracked grains, construction of personal clay threshing floor, and seed storage in sealed containers were frequently encountered as ways of preserving seed quality. Although still used on a relatively small scale, these practices are available, to be encouraged, improved and scaled up. Studies in other countries (Diaz et al., 1998 in the Philippines, Tin et al., 2008 in Vietnam) reported between 7% and 20% yield increase by improving farmers’ practices of seed management through regular face-to-face training sessions. In Bangladesh, a low-cost video-mediated learning group on seed health improved farmers’ rice yields by 15% and reduced their seed rate (Van Mele et al., 2007, Chowdhury et al., 2011).

Seed renewal

Farmers' seed renewal is rarely mentioned in literature on informal seed systems. We found that farmers renew their seed stock once a certain level of mixing was observed and also when lacking labour to restore purity by harvesting panicle by panicle. The time period for seed renewal is variable and depends on the level of mixture observed. Further research is needed to investigate this aspect. The time after which farmers renewed their own seed seemed longer than the three years the formal seed sector generally recommends for improved varieties. A reason might be that farmer varieties of rice do not segregate, as they are mainly self-pollinated (Nuijten and Richards, 2011).

Summing up, farmers develop context-specific practices that, depending on their socio-economic situation, allow them to produce seed, a major agricultural input. Understanding these practices demands an understanding of the wider socio-economic and physical context in which farmers live. This study has argued that the quality of seeds resulting from farmer processes of seed production should be regarded as being high relative to the limitations of the local context. Farmer seed production is not and cannot be the product of a carefully-calibrated design. Consequently, recommendations for improvement cannot be limited to a set of planned actions and actors. Total system replacement with another model designed from scratch may be attractive to governments and donors, but it is also risky, as witnessed by the failure rate of formal seed projects. A safer approach is that improvement should start from a good understanding of what already works well, and what works less well than it might. This should guide the choice of focal points for spot improvement. This paper has identified some areas of farmer practice - for example seed conservation (storage materials), management of threshing and drying floors, and choice of a periods and techniques of seed threshing to reduce non-intentional mixing - that could well be strengthened. Although the formal seed system has been successful in producing seed for many commercial crops, particularly hybrid seeds, there are fewer success stories for food crops such as rice (for exceptions see Van Mele et al., 2011). The lesson of this paper is that there are, nevertheless, many ways in which farmers guarantee their own seed supplies, and often to a surprisingly high quality standard. The focus now should be placed on protecting those capacities, and building them outwards and upwards as informal networks for quality seed, involving local agency as much as possible, with science playing a vital, imaginative and flexible support role.

ACKNOWLEDGEMENTS

The Netherlands Organization for International Cooperation in Higher Education (NUFFIC) funded this research. The Africa Rice Center (AfricaRice) provided additional funds for field activities. The Institut de Recherche Agronomique de Guinée (IRAG) and the Association pour la Promotion Economique de Kindia (APEK) assisted in practical organisation of the field work. The authors would like to thank R. Glèle for advice on statistical analysis, N'Famoussa Camara for his assistance in data collection and all informants, especially farmers, for the time they willingly shared in answering questions.

REFERENCES

Almekinders, C.J.M. and Louwaars, N.P. (2002) The importance of the farmers' seed systems in a functional national seed sector, *Journal of New Seeds* 4,15-33.

Almekinders, C.J.M., Thiele, G. and Danial, D.L. (2007) Can cultivars from participatory plant breeding improve seed provision to small-scale farmers? *Euphytica* 153, 363-372.

Barry, M.B., Pham, J-L., Noyer, J.L., Billot, C., Courtois, B. and Ahmadi, N. (2007) Genetic diversity of the two cultivated rice species (*O. sativa* & *O. glaberrima*) in Maritime Guinea. Evidence for interspecific recombination, *Euphytica* 154, 127-137.

Bèye, A.M., Jones, M., Simpson, B., Mané, O., Coly, J-P. and Malou, J-P. (1997) Fiche synoptique du système semencier communautaire; Community based seed system-CBSS. 7 p. http://www.fidafrique.net/IMG/pdf/0_Systeme_CBSS_AMB.pdf. Accessed on 27 February 2011.

Bèye, A.M., Jones, M.P. and Simpson, B.M. (2005) Système semencier communautaire: cas de la riziculture traditionnelle. Guide du technicien. Collection ADRAO Formation. Bouake, Côte d'Ivoire: ADRAO.

Bush, R. (2010) Food riots: poverty, power and protest. *Journal of Agrarian Change* 10(1), 119-129.

Chowdhury, A.H., Van Mele, P. and Hauser, M. (2011) Contribution of farmer-to-farmer video to capital assets building: Evidence from Bangladesh, *Journal of Sustainable Agriculture* 35(4), 408–435.

Cleveland, D.A. and D. Soleri. (2007) Extending Darwin's analogy: bridging differences in concepts of selection between farmers, biologists and plant breeders, *Economic Botany* 61, 121–136.

Cromwell, E. and Tripp, R. (1994) Proximity is a plus: the economics of farmers seed production and distribution in developing countries. In: J. Hanson (ed.) *Proceedings of the ILCA/ICARDA. Seed Production by Smallholders Farmers*.

Diaz, C., Hossain, M., Merca, S. and Mew, T. (1998) Seed quality and effect on rice yield: Findings from farmer participatory experiments in Central Luzon, Philippines, *Philippines J. Crop Sci.* 23(2), 111-119.

Dorward, P., Craufurd, P., Marfo, K., Dogbe, W. and Bam, R. (2007) Improving participatory varietal selection processes: participatory varietal selection and the role of informal seed diffusion mechanisms for upland rice in Ghana, *Euphytica* 155, 315-327.

Guei, R.G, Somado, E.A. and Akintayo I. (2008) Improving Nerica seed availability to end-user farmers (Module 11). In: Somado, E.A., Guei, R.G. and Keya, S.O. (Ed.) *NERICA: the New Rice for Africa – a Compendium*. Africa Rice Center (WARDA): http://www.warda.cgiar.org/publications/nerica-comp/Nerica%20Compedium.pdf. Access 24 August 2011.

Hossain, M., Janaiah, A., Husain, M., Naher, F. (2003) Rice seed delivery system and seed policy in Bangladesh. Poster paper presented at PETRRA Communication Fair. Dhaka, Bangladesh. , http://www.cpd-bangladesh.org/publications/cpdiri/poster_2.pdf Accessed 27 February 2011.

Jusu M.S. (1999) Management of Genetic Variability in rice (*Oryza sativa* L. and O. glaberrima Steud.) by breeders and Farmers in Sierra Leone. Published PhD thesis, Wageningen University, Wageningen, The Netherlands.

Longley, A.C. (2000) A social Life of Seeds: Local Management of Crop Variability in North-Western Sierra Leone. PhD thesis, University College London, London, UK.

Longley, C. (1999) On-farm rice variability and change in Sierra Leone : Farmers' perceptions of semi-weed types. *Agricultural Research and Extension Network Paper (ODI)* 96b, 10-14.

Louwaars, N. (2007) Seeds of Confusion: the Impact of Policies on Seed Systems. Published PhD thesis. Wageningen University, Wageningen, the Netherlands.

MAEF (Ministère de l'Agriculture des Eaux et Forets) (2007a) Politique Nationale de Développement Agricole Vison 2015. Vol.1: Bilan Diagnostic de la LPDA 2 (1998–2005). Conakry.

McGuire, S. (2005) Getting Genes: Rethinking Seed System Analysis and Reform for Sorghum in Ethiopia. Published PhD thesis, Wageningen University, Wageningen, The Netherlands.

Mercer, K.L. and Perales, H.R. (2010) Evolutionary response of landraces to climate change in centers of crop diversity, *Evolutionary Applications* 3, 480–493.

Mokuwa, A., E. Nuijten, F. Okry, B. Teeken, H. Maat, P. Richards and P.C. Struik (Forthcoming). Robustness and strategies of adaptation within a large set of farmer varieties of African rice (Oryza glaberrima Steud.) and Asian Rice (Oryza sativa L.) Across West Africa. *Plos One* Submitted.

Mouser, B., E. Nuijten and P. Richards, 2011. A Colour Bar? The Commercialization of Rice At Sierra Leone. Workshop, "New Histories of Rice", Max Planck Institute for the History of Science, Berlin, 25-26th March 2011.

Murphy, W.P. (1990) Creating the appearance of consensus in Mende Political Discourse, *American Anthropologist* 92 (1), 24-41.

Ndjeunga, J. (2002) Local village seed systems and pearl millet seed quality in Niger, *Experimental Agriculture* 38, 149-162.

Nuijten, E. (2005) Farmer Management of Gene Flow: the Impact of Gender and Breeding System on Genetic Diversity and Crop Improvement in the Gambia. Published PhD dissertation, Wageningen University, Wageningen, the Netherlands.

Nuijten, E. and Richards, P. (2011) Pollen flows within and between rice and millet fields in relation to farmer variety development in the Gambia, *Plant Genetic Resources: Characterization and Utilisation*, doi:10.1017/S1479262110000481, 1-14.

Nuijten, E., Richards, P., Glover, D., Maat, H., Mokuwa, A., Okry, F., Teeken, B., Temudo, M. and Struik, P. C. (2010) Understanding the complex mechanisms of Technology × Environment × Society interactions in 'suboptimal' rice farming systems. *Proceedings of the 3rd International Rice Congress*, Hanoi, Vietnam, 8-12 November, 2010.

Nuijten, E., Van Treuren, R., Struik, P. C., Mokuwa, A., Okry, F., Teeken, B. & Richards, P. (2009) Evidence for the emergence of new rice types of interspecific hybrid origin in West-African farmers' fields, *PLoS ONE* 4(10): e7335. doi:10.1371/journal.pone.0007335.

Okry, F., Dalohoun, D. N., Diawara, S., Barry, M. B. & Van Mele, P. (2011 b) Networks that work. In: Van Mele, P., Bentley, J. W. and Guéi R. G. (eds.) *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishing.

Okry, F., Nuijten, E., Van Mele, P., Struik P.C. and Richards P. (Forthcoming). Adaptation of the Informal Seed System to Agrarian Changes: The Emergence of Market Oriented Local Seed Dealers within the Informal Seed Sector of Rice in Guinea. Under review *Journal of Agrarian Change*.

Okry, F., Van Mele, P., Nuijten, E., Struik, P. C., and Mongbo, R. L. (2011 a) Organizational analysis of the seed sector of rice in Guinea: stakeholders, perception and institutional linkages, *Experimental Agriculture* 47(1), 137-157.

Portères, R. (1966) Les noms des riz en Guinée, *Journal d'Agriculture Tropicale et de Botanique Appliquée* 13(9), 1–346.

Richards, P. (1985) Indigenous agricultural revolution: ecology and food production in West Africa. London: Unwin Hyman.

Richards, P. (1986) Coping with Hunger: Hazard and Experiment in an African Rice-farming System. London: Allen & Unwin.

Richards, P. (1989) Agriculture as a performance. In Chambers, R., Pacey, A. and Thrupp, L.A. (ed.) *Farmer First: Farmer Innovation and Agricultural Research*. London: Intermediate Technology Publications.

Richards, P. (1995) The Versatility of the Poor: Indigenous Wetland Management Systems in Sierra Leone. *GeoJournal,* 35(2), 197-203.

Richards, P. (1997) Towards an African Green Revolution? An anthropology of rice research in Sierra Leone, In Nyerges, E. (ed.) *The ecology of practice: studies of food crop production in sub-Saharan West Africa*, Amsterdam: Gordon and Breach.

Richards, P. (2009) Knowledge networks and farmer seed systems. In: Scoones, I. and Thompson J. (ed.) *Farmer First Revisited: Innovation for Agricultural Research and Development*. Warwickshire: Practical Action Publishing.

Richards, P. (2010) Ritual dynamics in humanitarian assistance, *Disasters* 34, 138-146.

Richards, P. and Longley, C. (1993) Farmer innovation and local knowledge in Sierra Leone, In Amanor, K., de Boef, W., A. Bebbington and Wellard, K. (eds.) *Cultivating knowledge*, London: Intermediate Technology Press.

Richards, P., De Bruin-Hoekzema, M., Hughes, S. G., Kudadjie-Freeman, C., Offei, S. K., Struik, P. C., Zannou, A. (2009) Seed systems for African food security: linking molecular genetic analysis and cultivator knowledge in West Africa. *International Journal of Technology Management*, 45, 196-214.

Rubyogo, J.C., Dickinson, M., Mayes, S. and Assefa, T. (2009) Seed-health assessment of different bean seed grades and sources from Ethiopia using molecular tools, *Journal of New Seeds* 10, 293-310.

Sambodo, L. A. A. T. and Nuthall P. L. (2010) A behavioural approach to understanding semi-subsistence farmers' technology adoption decisions: The case of improved paddy-prawn system in Indonesia, *Journal of Agricultural Education and Extension*16(2), 111-129.

SNPRV (Service National de la Promotion Rurale et de laVulgarisation) (2001) Multiplication and Diffusion of Community- Based Seeds of NERICA Rices Developed by WARDA. Conakry.

Somado, E.A., Guei, R.G. and Keya, S.O. (Ed.) NERICA: the New Rice for Africa – a Compendium. Africa Rice Center (WARDA). http://www.warda.cgiar.org/publications/nerica-comp/Nerica%20Compedium.pdf. Access 24 August 2011.

Squire, F. A. 1943, Notes on Mende rice varieties, Sierra Leone Agricultural Notes No. 10.

Teeken, B., Nuijten, E., Okry, F., Mokuwa, A., Temudo, M., Struik, P.C. and Richards P. (2010) Advocating the integration of socio-cultural factors in models for variety dissemination. *Proceedings of the 3rd International Rice Congress*, Hanoi, Vietnam, 8-12 November, 2010.

Thiele, G. (1999) Informal Potato Seed Systems in the Andes: Why Are They Important and what should we do with them? *World Development* 27, 83- 99.

Tin, H.Q. (2009) Impacts of Farmer-Based Training in Seed Production in Vietnam. Published PhD dissertation, Wageningen University, Wageningen, the Netherlands.

Tin, H.Q., Struik, P.C., Price, L.L. and Tran Be T. (2008) Comparative analysis of local and improved practices used by farmer seed production schools in Vietnam, *Field Crop Research* 108, 212-221.

Tin, H.Q., Struik, P.C., Price, L.L., Tuyen, N.P., Hoan N.P. and Bos H. (2010) Increase of farmers' knowledge through farmer seed production schools in Vietnam as assessed on the basis of Ex-ante and Ex-post tests. *Journal of Agricultural Education and Extension*, 16(3), 229-247.

Van Mele, P., Bentley, J.W and Guéi, R.G. (2011) African Seed Enterprises: Sowing the Seeds of Food Security. Wallingford: CABI Publishing

Van Mele, P., Zakaria, A.K.M., Hosne-Ara-Begum, Harun-Ar-Rashid and Magor, N.P. (2007). Videos that strengthen rural women's capability to innovate. *Communication for Development and Social Change*, 1(3), 273-293.

WARDA. (2007) Africa rice trends: Overview of recent developments in the Sub-Saharan African rice sector. Cotonou: Africa Rice Center.

Witcombe, J.R., Joshi, A., Joshi, K.D. and Sthapit, B.R. (1996) Farmer participatory crop improvement. I: varietal selection and breeding methods and their impact on biodiversity. *Experimental Agriculture,* 32, 445-460.

CHAPTER 8

SYNTHESIS AND CONCLUSIONS: INTEGRATING LOCAL DYNAMICS INTO APPROACHES OF VARIETY DEVELOPMENT AND SEED SYSTEM DESIGN

Florent Okry

8.1 INTRODUCTION

Rice is an important crop for global food security. This makes rice a crop of focus in a range of scientific disciplines, and among policy makers and governments. The importance of rice in local economies varies across regions. In West African countries, rice is a major food in people's diet, and of increasing importance. Countries such as The Gambia, Sierra Leone and Guinea have the largest per capita consumption (WARDA 2007). Despite increases in rice production in the region, domestic production has still to meet the demand; the gap (37%) is annually filled by large rice imports (FAO, 2004). A particularity of West Africa is that rice is cultivated mainly by small scale farmers representing 80% of the agricultural population and supplying 80% of the region's food security. These farmers operate in fragile agro-ecologies dominated by variable soil fertility, erratic rainfall and low or no use of external agricultural inputs. Another particularity of West Africa is its richness in rice genetic resources, as (uniquely) two rice species are grown - *O. sativa* introduced in the region approximately 500 years ago and *O. glaberrima* originating in West Africa and cultivated for more than 3000 years. The coexistence of these two species has led to the idea that interspecific hybrids may have some future relevance in the region. The current thesis began with a research chapter suggesting that this expectation might be correct, but that the story is more complex than initially understood, because farmers have also developed some hybrid rice types. This observation introduced the main topic of the thesis - an interest in assessing the relative merits of formal and farmer-based seeds and seed distribution systems. If seed innovation comes only "from above" then it makes sense to concentrate on formal channels of dissemination. If, however, farmers themselves are a useful source of new and well-adapted seed types then consideration needs to be given to the functioning of farmer seed systems, and to the meshing of both formal and farmer-managed channels of seed dissemination. This (in a nutshell) is the case made in this thesis for the integration mentioned in the chapter title.

The focus of this thesis has been on seed systems. West African farmers have long experience in rice cultivation, hence have developed diverse local practices that assure rice production and seed supply. To strengthen food security mainly to provide cheap food to cities and urban areas, formal institutions have also emerged and have the mission to increase rice production. These institutions in order to develop a strong rice sector have tackled the development of an efficient formal seed sector as a priority. A case is made in this thesis for re-thinking an approach to seed systems based solely on formal assumptions.

A lot of efforts have been made by scientists, policy makers and development practitioners to increase the understanding of the farming agro-ecologies. Yet scientists, policy makers and development practitioners are not well aware of and/or value less many aspects of the technical, socio-economic and political-institutional contexts in which low-resource farmers operate and which constrain their priority setting. The relatively low acquirement of seed (8% being a typical figure) from the formal seed system by small-scale farmers poses serious questions about the effectiveness of formal seed systems, and neglect of the informal seed system by formal institutions. To date these two seed systems continue to operate in parallel, a few initiatives to back up research findings into the informal seed system notwithstanding. Hence the issues of rethinking, strengthening and integrating as much as possible the formal and the informal seed systems surface as major concerns, in order to better meet the seed needs of the region's small-scale farmers for quality seed of suitable and desired variety.

The ultimate goals of this study were thus to improve the understanding of the functioning of the rice seed systems and to suggest possible ways of strengthening them to support rice production and livelihood of small scale farmers in West Africa. The study used an interdisciplinary approach. It combined research methods from the natural sciences (molecular characterisation of farmer varieties, field trials, and many other measurements at field level) and social sciences (structured, semi – structured and informal interviews, group discussions, participant observations, story-telling etc.). This concluding chapter (Chapter 8) summarizes and discusses the main findings of the research, underlines some mechanisms behind certain farmer behavioural patterns within the context established earlier in the thesis, suggests some institutional arrangements to improve impact of the formal seed system on rural livelihoods, and discusses possibilities and ways for integrating the two seed systems, for better efficiency of variety development and seed production, distribution and use. For presentational reasons, the sections of this synthesis chapter do not follow the same chronological order of appearance of the chapters in the main document. This allows us to further discuss the findings.

8.2 TOWARDS A POLITICAL ECONOMY OF THE RICE SEED SECTOR IN WEST AFRICA

From the 1960s (the decade of independence for most West African countries) several formal interventions, designed in accordance with the approaches of the Asian *Green Revolution* were implemented in the seed sector of several countries of the region (Amanor 2011). The objective was to develop a formal seed system to replace the existing (informal) seed system. This existing system was believed to disseminate poor seed of low-yielding varieties. The formal seed sector was born in an era in which most countries directly linked national agricultural research institutes and publicly-funded extension services. Chapter 4 explored the organization of the seed sector in Guinea, as well as some of the discourses that led to its formation. Three major interventions in the seed sector development in Guinea were outlined. These were a State-led intervention from 1985 to 1989, with privatization of seed centres in 2004, an NGO-led intervention from 1997 to 2003, and a collaborative (research-led) intervention from 1997 to date. All these interventions were built around the assumption that improved varieties were superior to local varieties, and that farmers ought therefore to use certified seed of improved varieties to increase food production (Chapter 4).

Two main governmental bodies conducted the State-led intervention: the national agricultural research institute (IRAG) and the national extension service. They were both creatures of the post-1985 "liberalization" of an earliest Marxist regime. The State, shortly after initiating this first formal intervention with a top-down approach centred on seed centres built to process, conserve and package seed, passed on the torch to a civil society network comprising NGOs, private entrepreneurs and farmers' associations in the early 1990s. The role of the state has since been limited to research activities (breeding and provision of breeder seed) and a limited amount of seed dissemination. All other activities related to the multiplication of seed and seed commercialization have been assigned to the civil society network (Chapter 6). This rapid change happened in the context of a more general privatization and market liberalization process recommended by the international community under the Structural Adjustment Programme (SAP). But "liberalization" did not empower farmer demand for local rice seed material. The same assumptions of the superiority of improved varieties survived unscathed, and consequently mostly "improved" varieties were distributed by the components in the civil society system (Chapter 4). The same happened under the collaborative (Research-led) intervention, which also distributed only Nerica. The two bodies of the Ministry of Agriculture (Research and extension) and their assigned civil society partners remained the key stakeholders for any interventions (Chapter 4). On this basis rested the implementation of the reforms mentioned above.

However, a shift of focus was observed during the NGO-led intervention. This placed an emphasis on the professionalization of small-scale seed production, provided subsidies, and tried to link seed producers to markets. The formal seed producers (contract seed producers) thus emerged. Research and Extension recruited and trained formal seed producers in techniques of seed production and conservation. NGOs (namely SG 2000) subsidized their activities and sought to elevate them into seed businesses (Chapter 4). These changes met the perceived vision and policy objectives of the World Bank seeking to promote links between markets and small-holder agriculture (Daddieh 1994, Watts 1994, Amanor 2011). The collaborative intervention also used the formal seed producers to multiply seed. The formal seed producers were not seed traders prior to their involvement in seed production and trade. During their collaboration with seed projects, they had no need to develop intimate knowledge of actual seed markets and consumer preferences, since development projects systematically bought up their entire seed output. This lack of detailed knowledge of the seed market and of farmer needs contributed to the low adoption rates for improved varieties, and as a result most formal seed producers ceased their activities shortly after the projects ended and subsidies were removed (Chapter 4).

The formal seed producers who stayed longer in the seed business did so by incorporating local varieties in their varietal portfolio to sustain their businesses (Chapter 6). This confirms that there was a problem with the assumption of varietal superiority promoted by the formal seed sector at the outset. In the informal seed system, local seed dealers developed trust relationships with farmers (Chapter 4) and supplied most of the seed purchased (Chapter 5). The local seed dealers were unknown to the key actors in the formal seed sector (Research and Extension). Local NGOs did know them, but saw them as paddy dealers only. This limited any possibility of collaboration between the formal seed sector and local seed dealers (Chapter 4). In sum, this study has shown that the development of the formal seed sector reflects a strong political desire to replace the informal seed system by the formal one. Improved varieties - the output of research laboratories - have been promoted as superior to the local ones, not because they have been shown to be superior in farmer conditions, but because the State and the international community assume that their knowledge exceeds that of poor peasants in all respects. This is at root a flawed assumption and not a scientific judgement, as other chapters in the thesis focused on the performance of farmer varieties under realistic local conditions showed. Actors in the formal seed sector remain unshakeably convinced that farmers need to adopt improved varieties and buy certified seed to increase their food production and improve their livelihoods (Chapter 4). Even the promotion of more farmer-oriented development models is no guarantee for farmers being served better, as a lot depends on the attitude of the research and extension staff involved (Van Mele et al. 2011a). In the end these perceptions and behaviour of actors of the formal system are a product of how resources are mobilised and flow in the international system, and on, down through state, and state-approved marketing channels, and not a product of peasant farmer demand.

8.3 THE INFORMAL SEED SYSTEM: WHY IT PERSISTS

8.3.1 Farmer varietal diversity: a neglected asset

This study has produced evidence that by contrast to the formal seed sector the informal system produces and circulates both improved and local varieties (Chapter 5), even though local varieties of *O. glaberrima* and *O. sativa* continue to dominate the varietal portfolio of the informal seed system. In short it offers a greater range of diverse and adapted varieties, including rice types neglected by formal research, such as *O. glaberrima* varieties (Linares 2002, Richards 2006). African rice has been neglected by researchers because of its simple structure of panicles, lodging and shattering characteristics presumed to lead to comparatively poor yields (Dingkuhn et al. 1998, Semon 2005) even though it is still cultivated in the study area of Guinea (Chapter 5). African rice is maintained in the farming system for diverse reasons: 1) because of its adaptability to poor soils and erratic rainfall and 2) because of the assurance it gave to farmers in building their strategies of food security. The long digestion time for African rice types makes African rice, in the eyes of the farmers, a reliable crop during the hungry season (Chapter 5).

Teeken et al. (2010) show that, in many areas, local varieties in cultivation reflect a good assessment of characteristics that are especially important in farmers' conditions. They demonstrate that in many contexts farmers search in newly introduced/selected varieties, the characteristics of *glaberrima* they like most. This is also why African rice remains a favoured species. In Guinea, the two most highly favoured upland varieties both belong to the Asian species: Saidou Gbéli, a variety of *O. sativa* ssp. indica, with red pericarp, and Saidou Firê, a variety of *O. sativa* ssp. indica, with white pericarp (Chapter 5). The point here is that they are preferred because they have two of the characteristics favoured elsewhere in African rice, viz. long digestion time and capacity to perform well on poor soils. In fact, in Guinea, they out-yielded other varieties, including African rice varieties, especially in good years (good rainfall conditions). Hence, the preferred characteristics of *glaberrima* seem to determine the adoption of newly introduced/selected varieties and their dissemination including local varieties of *O. sativa* and local varieties of interspecific background. This shows that West African rice farmers are shrewd in assessing what works. It is wrong to assume that they hold on to "old" varieties because they know no better. The findings of this thesis confirm that farmers are very aware of uncertainties in farming conditions and face decline in soil fertility, erratic rainfall, etc. A prediction from this is that many low-resource farmers will continue to opt for robust and adaptive varieties in order to achieve food security in their given conditions. This farmer reality contrasts with the economic theory of optimization, under which it is assumed that farmers will invest in land improvement technologies under declining conditions, buy improved varieties that go with these technologies, or sell up to larger farmers who can. Where would these farmers go and what would they do? Careful varietal selection is their lifeline, and the seed system needs to reflect this fact.

To get better policy for seeds it is first important to study the performance of farmer varieties, and get away from the ideological assumption of the inherent superiority of improved varieties. Chapter 3 dived into these aspects. The results of experiments carried out in five coastal West African countries to compare the robustness of 24 farmer varieties revealed that most farmer varieties showed large adaptability to the five trial environments, though at different levels. *O glaberrima* best maintained its yield across environments. A clear divide was observed between *glaberrima* genotypes according to their area of collection. *Glaberrima* genotypes collected from the Lower Guinea Coast maintained their yield across environments by increasing tillering and grain weight while *glaberrima* types from the Upper Guinea Coast produced fewer tillers but taller plants and longer panicles. The two *glaberrima* groups showed similar yield across environments. This was the most robust of the three studied botanical groups. The indica group also split into two clusters differing in performance. The indica from Guinea (the country) performed like *glaberrima* but was less able to maintain its yield under less favourable conditions. The second cluster of indica (from Ghana) showed adaptability to niches. The japonica group also divided into two clusters. Yields of the types from Ghana and Guinea Bissau were similar to *glaberrima* and indica from Guinea (the country), but showed higher probability of crop failure under severe stress conditions. Like the indica from Ghana, the japonica from Sierra Leone also show niche adaption. The subdivision within botanical groups suggested by the molecular analysis (cf. Nuijten et al. 2009) corresponded to these observed genotypes groupings (within botanical groups) according to their performance. This suggests that the selection processes for farmer varieties (in effect genotype × environment × society interaction) resulted in different levels of robustness and wide agro-ecological adaptability.

In formal breeding breeders often select for broad adaptation. Breeders therefore think the improved varieties are better able to adapt to larger environments than farmer varieties, which often are thought to be only adapted to local conditions. The relatively low use of improved varieties in West Africa might suggest that improved varieties are less well suited for farmers' actual environmental conditions than breeders imagine. Contrary to what scientists often think, Chapter 3 showed that local varieties are not always niche specific. Many of these are well adapted to a wide range of environments, suggesting that farmer varieties might well be included in seed dissemination programmes. According to farmer reports from the study area, some local NGOs have started this in north-western Sierra Leone as a recovery strategy after the long civil war.

8.3.2 Farmer variety creation: the beauty of a mess

The farmers' rice varietal portfolio in West Africa is more diverse than the scientific community often perceives it to be. Drawing on data from molecular analysis (AFLP) Chapter 2 showed, on the basis of 315 accessions from seven coastal West African countries, that farmer diversity has incorporated, for at least more than half a century, new types of rice that differ, on both molecular and morphological grounds, from the three known botanical groups, *O. glaberrima*, *O. sativa* ssp. indica and *O. sativa* ssp. japonica. In addition to confirming Jusu (1999), Nuijten and Van Treuren (2007), Semon et al. (2005) and Barry et al. (2007), Chapter 2 provided extensive evidence that there are varieties of interspecific origin between *O. glaberrima* and *O. sativa* other than the Nerica varieties in farmer fields in West Africa. These farmer hybrids were collected in Guinea Bissau, The Gambia, Senegal, Sierra Leone and Guinea. It was argued they result from farmer agency in unconsciously creating conditions for spontaneous back-crossing processes through selecting varieties and seeds, and managing their fields as described in Chapter 7 (Nuijten and Richards 2011).

Sterility of the F1 has long been seen as the main barrier in crossing *O. glaberrima* and *O. sativa*. Africa Rice Center (AfricaRice) successfully overcame this barrier in the laboratory in the 1990s

(Jones et al. 1997a) creating the Nerica, a scientific breakthrough (Dingkuhn et al. 1998). AfricaRice overcame the sterility barrier through two backcrosses with the *O. sativa* parent and embryo rescue (Jones et al. 1997b).

In the case of farmer hybrids, it was suggested in this thesis that local practices of field and seed management, such as the deliberate and unintentional seed mixtures, as reported in Chapter 7 of this thesis and also by other researchers (Richards 1986, Jusu 1999, Longley 2000, Nuijten 2005, Nuijten and Richards 2011), and local harvesting and conservation practices (Chapter 7), play crucial roles in allowing "accidental" backcrossing through which fertility is restored to spontaneous crosses emerging from farmer fields.

Historical evidence (regarding variety names) suggests that farmer hybrids may be at least as old as the 1940s. This is long before scientists (geneticists) managed to overcome the F1 sterility barrier in the 1970s (Yabuno 1977, Sano et al. 1980). The agronomic performance of these farmer hybrids has yet to be fully established, but it seems possible they might share the adaptive advantages known to inhere in the Nerica hybrids. It was suggested in this thesis that adverse situations such as war, population displacement and climatic instability may have played a part in drawing the utility of these crosses to farmers' attention, since they appear to have features (e.g. early flowering or adaptation to poorer soils and erratic climatic conditions) associated with some agro-ecologies, notably in Sierra Leone, Guinea Bissau and Senegal. In fact they seem to have the hardiness of the African rice parent.

In the Guinea research area farmer hybrids did exist (Chapter 2) but were cultivated on a relatively small scale because their short duration makes them less suitable to local farming conditions. The organization of the upland farming activities and the 6-months rainy season favoured varieties of longer crop duration (at least 4 months). The story of farmer rice hybrids helps to confirm that farmers in adverse situations are actively shaping and selecting new genotypes. In doing this they are creating seeds of intrinsic value, but also helping to conserve the local gene pool from which scientists and breeders could draw. These findings suggest, therefore, that it would make sense to create partnerships between science and local technological developments by marginalized groups in order to increase effectiveness of proposed solutions to food security challenges. These findings also reconfirm the importance of fully understanding crop development and human adaptation strategies as part of the background to scientific improvement initiatives.

8.3.3 At times erroneous conception of farmer world

O. sativa ssp. japonica varieties are believed to be adapted to upland conditions and *O. sativa* ssp. indica varieties adapted to the lowlands (Khush 1997, de Kochko 1987). Especially, indica types are often referred to as "aerobic rice" suitable to lowlands because of their adaptability to non-saturated soils (Saito and Futakuchi 2009). Consequently, a few studies evaluated the adaptation of indica cultivars to upland cultivation in West Africa (Dalton and Guéi 2003) and no improved upland indica have been released in West Africa (Saito and Futakuchi 2009). It has been reported, however, that in some agro-ecologies (e.g. Laos) improved indica could outperform the traditional japonica under sub-optimal and optimal upland conditions (Saito et al. 2007). Because of this conception, formal research bred only japonica for West African uplands. The results of the molecular analysis in Chapter 2 of this thesis showed that farmer upland varieties cultivated in the case study area of Guinea predominantly belonged to *O. sativa* ssp. *indica*. This suggests that the reality of the peasantry is, at times, different from the one conceived by the scientific world. Bringing science closer to farmer reality through thorough studies of what works for them is still a necessity to achieve the desired impact of formal research on rural livelihoods.

8.3.4 Seed distribution within the informal seed system

Evaluation studies of seed development programmes and large scale seed enterprises of the State-led intervention type showed high rates of failure, not only in Guinea, but also in most of the other African countries (Tripp and Rohrbach 2001, Amanor 2011). To reduce production costs formal seed producers were involved in seed production (Chapter 4). Van Mele et al. (2011b) also report some improvements over time through involving small and medium scale seed dealers who are able to keep the production costs low. This makes sense, since farmer seed production at the micro-scale is part of normal crop production cycle, and involves much smaller inputs than seed production in the formal seed sector (Chapter 7). Assessment in this thesis of farmer strategies of seed acquisition revealed that farmers acquired seed through several arrangements including purchase with cash. Each modality of seed acquirement served different purpose (Chapter 5). While a handful of gifted seed might trigger farmer experimentation, acquisition of seed in bulk mainly occurred through seed exchange (seed-for-seed) and purchase (Chapter 5). However, youngsters often obtained their first bulk seed through gifts from elders, as an expression of the social solidarity. Other modalities of seed acquisition involved barter deals, (seed-for-any other goods) and seed exchange for labour.

Local seed dealers are aware that village modalities of seed acquisition reflect ideas about local social solidarity (e.g. the notion that everybody needs seed in order to ensure household survival) and take such factors into account in consolidating ties with farmers and developing their seed businesses. The element of social solidarity was (as might be expected) less important for seed distribution in the formal seed sector. How to include issues of social solidarity in the formal seed sector is a very challenging question, considering the quickly gaining new conception of the formal seed sector as rooted in the capitalist model, where profit is all. Seed loans are an essential part of the village seed system. How can formal seed producers permit seed loans on village terms (postponed payments, payment in kind or payment with labour etc.), when they have to reimburse their own credit (obtained on commercial terms) in a timely manner? It has thus been suggested in this thesis that the formal seed sector will have more impact if it finds some means to incorporate local seed dealers and their locally adapted trade strategies into new business models. Aligning and adapting the market strategies of the local dealers to the formal sector will require considerable further consultation and experimentation, however (Chapters 6 and 7).

Local seed dealers emerged as a response of the informal seed system to the increase in demand by farmers for seed, especially in a context where (1) the extension service lacks resources to efficiently disseminate seed, varieties and related technical information, and (2) deteriorating political and economic contexts, intensified by rising global food prices, have forced some farmers to eat and/or sell their seed reserves, while at the same time more non-farming households are now drawn to invest, part-time, in rice cultivation, to beat rising food prices. Rossignol (2008) argued that rice seed centres in Guinea (based on a case study of the Koba centre) could not run cost-effectively (due to excessive overheads) if the only seed demands are those expressed by small-scale farmers, since these are unpredictable, fluctuating, and sometimes articulated in remote areas. The answer seems to be "to think local". Local seed dealers have made a specific contribution to the quickly changing entrepreneurial landscape in the seed sector and have been shown to meet farmers' seed demands in a rapidly changing agrarian system. They have acted in two different ways: (1) as variety dissemination channels, and (2) as sources of seed for replacement. Our findings in Chapter 5 clearly showed their willingness to participate in seed development activities. So the overall message is to re-engineer the formal seed system from below, and to incorporate within it the local entrepreneurial experts in decisions about variety multiplication and research strategies for crop improvement.

8.4 FORMAL SEED SYSTEM AT A CROSS-ROAD

8.4.1 In-between research planning and the reality of the peasantry

Not all farming activities are planned. Our findings showed large variations in farmers' practices. For example, the same task of seed harvesting was performed differently across various research sites, although there was some level of comparability (Chapter 7). Besides, the same farmer might harvest seed differently from one year to another, depending on gender and labour available, for instance (Longley 2000, Nuijten 2005). Seemingly scheduled activities at the beginning of the cropping season often deviated from plan at the very time of performing them (Chapter 7). In their given context farmers thus have developed coping strategies to create their livelihoods. Richards (1989) refers to this process as “performance” to stress the fact that farmers adapt to contingency, and that farm outcomes are the product of a performance sustained across a season. By analogy to improvisation in music he suggests that low-resource farmers elaborate coping strategies as need arises, in order to arrive at desirable ends; the overall objectives being to reduce risks and to produce enough food to cover the annual needs of the household. Hence, as we have argued in this thesis (Chapter 7), the gap between farmer practices and recommendations, and the deviation observed between farmer norms of practice and the actual application of these norms is mainly due to the specific socio-economic contexts in which they operate. This is in line with findings of Richards (1985, 1986, 1989) and Nuijten (2005) across West Africa. In areas where labour is pulled towards the cities, or when many crops compete for labour, farmers are often forced to modify their practices or rely on work gangs. By doing so, farmers at times adopt practices that do not preserve the quality of their seed (Chapter 7). We also showed that for some farmers, variety mixing is not a weakness as the formal seed system would present it, but a strength (Chapter 7). For these farmers variety mixing is rather a strategy to attain food sufficiency. These elements point to the complexity of the context in which farmers operate and which need to be fully understood to better target recommendations of the formal research. Seed development projects could therefore consider the global context within which farmers operate rather than narrowly focusing on knowledge as the only missing component of seed development. Several organisations e.g. Sassakawa Global 2000 (SG 2000) worked with such a holistic approach combining mechanisation, input market development, professionalization of seed production, access to micro-credit and so on, in Guinea, as well as in many other developing countries. Linking these interventions to the daily performance of small-scale farmers and to the local context (e.g. involving both local seed dealers and formal seed producers instead of the only formal seed dealers who lacked specific knowledge on the seed markets), long-term commitment and follow-up action by national governments are needed to sustain and extend these achievements.

In contrast to the informal seed system, the formal research system is entirely based on planning. The different schemes of seed production proposed by the formal seed system and the Community Based Seed System (CBSS) have a set of rigid stages where specific actors conduct specific tasks. Such planning could work for new crops or commercial crops. But for indigenous food crops like rice, for which farmers have developed several diverse practices of seed production integrated in a process of performance (Chapter 7), ways and strategies of including farmers in seed production other than using them primarily as contracted labour are still to be elaborated. As far as the Guinea case study evidenced, the formal and the informal seed systems still remain parallel. Promoting elements of convergence between - such as instituting some kind of informatic clearing house system to support seed swaps at inter-village level - might be worth considering.

8.4.2 Re-conceiving strategies of seed development in the formal seed system

Variety dissemination and seed acquisition have different significance in the informal seed system. Variety dissemination typically involves a strictly limited amount of seed, often obtained through gift. A handful of seed of a new variety is known to trigger farmers' curiosity. Such seed exchanges even confer blessing, consideration and consolidate ties, although sometimes projecting the power of the sender towards the receiver (Okry 2005). Dissemination of new varieties thus follows typical routes dominated by gift and involves social processes. A bulk distribution system is not well-adapted to dissemination of new varieties, since there are few farmers willing to take on a new seed type until they have passed through an experimental phase.

But in some case new varieties were also sold. This thesis has shown that in the local seed trade new varieties (be it improved or local varieties) were sold in limited quantity, compared to well-known varieties, where greater bulk is needed (Chapter 5). New varieties entered the informal seed trade at a heavy discount. Their price, dealers said, will increase if they suit farmers' agro-ecologies and farmers demand them. Hence, within the local seed trade, new varieties also follow a specific trend.

Acquisition of bulk seed, in order to plant a field before the rains advance, involved different routes from those of variety dissemination. The larger amount of seed required cannot be acquired through gift alone. Bulk seed is mainly obtained through exchange (of seed of poor quality for planting against a good one, or by swapping one variety against another by farmers with complementary planting needs), or through seed purchase (Chapter 5).

In sum, low-resource farmers in Guinea acquire rice seed to attain their objective of food sufficiency. They do not, by and large, adopt varieties in bulk, although they are eager to try new varieties to see what they can do on their soil types. Variety dissemination and seed acquirement are therefore two different processes, with different operational constraints. Susu farmers of Guinea and Sierra Leone produced primarily for subsistence and organised themselves in such a way that enough rice is produced to cover their annual needs (Chapter 5), rice being a staple and culturally important food. The choice of a variety to be grown depends on the confidence farmers have in its agronomic performance. This is achieved after several years of experimentation of the variety on various soils, or is based on witnessing senior trusted farmers. The standard economic assumption behind many breeding programmes is that farmers should prefer high-yielding varieties, even if this means that they have to acquire other inputs to ensure high output. The findings of this thesis suggest a different rationale prevails among farmers. Farmer-selected varieties are characterised by adaption to low input conditions thus suggesting that farmers working sub-optimum conditions, have tended to select varieties that assure a minimum and stable yield over a range of difficulties e.g. erratic rainfall, declining soil fertility and no or low availability of external inputs. The robustness of local varieties has been demonstrated in Chapter 3.

The formal seed system, by contrast, does not differentiate between variety dissemination and bulk seed supply. Here the dominant mode of seed acquisition is through cash, or sometimes by donation via emergency/humanitarian programmes. The official price of seed of improved varieties is often higher than the price of the seed that farmers acquire from local markets or informal networks (Chapter 5).

8.4.3 Redefining success indicators in the formal seed system

Evaluation of seed projects within the formal seed system is often based on adoption logic. Areas covered by new varieties on maps are major indicators of success. Evaluation sometimes takes place very soon after implementation of the projects, since donors often need success stories within a certain time frame (Mosse 2005). As mentioned above variety dissemination and bulk seed supply are two distinct processes for farmers and consequently have different operational constraints. When targeting "adoption" formal projects should realise that adoption is a long-term process, and that it is inappropriate to evaluate this aspect too quickly. For example, it took 10 years for varieties promoted by SG2000 in 1997 to appear significantly in farmers' fields and in the local seed trade as reported in Chapters 4 and 5.

In the formal seed system, by contrast with the informal seed system, projects often combine the objective of "adoption of new varieties" and "bulk seed delivery" in the same set of activities. As they can only achieve this dual impact by selling seeds directly to low-resource farmers, they compete with and undercut local merchants, who offer familiar varieties in a timely manner at acceptable (un-subsidised) prices for farmers. For instance, at sowing time (meaning after seven months of consumption of the previous harvest and at only two to three months to the hungry season), acquiring seed from the formal seed sector to sow one hectare of upland rice field, at a seed rate of 56 kg ha^{-1} (local standards, Chapter 7), requires low-resource farmers to sell 194 kg of their reserved paddy to get cash, providing they find buyers (Chapters 4 and 7). This, obviously, is out of the reach of many low-resource farmers as they have limited paddy available at that time of the year. With the local dealers, farmers would need to sell or exchange only 74 kg of their reserved paddy to obtain the same amount of seed. The choice seems easy. The formal seed sector cannot compete with local merchants in a sustainable manner on bulk seed delivery.

The key to distribution success may be to work with what farmers do and to abandon the "language" of adoption. So to allow farmers experimenting with new varieties, projects could concentrate on distributing small starter packs and carefully monitor effects. Scaling up means mostly widening the scope of the distribution of starter packs. Projects could then mobilise local capacity (mainly in the form of local seed dealing partners) for bulk delivery of seed. At the current state of affairs, the formal seed system cannot compete with the informal one as far as the delivery of bulk seed to low-resource farmers is concerned. The two systems should work out their complementarities and seek to combine. Any idea on the part of the formal system of replacing the local dealers could be a recipe for disaster. If the formal system fails (e.g. faces bankruptcy) who then would step in if meanwhile local seed dealers have been eliminated?

8.5 CONCLUSIONS: SUGGESTIONS TO INTEGRATE AND/OR IMPROVE THE TWO SEED SYSTEMS

Complementarity between the two systems requires knowledge, respect and trust on the part of the potential partners. Constant seed availability and quality, and research varieties tailored accurately to farmer needs and preference, might be mechanisms to build trust between the two seed systems. So in order to build this trust the formal system needs to listen better to farmers' priorities and preferences, and acknowledge why farmers may not be able to grow improved varieties under their conditions. A first step may be to recognise the logic built into farmer varieties, and seek ways of using scientific knowledge to expand the range of choices of robust varieties. This may mean further exploration of "with farmer" research techniques, such as PVS (Participatory Variety Selection). PVS aims to help select and identify varieties of greatest interest to farmers at the earliest possible stage. Although PVS is an improvement of the variety selection process, the low adoption rate of improved upland varieties in the case study area suggests the ways the PVS approach is implemented require further modification. Involving seed dealers in PVS at an early stage might be an important step towards speeding up dissemination of such varieties.

The idea that (external) knowledge is the only missing factor in the informal seed system should (on the basis of results presented in this thesis) be firmly abandoned. Farmers face multiple realities that make them improvisers rather than planners. It seems good sense to adopt a flexible approach to contingencies, and seeds are needs that match this cognitive style of thinking. Furthermore, when knowledge is to be introduced, formal interventions too often focus narrowly on certain actors and not on capacity building across all actors. A clear instance of this is the tendency for actors in the formal seed system to be largely unaware of the dense network of local seed dealers meeting farmer needs. The formal research system would perhaps find it easier to adjust to the perspectives of farmer by adopting a more holistic and inclusive approach.

The vision of superiority of improved varieties over local ones also needs to be changed. However, changing attitudes among R&D actors is often more easily said than done (Van Mele et al. 2011a). Farmer varieties are here shown to be better adapted to farmers' sub-optimum conditions of production. What would be desirable, therefore, is a coupling of local and improved varieties within the emergent supply chain for seeds in Guinea.

Small packets of improved varieties might well trigger farmer experimental behaviour. But the production of bulk certified seed should be organised wherever possible by farmers and seed dealers to reduce production costs.

Perhaps, overall, the most important finding of this thesis is that the informal seed system is closer to farmers because it reflects (and is integrated with) local ideas about food security and social solidarity. This social dimension is missing in the formal system, designed and funded by experts who neither live by planting rice nor share in the local sets of assumptions about social reciprocity and obligation. Guinea may be selling its long-term food security down the river if it fails to seek to replace a social seed system with one driven solely by abstract ideas of economic rationality. The better option, supported by the weight of evidence in this thesis, is surely to seek complementarity and synergy between the two systems.

REFERENCES

Amanor, S.K. (2011) From Farmer Participation to Pro-poor Seed Markets: The Political Economy of Commercial Cereal Seed Networks in Ghana, *IDS Bulletin* 42(4), 48-58.

Barry, M. B., Pham, J-L., Noyer, J. L., Billot, C., Courtois, B. and Ahmadi, N. (2007). Genetic diversity of the two cultivated rice species (*O. sativa* & *O. glaberrima*) in Maritime Guinea. Evidence for interspecific recombination, *Euphytica* 154, 127-137.

Daddieh, C.K. (1994) Contract Farming and Palm Oil Production in Côte d'Ivoire and Ghana. In Little, P. and Watts, M. (eds). *Living under Contract: Contract Farming and Agrarian Transformation in Sub-Saharan Africa*. Madison WI: University of Wisconsin Press.

Dalton, T.J., Guei, R.G. (2003) Productivity gains from rice genetic enhancements in West Africa: countries and ecologies, *World Development* 31, 359–374.

de Kochko, A. (1987) Isozymic variability of traditional rice (*Oryza sativa* L.) in Africa, *Theoretical and Applied Genetics* 73, 675-682.

Dingkuhn, M., Jones, M.P., Johnson, D.E. and Sow, A. (1998) Growth and yield potential of *Oryza sativa* and *O. glaberrima* upland rice cultivars and their interspecific progenies, *Field Crops Research* 57, 57–69.

FAO, 2004: http://faostat.fao.org/faostat [accessed 25 december 2006]

Jones, M.P., Dingkuhn, M., Aluko, G.K. and Semon, M. (1997) Inter-specific *O. sativa* L. x *O. glaberrima* Steud: progenies in upland rice improvement, *Euphytica* 92, 237-246.

Jones, M.P., Dingkuhn, M., Johnson, D.E. and Fagade, S.O. (1997) Interspecific Hybridization: Progress and Prospect. *Proceedings of the Workshop: Africa/Asia Joint Research, Interspecific Hybridization between African and Asian Rice Species ed. (Oryza glaberrima and Oryza sativa*), Bouaké: WARDA.

Jusu, M.S. (1999) Management of Genetic Variability in rice (*Oryza sativa* L. and *O. glaberrima* Steud.) by breeders and Farmers in Sierra Leone. Published PhD thesis, Wageningen University, Wageningen, The Netherlands.

Khush, G.S. (1997) Origin, dispersal, cultivation and variation of rice. Plant Molecular Biology 35: 25-34.

Linares, O.F.(2002) African Rice (*Oryza glaberrima*): History and Future Potential, *PNAS* 99(25), 16360-16365.

Longley, A.C. (2000) A social Life of Seeds: Local Management of Crop Variability in North-Western Sierra Leone. PhD thesis, University College London, London, UK.

Mosse, D. (2005) *Cultivating development. An ethnography of aid policy and practi*ce. London: Pluto press.

Nuijten, E. (2005) Farmer Management of Gene Flow: the Impact of Gender and Breeding System on Genetic Diversity and Crop Improvement in the Gambia. Published PhD dissertation, Wageningen University, Wageningen, the Netherlands.

Nuijten, E. and Richards, P. (2011) Pollen flows within and between rice and millet fields in relation to farmer variety development in the Gambia, *Plant Genetic Resources: Characterization and Utilisation*, doi:10.1017/S1479262110000481, 1-14.

Nuijten, E. and Van Treuren R. (2007) Spatial and temporal dynamics in genetic diversity in upland rice and late millet in The Gambia, *Genetic Resources and Crop Evolution* 54, 989–1009.

Nuijten, E., Van Treuren, R., Struik, P. C., Mokuwa, A., Okry, F., Teeken, B. and Richards, P. (2009) Evidence for the emergence of new rice types of interspecific hybrid origin in West-African farmers' fields, *PLoS ONE* 4(10): e7335. doi:10.1371/journal.pone.0007335.

Okry, F. (2005) A Socio-Technical Development of a Seed (planting material) System: The Case of Yam in the Republic of Benin. Master thesis, Wageningen University, Wageningen, The Netherlands.

Richards, P. (1985) Indigenous Agricultural Revolution: Ecology and Food Production in West Africa. London: Unwin Hyman.

Richards, P. (1986) Coping with Hunger: Hazard and Experiment in an African Rice-farming System. London: Allen & Unwin.

Richards, P. (1989) Agriculture as a Performance. In Chambers, R., Pacey, A. and Thrupp, L. A. (Ed.) *Farmer First: Farmer Innovation and Agricultural Research*. London: Intermediate Technology Publications.

Richards, P. (2006) The History and Future of African Rice: Food Security and Survival in a West African War Zone, *Afrika Spectrum*, 41(1), 77-93.

Rossignol, L. (2008) La Problématique de l'Approvisionnement en Semences de Riz en Zone de Mangrove. Projet riz Basse Guinée. Conakry, Guinea.

Saito, K. and Futakuchi, K. (2009) Performance of diverse upland rice cultivars in low and high soil fertility conditions in West Africa, *Field Crops Research* 111, 243–250.

Saito, K., Atlin, G.N., Linquist, B., Phanthaboon, K., Shiraiwa, T.and Horie, T. (2007) Performance of traditional and improved upland rice cultivars under nonfertilized and fertilized conditions in northern Laos, *Crop Science* 47, 2473–2481.

Semon, M., Nielsen, R., Jones, M.P. and McCouch, S.R. (2005) The population structure of African cultivated rice *Oryza glaberrima* (steud.): Evidence for elevated levels of linkage disequilibrium caused by admixture with *O. sativa* and ecological adaptation, *Genetics* 169, 1639-1647.

Teeken, B., Nuijten, E., Okry, F., Mokuwa, A., Temudo, M., Struik, P.C. and Richards P. (2010) Advocating the integration of socio-cultural factors in models for variety dissemination. *Proceedings of the 3rd International Rice Congress*, Hanoi, Vietnam.

Tripp, R. and Rohrbach, D. (2001) Policies for African Seed Enterprise Development, Food Policy 26, 147–161.

Van Mele, P., Bentley, J.W and Guéi, R.G. (Eds.) (2011). *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford: CABI Publishing.

Van Mele, P., Bentley, J.W., Dacko, R.M., Yattara, K. and Acheampong, G.K. (2011) Attitude counts: engaging with rice farmers in West Africa. *Development in Practice*, 21(6), 806-821.

WARDA. (2007) Africa rice trends: Overview of recent developments in the Sub-Saharan African rice sector. Cotonou: Africa Rice Center.

Watts, M. (1994) Life under Contract: Contract Farming, Agrarian Restructuring, and Flexible Accumulation. In Little, P.and Watts, M. (eds*). Living under Contract: Contract Farming and Agrarian Transformation in Sub- Saharan Africa*. Madison WI: University of Wisconsin Press.

Yabuno T (1977) Genetic studies on the interspecific cytoplasm substition lines of japonica varieties of Oryza sativa L. and O. glaberrima Stued. *Euphytica* 26: 451-463.

Sano Y, Chu Y.E., Oka H.I. (1980) Genetic studies of speciation in cultivated rice. 2. Character variations in backcross derivatives between *Oryza sativa and O. glaberrima*: M-V linkage and key characters. *Japanese Journal of Genetics* 55: 19-39.

SUMMARY

The research reported in this thesis examined the functioning of rice seed systems in West Africa. It aimed to contribute to a better understanding of farmer seed systems and to suggest ways of effectively linking the formal and informal seed systems, with the overall objective of supporting the development of a more efficient rice seed system. The research started with a regional focus on farmer rice varietal diversity in seven West African coastal countries (the Gambia, Ghana, Guinea, Guinea Bissau, Senegal, Sierra Leone and Togo) and focuses on specific (field-work based) case studies in Guinea (with some comparison with neighbouring Sierra Leone) in order to understand how seed systems developed and managed this diversity. The study used an interdisciplinary approach, combining research methods from social and biological sciences. Quantitative and qualitative data were integrated to provide explanations and interpretations of various aspects of the seed systems.

Chapter 1 reviewed literature on the functioning of the seed systems. The formal seed system has received a lot of attention from research organisations, governments and policy makers but several studies report its inability adequately to supply seed to small-scale farmers. Promoted varieties often do not suit farmers' agro-ecologies, or when they do, they are channelled along dissemination pathways disconnected from rural realities and embedded in formal arrangements hampering access by small-scale farmers (see also Chapter 4). To improve the impacts of the formal seed system on local food security, several intermediate models of variety development and seed dissemination have been proposed. They aim to combine the principles of the formal and informal seed systems. Some researchers report that these efforts to develop intermediate seed systems are theoretical in orientation rather than grounded on knowledge of the functioning of actual seed systems. The thesis aimed to redress this deficit.

Chapter 2 explored and characterised farmer varietal diversity. Based on molecular analysis of a large set of farmer varieties collected across seven West African coastal countries, we concluded that farmer diversity is greater than often perceived by scientists and thus represents an important gene reserve breeders might tap. Molecular analysis also revealed that new types of rice of interspecific origin, different from the Nerica series (created in the laboratory in the late 1990s) have emerged in farmers' fields. There is evidence that these farmer-selected interspecific types have been cultivated for a considerable period (at least 50 years) and that their dissemination may have been promoted by adversity (e.g. drought and war). It is in adapting to adversity that farmers look for varieties able to perform well under harsh conditions and with minimum management. Farmer hybrids should now be evaluated for inclusion in breeding and seed dissemination programmes.

If farmers select for adversity then farmer varieties should show superior robustness and adaptive plasticity. **Chapter 3** examines this hypothesis. It is shown that West African farmer selected rice varieties which perform well under diverse environmental conditions. A set of 24 farmer varieties (*O. glaberrima* and *O. sativa*) selected from among 315 varieties studied in Chapter 2 were put into trials in five West African countries (Ghana, Guinea, Guinea Bissau, Sierra Leone and Togo) to study their phenological behaviour in sub-optimal conditions. Performance of the varieties in terms of canopy development, yield components and yield were observed and compared across environments better to understand underlying mechanisms for adaptive plasticity. The findings showed that farmer varieties were tolerant to suboptimal conditions. They were robust, but expressed different strategies to cope with stress, making them suitable for a range of farmer conditions. Varieties of *O. glaberrima* were the most robust, followed by those of the indica and japonica sub-species of Asian rice. The varieties of each botanical group clustered according to their origin of collection (cf. molecular analysis in Chapter 2). Each of these molecular clusters displayed different coping strategies. *Glaberrima* from Lower Guinea Coast, *glaberrima* from Upper Guinea Coast, indica from Guinea and japonica from Ghana-Guinea Bissau were the most robust, maintaining their yield across environments. They displayed different adaptive strategies to reach similar yields. Indica from Ghana and japonica from Sierra Leone showed some degree of crop failure in certain environments. The most robust varieties were the most wide-spread in their area of collection. This indicated that farmers select and cultivate robust varieties to assure them a

basic yield under less than ideal environmental circumstances. Farmer varieties, especially of the African rice species, have received scant scientific attention for improvement and dissemination. As products of farmers' agency, they result from long selection process combining agronomic and natural selection pressures. Farmer varieties can adapt to different environments, contrary to the belief that they adapt only to local conditions.

Chapter 4 investigated how seed systems developed around and organised this diversity. Guinea provided a case study. Findings show that the formal seed system has been favoured by researchers, government, and international policy makers, and is designed to promote improved varieties. Current institutional settings and perceptions of stakeholders from the formal seed sector inhibit smallholder farmers' access to seed. Seed interventions in the past two decades have mainly relied on the national extension system, the research institute, NGOs, farmers' associations and formal seed producers (contract farmers) to assure seed delivery. Formal seed producers were encouraged to multiply foundation seed and establish seed businesses. In most cases projects bought the produced seed and consequently formal seed producers developed little knowledge about local seed markets. Although local seed dealers play a central role in providing seed to farmers, governmental organisations ignored their role. The chapter underlines the need to find common ground and to develop alternative models of seed sector development incorporating local seed dealers, thus linking smallholder farmers to seed from the formal sector.

The world of local seed dealers was largely unknown to most stakeholders of the formal seed system. **Chapter 5** looked into this particular and less documented aspect of the informal seed system. The findings suggested that local seed dealers have been operating since about 40 years ago in the study area. In 2007 dealers studied had an average of 14 years of experience in seed business. The local seed dealers emerged and developed as a response to an increased demand for seed, especially in a context where, amongst others, (1) the extension service lacked resources to disseminate seed, varieties and related technical information efficiently, and (2) farmers had lost previously ample seed reserves due to political fragility and economic reverses, recently worsened by a global food crisis, which had also induced non-farming households to invest in rice cultivation. Seed dealers mostly sold local varieties. Improved varieties represented 32% of the varieties sold and 31% of total seed sale by volume. Improved varieties were similarly under-represented in farmers' varietal portfolios (21% of varieties and only 6% of total seed planted by volume), thus indicating that local seed dealers appreciated and responded to the demand for diversities of their customers. At open market, seeds of improved varieties were significantly cheaper than seed of local varieties, and this price differential encouraged experimentation. Thus seed dealers contributed to the distribution of improved varieties. A scenario mapping exercise showed dealers willingness to cooperate with formal seed dissemination projects. But any such collaboration will have to respect the values of the local seed system. Among conditions of collaboration, dealers clearly mentioned the need to maintain local varieties as part of their varietal portfolio.

The fact that dealers sold more local varieties could be attributed either to the fact that local seed dealers came from communities constituting the social matrix for the informal seed system or that local varieties simply were superior to most of the improved varieties in farmer's sub-optimal conditions. **Chapter 6** accepted the challenge to study and characterise a range of seed producers and dealers, whether local seed dealers, formal (contract) seed producers or agro-input dealers. The study re-constructed trajectories of seed enterprise development and analysed market and network development strategies. It was shown that over time seed enterprises have learned about their markets and how to adapt to a changeable environment where seed demands are typically small in volume and unpredictable, where there are no subsidies or credit facilities, and where farmers are often reluctant to pay extra for improved seed (e.g. because they do not know the variety, or were unsure about the quality, or believed they could save seed of similar or even better quality as part of their routine farming operations).

The chapter differentiated the response of formal and informal seed dealers. To stay in business, successful formal seed producers, who used to receive subsidised inputs, had introduced local varieties into their varietal portfolios, to reduce production costs and to better reflect local demand.

Local varieties are able to perform without fertilisers, a costly input that farmers can rarely afford. The local seed dealers produced exclusively local varieties without agrochemicals, and thus kept production costs low. They capitalised on communal social networks to sell seed to farmers who found it somewhat demeaning not to be able to produce their own seed supplies any more.

The agro-input dealers studied in the thesis mainly bought seed locally, and to a lesser extent from research centres, to minimise risks related to seed production. Local seed dealers used their social networks to deploy young people to scour the area for quality seed at harvest time. These dealers often lacked functional links to formal sector seed institutions, but made their business by selling quality seed of local varieties. Their networks and reputations were their most important assets.

Chapter 7 examined farmer seed selection and production activities and showed that they were integral in their crop production systems. Knowledge was not the only limiting factor for small-scale farmer seed production, but also the contingencies that force farmers to alter their initial plans. Adapting to contingencies selects for certain kinds and qualities of seeds adapted to sub-optimal conditions. Hence, farmer seed production is not and cannot be regarded as a pre-determined system. Consequently, recommendations for its improvement cannot be limited to a series of planned actions to be implemented by actors with predetermined roles, as the formal seed system often conceives it. **Chapter 7** further developed the argument that incompatibility between the planning approach (associated with the formal seed systems) and farmers' performance-based approach (coping strategies) is an essential challenge to resolve before a proper integration of farmer practices of seed selection and technical schemes of seed production can be realised.

Chapter 8 summarised key findings of the research, underlined some mechanisms behind certain farmer behavioural patterns, suggested some institutional arrangements to improve impact of the formal seed system on rural livelihoods, and discussed possibilities and ways of linking the formal and informal seed systems better to service the seed needs of small-scale farmers.

Perhaps, overall, the most important finding of the thesis is that the informal seed system works better for farmers because it reflects (and is integrated with) local ideas about food security and social solidarity. This social dimension is missing in the formal system, designed and funded by experts who neither live by planting rice nor share in the local sets of assumptions about social reciprocity and obligation. Rather than replace the informal seed system with a formal system, planned along international lines, the better option, supported by the weight of evidence in this thesis, is surely to seek complementarity and synergy between the two seed systems.

SAMENVATTING

Het onderzoek, dat in dit proefschrift wordt beschreven, betrof het functioneren van de zaaizaadsystemen van rijst in West-Afrika. Het onderzoek beoogde bij te dragen tot een beter begrip van de boerenzaaizaadsystemen en wegen aan te duiden om de formele en informele zaaizaadsystemen effectief aan elkaar te koppelen, teneinde uiteindelijk de ontwikkeling van een efficiënt zaaizaadsysteem voor rijst te bevorderen. In het eerste deel van het onderzoek werd ingezoomd op de diversiteit van boerenrassen van rijst in zeven landen aan de West-Afrikaanse kust: Gambia, Ghana, Guinee, Guinee-Bissau, Senegal, Sierra Leone en Togo. Vervolgens concentreerde het onderzoek zich op specifieke, op veldwerk gebaseerde case studies in Guinee (waarbij voor een aantal vragen een vergelijking werd gemaakt met het naburige Sierra Leone) om een beter begrip te krijgen hoe in formele en informele zaaizaadsystemen diversiteit ontwikkeld en beheerd werd, en hoe deze twee systemen te koppelen. Het onderzoek was gebaseerd op een interdisciplinaire benadering, waarin onderzoeksmethodieken vanuit de sociale en biologische wetenschappen werden gecombineerd en kwantitatieve en kwalitatieve data werden geïntegreerd.

Hoofdstuk 1 geeft een overzicht van de literatuur over het functioneren van zaaizaadsystemen. Uit dit hoofdstuk komt naar voren dat de formele zaaizaadsystemen veel aandacht kregen van onderzoeksorganisaties, overheden en beleidsmakers. Er bestaan echter verschillende studies die aangeven dat dit formele systeem niet afdoende in staat is om zaaizaad te leveren dat voldoet aan de agronomische en sociaaleconomische criteria van kleine boeren. Aanbevolen rassen die wel geschikt zijn, worden verspreid via kanalen die zijn ingebed in formele instituties waartoe kleine boeren geen toegang hebben (zie ook Hoofdstuk 4). Verscheidene tussenvormen van rasontwikkeling en zaaizaadverspreiding zijn voorgesteld om de invloed van het formele zaaizaadsysteem op de lokale voedselzekerheid te verbeteren. Deze tussenvormen proberen de principes van de formele en informele zaaizaadsystemen te verenigen. Sommige wetenschappers berichtten dat dergelijke inspanningen om tussenvormen van zaaizaadsystemen te ontwikkelen vaak meer gebaseerd waren op theoretische of ideologische principes dan op uitgangspunten afgeleid van het eigenlijke functioneren van het lokale zaaizaadsysteem. Tot de minder goed geteste aanbevelingen om het formele zaaizaadsysteem te versterken of de formele en informele systemen te integreren behoorde het voorstel om een gedegen studie te verrichten naar het informele systeem om het functioneren daarvan in relatie tot de complexe realiteit van de boeren beter te doorgronden. Dit proefschrift probeert deze leemte te vullen.

In **Hoofdstuk 2** wordt de bestaande diversiteit van boerenrassen verkend en gekarakteriseerd. Op basis van een moleculaire analyse van een groot aantal die in zeven West-Afrikaanse kustlanden waren verzameld, concludeerden we dat de door boeren geschapen diversiteit groter is dan vaak door wetenschappers gedacht. Derhalve vormt deze biodiversiteit een belangrijke bron van genetische variatie waarvan veredelaars gebruik kunnen maken. De moleculaire analyse toonde ook aan dat van de drie botanische groepen *glaberrima* en japonica een vergelijkbare maar geringe genetische variatie vertoonden. De indica groep vertoonde de grootste diversiteit. Belangrijker is echter dat de moleculaire analyse ook aantoonde dat nieuwe rijsttypen van inter-specifieke oorsprong werden aangetroffen op het boerenland. Deze verschilden van de zogenaamde Nerica typen die aan het eind van de negentiger jaren van de vorige eeuw in het laboratorium waren ontwikkeld. We hebben bewijs gevonden dat deze rassen al lang (ten minste 50 jaar of langer) worden verbouwd en dat hun verspreiding door oorlog en andere tegenspoed (bijvoorbeeld droogte) werd gestimuleerd. Dat zijn immers omstandigheden waarin boeren op zoek zijn naar rassen die het goed doen onder moeilijke teeltomstandigheden en die weinig beheer vereisen. Deze boerenhybriden zouden nu een plek moeten krijgen in veredeling- en zaaizaadverspreidingsprogramma's.

Als boeren selecteren voor moeilijke omstandigheden dan zouden boerenrassen robuuster moeten zijn en een grotere plasticiteit moeten vertonen, en dan vooral rassen van *O. glaberrima* omdat ze hun oorsprong in West Afrika hebben. **Hoofdstuk 3** onderzoekt deze hypothese. Het toont aan dat de West-Afrikaanse boer rijstrassen selecteerde die het goed deden onder ongunstige milieuomstandigheden. Vierentwintig boerenrassen (*O. glaberrima* en *O. sativa*), die uit de 315 rassen van Hoofdstuk 2 werden geselecteerd, werden in veldproeven in vijf West-

Afrikaanse landen, te weten Ghana, Guinee, Guinee-Bissau, Sierra Leone en Togo beproefd om hun fenologisch gedrag onder suboptimale omstandigheden te toetsen. We vergeleken deze rassen in termen van gewasontwikkeling, opbrengstcomponenten en opbrengst in de verschillende milieus om zo een beter begrip te krijgen van de mechanismen die ten grondslag liggen aan het verschijnsel plasticiteit. De resultaten toonden aan dat de boerenrassen robuust waren en dat ze verschillende strategieën hadden om met stress om te gaan. Rassen van *O. glaberrima* bleken in het algemeen meer robuust dan die van *O. sativa* ssp. *indica* en *O. sativa* ssp. *japonica*. De rassen van elke botanische groep clusterden op basis van hun herkomst (zie ook de moleculaire analyse van Hoofdstuk 2). Elk van deze moleculaire clusters vertoonde een verschillende strategie om met stress om te gaan. De twee clusters van *O. glaberrima*, het *O. sativa* ssp. *indica* cluster uit Guinee en het *O. sativa* ssp. *japonica* cluster uit Ghana-Guinee-Bissau waren het meest robuust Maar ze vertoonden verschillende aanpassingsstrategieën om vergelijkbare opbrengsten te realiseren. Het *O. sativa* ssp. *indica* cluster uit Ghana en het *O. sativa* ssp. *japonica* uit Sierra Leone pasten zich lokaal goed aan, maar in de andere milieus konden ze volledig mislukken. Boeren selecteren en verbouwen dus rassen die ten minste een stabiele opbrengst onder hun suboptimale omstandigheden garanderen. Deze rassen, en dan vooral van *O. glaberrima*, die weinig aandacht vanuit de wetenschap hebben genoten, komen voort uit het handelen van boeren. Zij zijn het resultaat van een lang selectieproces waarin de selectiedruk bestond uit agronomische factoren, natuurlijke factoren en sociaaleconomische factoren. Veel boerenrassen kunnen zich aan verscheidene milieus aanpassen, in tegenstelling tot de algemene opinie dat zij zich slechts aan lokale condities aanpassen.

In **Hoofdstuk 4** werd onderzocht hoe zaaizaadsystemen zich ontwikkelen in relatie tot deze diversiteit en hoe ze deze diversiteit mede vorm gaven. Als case study werd Guinee gekozen. De resultaten laten zien dat onderzoekers, overheden en internationale beleidsmakers een voorkeur hebben voor het formele zaaizaadsysteem en dat dit systeem is ontworpen om verbeterde rassen te verspreiden. Echter, de huidige institutionele opzet en de percepties van actoren van de formele zaaizaadsector belemmeren de toegang tot zaad voor de kleine boeren. Voor hun zaadleveranties hebben zaaizaadinterventies in de afgelopen twee decennia meestal vertrouwd op het nationale voorlichtingsapparaat, het nationale onderzoeksinstituut, de niet-gouvermentele organisaties, de boerenorganisaties en de producenten van het formele zaaizaad (de contracttelers). Deze contracttelers werden aangemoedigd om basiszaad te vermeerderen en zaaizaadbedrijven op te zetten. In de meeste gevallen kochten projecten het geproduceerde zaaizaad en derhalve ontwikkelden de formele zaaizaadproducenten weinig kennis over de lokale zaaizaadmarkten en de wensen van boeren. Hoewel lokale zaaizaadhandelaren een centrale rol spelen in de zaaizaadvoorziening hebben overheidsorganisaties hun rol niet onderkend. Hoofdstuk 4 onderstreept de noodzaak om een gemeenschappelijke benadering te vinden voor alternatieve modellen voor de ontwikkeling van de zaaizaadsector, waarin lokale zaaizaadhandelaren betrokken worden om het informele zaaizaadcircuit van de kleine boeren te koppelen aan de formele zaaizaadsector.

De meeste belanghebbenden in het formele zaaizaadsysteem kenden de wereld van de lokale zaaizaadhandelaren nauwelijks. **Hoofdstuk 5** onderzocht in detail dit specifieke en slecht gedocumenteerde aspect van het informele zaaizaadsysteem. De resultaten suggereerden dat lokale zaaizaadhandelaren gedurende de laatste 40 jaar actief zijn geweest in het gebied. Uit de gegevens van 2007 bleek dat de gemiddelde ervaring in de zaaizaadhandel 14 jaar bedroeg. De lokale zaaizaadhandelaren kwamen op in reactie op een toename van de behoefte aan zaaizaad, vooral in een context waarin (i) de voorlichtingsdienst geen middelen had om zaaizaad te verspreiden, (ii) de boeren hun vroeger ruim voorradige zaaizaadreserves hadden verloren vanwege politieke instabiliteit of economisch moeilijke tijden, verergerd door een wereldwijde voedselcrisis, waardoor ook huishoudens die tot dan toe niet boerden, gedwongen werden om rijst te gaan verbouwen. Zaaizaadhandelaren verkochten meestal lokale rassen. Verbeterde rassen vertegenwoordigden 32% van de verkochte rassen en 31% van het totaal verkochte volume. Verbeterde rassen waren evenzeer ondervertegenwoordigd in het rassenassortiment dat boeren verbouwden (21% van de rassen en slechts 6% van het totale volume aan zaaizaad dat werd uitgezaaid). Dit betekent dat lokale zaaizaadhandelaren goed zicht hadden op de behoefte van hun klanten om te diversifiëren en ook goed op die behoefte inspeelden. In de open markt was het zaaizaad van de verbeterde rassen aanmerkelijk goedkoper dan het zaaizaad van de lokale rassen en dit prijsverschil moedigde experimenteren aan. Op deze wijze droegen de lokale zaaizaadhandelaren bij aan de verspreiding van de verbeterde rassen. Een “scenario mapping exercise” toonde aan dat de handelaren bereid waren samen te werken met projecten waarin formeel zaaizaad werd verspreid. Maar elke vorm van samenwerking zal de waarden van het lokale zaaizaadsysteem moeten respecteren. Onder de voorwaarden voor samenwerking noemden de handelaren duidelijk de noodzaak om de lokale rassen in stand te houden als onderdeel van hun rassenassortiment.

Het feit dat de handelaren meer lokale rassen verkochten kon worden toegeschreven aan het feit dat de handelaren hun wortels hebben in het informele zaaizaadsysteem of dat lokale rassen eenvoudigweg beter waren dan de meeste verbeterde rassen onder de omstandigheden waarin de boeren werkten. In **Hoofdstuk 6** werd de uitdaging aangegaan om een diverse groep lokale zaadhandelaren, formele contractzaaizaadproducenten en agro-input handelaren te karakteriseren. De studie reconstrueerde de trajecten van ontwikkeling van deze zaaizaadondernemingen en analyseerde markt- en netwerkontwikkelingsstrategieën. De zaaizaadondernemingen bleken te hebben geleerd over hun markten en hoe zich aan te passen aan een veranderende omgeving waar de behoefte aan zaaizaad qua volume klein is en bovendien onvoorspelbaar, waar geen subsidies of creditfaciliteiten bestaan en waar boeren vaak huiverig zijn, om verscheidene redenen, om extra te betalen voor verbeterd zaad.

Het hoofdstuk maakte onderscheid tussen de respons van formele en informele zaaizaadhandelaren. Om zaken te kunnen blijven doen, hadden succesvolle formele zaaizaadproducenten, die gesubsidieerde inputs ontvingen, lokale rassen opgenomen in hun rassenassortiment om de productiekosten te verlagen en om beter in te spelen op de lokale behoefte. Lokale rassen doen het ook goed als er geen kunstmest wordt toegediend, een dure input die de boeren zich zelden konden veroorloven. De lokale zaaizaadhandelaren produceerden uitsluitend lokale rassen zonder agro-chemicaliën en dus hielden ze hun productiekosten laag. Tevens gebruikten zij hun sociale netwerken om jonge mensen aan te stellen die rond de oogststijd het gebied afstroopten op zoek naar zaaizaad van hoge kwaliteit. Deze handelaren hadden vaak geen contacten met de instituties uit de formele zaaizaadsector, De handelaren in agro-inputs die in dit proefschrift werden onderzocht, kochten hun zaaizaad meestal lokaal en in mindere mate ook van onderzoeksinstituten, om de risico’s van zaaizaadinkoop te minimaliseren.

Hoofdstuk 7 onderzocht de activiteiten die boeren ondernamen bij de selectie en productie van zaaizaad welke een integraal onderdeel waren van hun gewasproductiesystemen. Kennis was niet zozeer de limiterende factor voor de zaaizaadproductie van kleine boeren, maar eerder allerlei onzekerheden die boeren noopten hun oorspronkelijke plannen te wijzigen. Het proces van omgaan met deze onzekerheden bepaalt mede de geteelde rassen en kwaliteiten zaaizaad die aangepast zijn aan deze suboptimale omstandigheden. Daarom kan zaaizaadproductie niet worden beschouwd als een vastomlijnd systeem. Derhalve kunnen ook aanbevelingen voor betere zaaizaadproductie niet worden beperkt tot een serie geplande acties die door actoren met vaststaande rollen kunnen worden geïmplementeerd, zoals zo vaak door het formele systeem wordt opgevat. In **Hoofdstuk 7** wordt het argument verder ontwikkeld dat de incompatibiliteit tussen de planningsbenadering (zoals gewoon is bij de formele zaaizaadsystemen) en de benadering die is gebaseerd op het werk van de boeren (strategieën om met tegenspoed om te gaan) een wezenlijke uitdaging vormt die moeten worden aangegaan alvorens de boerenpraktijken van zaaizaadselectie kan worden verenigd met de formele zaaizaadproductieprogramma’s.

In **Hoofdstuk 8** worden de belangrijkste bevindingen van het onderzoek samengevat, worden enkele mechanismen achter bepaalde gedragspatronen van de boeren onderstreept, worden suggesties gedaan voor enkele institutionele veranderingen om het effect van formele zaaizaadsystemen op de leefbaarheid van het platteland te verbeteren, en worden de mogelijkheden en wegen bediscussieerd die moeten leiden tot een betere koppeling van de formele en informele zaaizaadsystemen teneinde beter te voorzien in de behoefte van kleine boeren aan zaaizaad. Wellicht is over het geheel genomen de belangrijkste bevinding van dit proefschrift wel het feit dat op dit moment het informele zaaizaadsysteem beter werkt voor de boeren omdat het de lokale ideeën over voedselzekerheid en sociale solidariteit in ogenschouw neemt. Deze sociale dimensie ontbreekt in het formele systeem, dat immers is ontworpen en wordt gefinancierd door deskundigen die niet hoeven te leven van het zaaien van rijst noch de lokale set van aannames over sociale wederkerigheid en verplichting delen. In plaats van het eenvoudigweg vervangen van het informele systeem door een formeel system, op internationale leest geschoeid, is het beter om, ondersteund door het gewicht van dit proefschrift, te zoeken naar complementariteit en synergie tussen de twee zaaizaadsystemen.

BIOGRAPHY

Florent K. Okry was born on June 28, 1975 in Thio, Benin Republic. After completing his secondary education at College Akpakpa-Centre, Cotonou (Benin) in 1995, he studied agricultural sciences at Faculté des Sciences Agronomiques of the University of Abomey Calavi (Benin) where he graduated in 2000 as Agricultural Engineer with major in Agricultural Economics and Rural Sociology. His Engineer thesis developed in collaboration with IRD (France) and Biodiversity International dealt with yam cropping systems and domestication of some of its wild species in central Benin. Immediately after graduation he worked successively as trainer of women groups with profit-driven activities (PROMIC), as extension agent (Association Interprofessionnelle de Coton and the Ministry of Agriculture of Benin) and as national supervisor of the socio-economic studies of PARCOB (Projet d'Appui à la Recherche Cotonniere du Benin); a joint project between Institut National de Recherche Agricole du Benin (INRAB) and CIRAD (France). Cumulatively, he acted as master trainer for several NGOs. In 2003 he decided to pursue interdisciplinary studies at Wageningen University, The Netherlands. He joined the master programme Development and Rural Innovation (ex MAKS programme) from which he obtained a Master degree in 2005. His MSc thesis dealt with socio-technical development of yam planting materials (seed) in Benin. Shortly after graduation he was appointed research assistant to the Programme Learning and Innovation Systems of Africa Rice Center (AfricaRice), a CGIAR centre. End of 2006, he went back to Wageningen University. Under the supervision of Technology and Agrarian Development group and Centre for Crop Systems Analysis he conducted this PhD research on rice seed systems and biodiversity conservation in West Africa in collaboration with Africa Rice Center. He conducted fieldwork in Guinea and Sierra Leone in 2007 and 2008. He has scientific interests in, amongst others, innovation systems, institutional analysis, local knowledge and technology development.

PUBLICATIONS

Peer reviewed Publications

Okry, F., Nuijten, E., Van Mele, P., Struik P.C. and Richards P. (Forthcoming). Adaptation of the informal seed system to agrarian changes: The emergence of market oriented local seed dealers within the informal seed sector of rice in Guinea. *Journal of Agrarian Change (under review)*.

Mouser, B., Nuijten E., **Okry F.** and Richards P. (Forthcoming). Red and white rice at Sierra Leone: Linked histories of slavery, emancipation and seed selection. In Global Rice: Promiscuity, Knowledge and Power, ed. Francesca Bray et al.

Mokuwa, A., Nuijten E., **Okry F.**, Teeken B., Maat H., Richards P. and Struik P.C. (Forthcoming). Robustness and strategies of adaptation within a large set of farmer varieties of African rice (Oryza glaberrima Steud.) and Asian Rice (Oryza sativa L.) across West Africa. *Plos One* Submitted. (The first four authors have equal contribution).

Okry F. et al., (Forthcoming). Rice seed production among the Susu in Guinea and Sierra Leone: Local knowledge and farmers' practices. To be submitted to *International Journal of Agricultural Sustainability.*

***Okry F**., Van Mele P., Nuijten E., Struik P.C., and Mongbo R. L. (2011). Organizational analysis of the seed sector of rice in Guinea: stakeholders, perception and institutional linkages. *Experimental Agriculture* 47 (1): 137-157.

Okry F., Dalohoun D.N., Diawara S., Barry M.B. and Van Mele P. (2011). Networks that work. In African Seed Enterprises: Sowing the Seeds of Food Security (Eds. P. Van Mele, J. W. Bentley and R. G. Guéi). Wallingford: CABI Publishing, 89-108.

Offei, SK, Almekinders CJM, Crane TA, Hughes SG, Mokuwa A, Nuijten E, **Okry F**, Struik PC, Teeken B and Richards P 2010. Making better seeds for African food security – a new approach to scientist-farmer partnerships. Aspects of Applied Biology 96:141-148.

*Nuijten E., Van Treuren R., Struik PC., Mokuwa A., **Okry F**., Teeken B., Richards P. (2009). Evidence for the emergence of new rice types of interspecific hybrid origin in West African farmers' fields. PLoS ONE 4(10): e7335. doi:10.1371/journal.pone.0007335.

Tostain S., **Okry F**., Baco N., Mongbo RL., Agbangla C. and Daïnou O. (2003). La domestication des ignames Dioscorea abissinica dans les sous-préfectures de Sinendé et de Bantè au Bénin (Afrique de l'Ouest). *Annales des Sciences Agronomiques du Bénin*. 4(1) : 24-54.

Tostain S., Agbangla C., Baco N., **Okry F**. and Daïnou O. (2003). Etude des relations entre ignames sauvages et ignames cultivées (Dioscorea sp.) dans deux sous-préfectures du Bénin à l'aide de marqueurs AFLP. *Annales des Sciences Agronomiques du Bénin* 4(1) 1-22.

Tostain S., Baco N.M., **Okry F**., Mongbo R.L., Agbangla C. and Daïnou O. (2002). Système traditional de production des ignames au Bénin. *Annales des Sciences Agronomiques du Benin* 3(2).

Tostain S., Baco M. N., **Okry F**., Mongbo R., Agbangla C. and Dainou O. (2002). La gestion dynamique des variétés d'ignames dans le système traditionnel de production de deux sous-prefectures du Bénin: Sinende et Bante. *Annales des Sciences Agronomiques du Benin,* 3 (2) 55-72.

***These two publications were nominated for the Vinus Zachariasse Awards 2009 and 2010, respectively as part of the top five publications of the Social Sciences of Wageningen University, the Netherlands.**

Thesis

Okry F. (2005). A socio-technical development of a seed (planting material) system: The case of yam in the Republic of Benin. MSc thesis Wageningen University and Research Centre, 84p.

Okry F. (2000). Yam in the Farming system of Bantè and Domestication of some wild species. Local knowledge and indigenous practices of cropping and genetic improvement. Engineer thesis, University of Benin, Faculty of Agricultural Sciences, 119p.

NEWSLETTER AND PROCEEDINGS

Okry F. and Van Mele P. (2006). Documenting validating and scaling up local Innovations. LEISA 22; 03.

Okry F., Van Mele P., Nuijten E., and Struik PC. (Forthcoming). The rice seed sector in Guinea: Are we missing out crucial stakeholders? Proceedings of the Africa Rice Congress 2010. Bamako, Mali, 22-26 March, 2010.

Teeken B., **Okry F**. and Nuijten E. (forthcoming). Improving rice based technology development and dissemination through a better understanding of local innovation systems. Proceedings of the Africa Rice Congress 2010. Bamako, Mali, 22-26 March, 2010.

Nuijten E., Richards P., Glover P., Maat H., Mokuwa A., **Okry F**., Teeken B., Temudo M. and Struik PC. (Forthcoming). Understanding the complex mechanisms of Technology × Environment × Society interactions in 'suboptimal' rice farming systems. Proceedings of the 3rd International Rice Congres, Hanoi, Vietnam, 8-12 November, 2010.

Teeken B., Nuijten E., **Okry F**., Mokuwa A., Temudo M., Struik PC. and Richards P. (forthcoming). Advocating the integration of socio-cultural factors in models for variety dissemination. Proceedings of the 3rd International Rice Congress, Hanoi, Vietnam, 8-12 November, 2010.

Van Mele P., **Okry F**., Idinoba P. and Kroma M. (2006). 'Technology transfer' at the Africa Rice Center: an assessment." Paper presented at the Africa Rice Congress in Tanzania, July 31-August 4.

Okry F., Richards P. and Mongbo RL. (2005). Ritualisation of seed (planting material) acquisition and distribution and agro Biodiversity conservation in the Central Benin: the Case of Yam (Dioscorea cayeninsis- rotundata). Abstract In Proc. "The Global Food & Product Chain-Dynamics, Innovations, Conflicts, Strategies". Deutscher Tropentag, October 11-13, 2005, Hohenheim.

Adegnika M., **Okry F**. and Ouedraogo B. (2005) (eds). Les évolutions en cours dans les filières cotonnières : conséquences pour la Recherche Agronomique et l'acquisition des intrants par les agriculteurs. Actes de la conférence Coton de l'Afrique de l'Ouest et du Centre tenue á Cotonou, Bénin, 10-12 mai 2005.

Tostain S., Scarcelli N., Baco N., **Okry F**., Houemassou J., Allomasso T., Mariac C., Agbangla C., Dainou O., Berthaud J., and Pham J-L. (2002). Etude des relations génétiques entre les ignames sauvages et les ignames cultivées (Dioscorea Sp) au Bénin á l'aide de marqueurs AFLP. In : Proc. 8ème Journée Scientifique du Réseau Biotechnologies, Amélioration des plantes et Sécurité Alimentaire ; Marrakech, Maroc 7-9 Oct.2002.

WASS PhD Education Certificate: Florent K. Okry
With the educational activities listed below the PhD candidate has complied with the educational requirements set by the Wageningen School of Social Sciences (WASS) which comprises of a minimum of total of 32 ECTs (=22 weeks of activities).

Wageningen School of Social Sciences

Name of the course	Department/Institute	Year	ECTS
I. General			
CERES orientation programme	CERES, Utrecht	2007	5
CERES presentation tutorials	CERES, Utrecht	2007	5.5
Literature review and research proposal development	TAO and Centre for Crop Systems Analysis	2007	6
II. Research Methods and Techniques and Domain Specific Theories			
Complexity in and between Social and Natural	CERES, WUR	2007	3
Technography: Researching Technology and Development	TAO, WUR	2007	6
III. Academic Skills			
Information Literacy and EndNote	Library, WUR	2007	1.5
On the job training scientific writing and publishing (In-service)	Wageningen University, Africa Rice Center and University of Abomey Calavi (Benin)	2009-2011	6
Tailor made modelling workshops (Methods of quantitative data analysis and Software: MatLab, Dip Image, SAS curve fitting, PASW)	Centre for Crop Systems Analysis, TAO, University of Abomey Calavi (Benin)	2009-2011	4
IV. Seminars and Workshops Presentations and Attendance			
TAO seminars	TAO, WUR	2006 to 2011	3
Proposal presentations to the national agricultural research system (Introduction to the study country)	Conakry and Kindia (Guinea)	2007	1
Presentations research findings years 1 and 2 to the national agricultural research system and NGOs	Conakry and Kindia (Guinea)	2007 and 2008	2
Presentation research findings at IFAD project launch: Seed for smallholders farmers in Guinea, DR Congo and Sierra Leone	Africa Rice Center, Cotonou, Benin	2009	1
Closing seminar of fieldwork under WOTRO/ Project (Biology and Anthropology of African Rice) and presentation of findings to a wider audience (West Africa).	University of Legon Accra, Ghana	2009	1.5
Africa Rice Congress: Oral presentation and paper writing for proceedings)	Organised by Africa Rice Center, Bamako, Mali	2010	2
Young research seminar: Oral and poster presentations	Organised by Agropolis Foundation, Montpellier, France	2010	2
International Rice Congress: Oral presentation	Organised by International Rice Research Institute (IRRI), Hanoi, Vietnam	2010	2
International Rice Congress: organisation of a mini workshop during International Rice Congress	Organised by International Rice Research Institute (IRRI), Hanoi, Vietnam	2010	2
TOTAL ECTS			**53.5**

Cover:
Photo front page by Florent Okry
Rice seed: Mixture of 231 farmer rice varieties from The Gambia, Ghana, Guinea, Guinea Bissau, Sierra Leone and Togo
Photo back page by Leo Zwarts