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DIAGNOSTIC STUDY OF FARMERS SEED QUALITY AND VARIETY PREFERENCE IN SOUTHERN MALI

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DIAGNOSTIC STUDY OF FARMERS SEED QUALITY AND VARIETY PREFERENCE IN SOUTHERN MALI

By

Marthe Diallo

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ABSTRACT

DIAGNOSTIC STUDY OF FARMERS SEED QUALITY AND VARIETY PREFERENCE IN SOUTHERN MALI

By

Marthe Diallo

Mali relies on agriculture as the backbone of its economic growth because agriculture employs more than 80% of the population and constitutes the main source of food. In the Koulikoro region (the study area), sorghum and millet are subsistence crops for almost all of the population. Groundnut constitutes the main source of income for women and is critical to family nutrition. These crops are grown by almost all the farmers in this region because they are adapted to semi-arid tropical ecologies and infertile soils, as well as being preferred in the diet. Despite their importance, an understanding of seed systems for these 'orphan' crops has been neglected.

To understand agricultural development in Mali, it is important to evaluate the entire seed system, including the seed quality of farmer-saved and foundation seed, seed saving methods on-farm, seed sourcing avenues, and how new varieties are accessed by small-holders. Informal and formal surveys were conducted, in conjunction with seed collection from a range of sources. Seed quality performance was tested for seed from a range of sources. To quantify seed quality, laboratory standard analytical methods and field performance were analyzed. Variety purity was also assessed for different seed sources that represented foundation seeds, and seeds maintained by farmers for different number of years. These tests were linked to farmer assessment of seed quality and variety preference conducted through surveys and farmer ranking exercises.

The seed quality assessment showed that farmer produced seed is generally high quality, as high as foundation seed. The seed meets Mali national seed service standards in almost all cases. However, there were some concerns identified concerning physical purity and health status of groundnut seeds.

The field trial analyses showed that there are no significant differences between the variety purity of seeds farmers had saved and produced and foundation seed. This was shown for the flowering time (beginning and end), number of off- types, and weight of panicles. Overall, farmers recycling of varieties (saving seed for several years) did not markedly alter variety traits in sorghum.

Results from both the on-farm field trial evaluation and the survey indicated that yield and adaptation to the local environment were very important in farmers' variety evaluation criteria. There were some additional traits of interest to farmers from Dioila and Mande, including cooking traits (easy processing, good taste of dishes made) and drought tolerance. However the farmers in Dioila were more interested in cooking quality than in drought tolerance.

Another interesting finding is that there is a cultural tradition that prohibits the purchase of seed, particularly for sorghum and groundnut, yet farmers' did express a willingness to pay for sorghum seeds of preferred, improved varieties. Farmers in both zones were ready to pay 200 FCFA/kg for seed for their preferred varieties. This is a surprisingly high price given the low income level, and the limited cultural concepts of paying for subsistence crop seed.

DEDICATION

To the loving memory of my mother Mariam Sanogo who did not live to see the accomplishment that built the foundation.

To my husband Nyadia and my two kids Esther and John-Ariel Goita for their love, support and patience when it was most needed.

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KEY TO SYMBOLS OR ABBREVIATION

ACOD : Association Conseil pour le Développement (Local NGO)

ACOPP : Association des Organisations Paysannes des Producteurs

APCAM : Assemblée Permanente des Chambre d'Agricultures Maliennes

APROFA : Agence de Promotion de Filières Agricoles.

AV : Association villageoise

BNDA : Banque Nationale pour le Développement Agricole

COPROSEM : Coopérative des producteurs de semences

CFC : Common Fund for Commodities

CILSS : Comite Inter-état de Lutte contre la Sécheresse au Sahel

CIMMYT: International Maize and Wheat Improvement Center

CMDT: Compagnie Malienne pour le Développement Textile (Cotton Company in Mali)

CIRAD: Centre International de Recherche Agronomique et de Développement

COPROSEM : Coopérative pour la Promotion de la Filiere semence

DGRC : Direction Générale de Régulation et Contrôle

Diff : difference

DNSI : Direction Nationale de la Statistique et d'Information

DNAMER : Direction Nationale d'Appuis au Monde Rural,

ECOFIL : Economie des filières Agricoles

EDS: Enquête Démographique et de Santé

FAO: Food and Agricultural Organization of the United Nation

Fcfa : Franc Communauté Financière d'Afrique

FPVS : Farmers Participatory Variety Selection

FV : Farmer variety

GDP : Gross Domestic Product

GIE : Groupement d'Intérêt Economique

GLM : Generalized Linear Model

gr = Gram

ICRISAT : International Crops Research Institute for Semi-Arid Tropics

IDRC : International Development Research Center

IER: Institut D'Economie Rural

IPR /IFRA : Institut Polytechnique Rural/Institut de Formation et de Recherche Appliquées

ISTA : International Seed Testing Association

Kg : Kilogram

LCV: Local control variety

LSM: Least Square Means

MV: Modern varieties

m^2 = meter square

NGO: Non Governmental Organization

n: Total number (Sample)

OHVN : Office de la Haute Vallée du Niger

OMA : Office des Marchés Agricoles

OPC : Organisation des producteurs de céréales.

R Var : response variable

PVP : Plant Variety Protection

PPB : Participatory Plant Breeding

ULPC : Union Locales des Producteurs de Céréales (local farmers' association)

SAS : Statistical Analysis Software

SSA: Sub-Saharian Africa

SSN : Service Semencier National

SD : standard deviation

SE : Standard Error

WOI: Weight of Impurities

INTRODUCTION

Mali, as most countries in Sub-Saharan Africa (SSA) relies on agriculture as the backbone of its economic and social development because it employs about 80% of the population, constitutes the main source of domestic food supply and produces about 45 GDP (Coulibaly, 2004). Sorghum (*Sorghum bicolor*) and millet (*Pennisetum glaucum)* constitute the main cereal crops in the Koulikoro region (the study area in Mali). They account for more than 40% of the total food grain production in the region, with small-holder farmers responsible for almost all the production (Tefft, 2004). In Mali, sorghum and millet are subsistence crops for almost all of the population and the total area that they occupy are bigger than that of all other crops. This is due to the fact that these crops can grow well in drier regions and on poor soils than other crops (Byth, 1993).

Groundnut on the other hand, constitutes the main source of income for women and source of food and condiments for the households in most of the study areas. Groundnut more than sorghum and millet can grow well in dry regions and on poor soils which are most of the time given to women (Weltzien et al. 2006). Another important point about groundnut is the fixation of atmospheric nitrogen which helps in restoring soils fertility. These three crops are grown by almost all the farmers in this region. Despite their importance in Mali, all these crops share constraints related to seed quality and access. To understand agricultural development in such an area, it is essential to look at crops that are grown by both men and women, especially the small-holders. Thus to assess seed quality at farmer's level in a participative way (involving all farmers: men and women), looking at seed of these three crops can give a good insight.

Seeds are the most important input in all crop-based agriculture and a prerequisite for the majority of the world's food production (Badstrue, 2007). They provide the basis of factors influencing crops' yield because they contain all the genetic information of varietal traits that determine yield potential, adaptation to environmental conditions, and resistance to pests and disease (Maredia et al .1999). Research has shown that healthy seed is one of the important factors in improving agricultural production (Gupta, 1999). Therefore, a farmer's most critical management decision is the selection of seed sources and varieties.

In Mali as in many SSA, farmers use seeds from informal sector (about 80%) (Siart, 2008), constituted of seeds produced by farmers without quality control and from local varieties. These seeds, even though inexpensive, are thought by some researchers to have some limitations, such as low germination rates, varieties with low yield and weak resistance to climatic stress, poor pest resistance, etc... That is why some argue that the agricultural productivity growth in SSA has not been as strong as compared to Asia, where the development, distribution (marketing) and use of improved seeds of new varieties were important components of the Green revolution (Maredia et al. 1999). In SSA, the existence of efficient seed systems including all source of seeds, e.g., a system where all farmers can access good quality of seeds (improved seed[1], high-yielding, disease-free) of locally adapted varieties (socio-economic and agro-ecological adapted varieties) on time is a primary determinant of productivity (Cromwell and Tripp, 1994).

The wide use of local seeds in Mali is due in part to the fact that most farmers are poor and therefore cannot afford new improved inputs particularly seeds

[1] Improved seed refers in this paper to seed produced under quality supervision by the national seed service

produced/developed by researcher and/or imported because of cash flow problem. They also have limited access to agricultural services and markets because of poor infrastructure (CIMMYT, 2007). This problem is important for grain crops produced mostly for subsistence (Yapi *et al*, 2000) and for legume crops characterized by difficult storage, disease susceptibility, low multiplication rates and high seeding rates (Vanderhofstadt, Bruno. 2002). Thus, seed suppliers find it too risky to invest in the seed sector because there is no sure demand (Tripp *et al,* 2001).

However, seed system analyses in Mali have shown that farmers are interested in trying new types of varieties that combine socio-economic quality traits (storability, easy to process, culinary quality, and marketable) (ICRISAT, 2005).

In the past, most agricultural research in Mali was focused on cash crops like cotton and rice (Tefft, 2004). Then, with the problem of food insecurity in Mali, some research institutions (IER and ICRISAT) started to focus on agronomic performance of grain crops such as sorghum millet, and maize in order to increase food security for the majority of the population. ICRISAT has been conducting research to produce superior sorghum germplasm and has developed some improved varieties for farmers to use.

In this new environment characterized by the existence of new improved varieties, farmers' willingness to try new varieties, investigating seed system functioning through assessing seed quality and varietal preference, will contribute significantly to improving farmers' access to good quality seed of their preferred varieties in Mali.

This research will focus on seed quality for the following three crops: millet, sorghum, and groundnuts. This project will investigate the status of existing seed quality from different sources for each crop by answering the following questions:

- **What is the quality of sorghum, groundnut and millet seeds used by farmers?**
- **How is the varietal purity of improved variety seeds affected by farmers' seed recycling?**
- **Which variety traits are preferred by farmers?**
- **How can seed sector performance be improved, based on information gathered through assessment of farmers' willingness to pay for improved seeds and their interest in seed fairs?**

The answers of these questions this research will help to address some of the major constraints to the development of a seed system that meet the needs of farmers in Mali. These constraints include:

1) Inadequate identification of quality concerns related to the recycling of seeds over several years, including the conditions of production and storage of seeds that most farmers use in Mali for sorghum, groundnut, and millet,

2) Difficulties in planning and programming seed production in relationship to the users' needs and varietal preferences, and

3) Inadequate knowledge and limited dissemination of information about varieties, particularly for these subsistence crops and "women's crops" (such as groundnut).

This project will contribute to the broader question of how to develop sustainable seed systems for low-income tropical countries in general. It will help African policy makers, NGOs, and donors to identify:

- Strengths and weaknesses of the current seed systems for these crops

- The critical areas for further investment and training

This research was conducted in two zones: Mande and Dioila in the Koulikoro region in Southern Mali (see figure 0-1). In each zone, four villages were selected and within each village, 20 households were selected. From each of the participating household seed samples were collected for field trial and laboratory analyses. The head of each household was interviewed as well as each individual grower of sorghum, millet and groundnut in the household. The selection methods for the villages and households are described in the next chapter (chapter 1)

Figure 0-1: Map of part of Mali indicating the study zones.
Source: Sonja Siart, 2008

The data (quantitative and qualitative) used to answer these questions were collected through both formal and informal surveys at farmers' level, field trials, and lab quality test on seeds collected from farmers, researchers, and local seed producers. These data were used to assess seed quality from different sources (own production versus market or research), different storage methods (grains versus panicles/pods), different

locations (Dioila and Mande), across the three crop types, and farmers' varietal preferences. I also used data collected during the seed fairs and variety evaluations to assess the possibilities to improve farmers' access to good quality seeds.

This dissertation is consists of four chapters in addition to this introductory part. Chapter 1 deals with farmers' seed quality documentation, and chapter 2 focuses on farmers' seed recycling for four ICRISAT improved varieties in production at farmers' level since 2003. Chapter 3 assesses farmers' preference for different variety traits among the improved sorghum varieties in on-farm-field trials. And chapter 4 examines ways to improve farmers' access to good quality seed of their preferred varieties through seed fairs and farmers' willingness to pay for varieties with their preferred traits.

OVERVIEW of SORGHUM, PEARL MILLET and GROUNDNUT

Sorghum and Pearl millet

Sorghum (*Sorghum bicolor*) is a diploid (2n= 20) and largely self-pollinated crop (2-20% outcrossing) (Minot et al., 2006). Sorghum is a c4 species adapted to dry conditions, with minimum requirement of about 500 mm of rainfall (Minot et al., 2006). According to the same source, sorghum is grown on 26 million ha in sub-Saharan Africa, with an average yields of only 800kg/ha due to low harvest index (FAOSAT, 2007). In West Africa, sorghum is an important dietary staple crop. The stover is valued as animal feed, fencing material and fuel in mixing cropping systems (Folkertsma et al., 2005).

Pearl millet (*Pennisetum glaucum)* is the most important of the millets and is the preferred cereal crop in the sahelian region of West Africa (Minot et al., 2006). Millet is a diploid species with 2n=14, and is an open-pollinated crop with 75% to 80% outcrossing. Like sorghum, millet is c4 species adapted to dry conditions. The early-maturing varieties

have a growing cycle of about 60 days, while the late-maturing ones can go up to 180 days. Millet is native to Africa, and West Africa is its center of diversity (Minot et al., 2006).

Groundnut

Cultivated groundnut (*Arachis hypogaea L.*) belongs to genus *Arachis* in sub-tribe *Stylosanthinae* of the tribe *Aeschynomenea* of family *Leguminosae*. It is a self-pollinated, tropical annual legume (Nigam et al., 2004). Groundnut is the sixth most important oilseed crop in the world. It contains 48- 50% oil and 26-28% protein and is a rich source of dietary fiber, minerals and vitamins (N'Tare et al, 2008). The optimum temperatures for growing groundnut range from 25°C to 35°C. Early-maturity varieties require 300-500 mm, while late-maturing ones need 1000-1200 mm rainfall. Groundnut produces well on well-drained sandy loamy soils.

Groundnut is grown on about 26 million ha worldwide, with a total production of about 37 million metric tons and an average productivity of 1 t/ha (FAO, 2003). Groundnut is grown in over 100 countries worldwide, with 97% of the global area and 94% of the global production in developing countries. The production is concentrated in Asia and Africa, with 56% and 40% of global area and 68% and 25 % of the global production respectively (Ntare et al, 2008). Grain legumes including groundnut are widely grown by smallholder farmers in many semi-arid countries like Mali because they derive multiple benefits from growing legumes grains, including nutritious food, soil fertility and cash income.

STUDY AREAS

The Republic of Mali is a landlocked country located in West Africa. It is surrendered by Algeria, Burkina Faso, Guinea, Cote d'Ivoire, Mauritania, Niger, and Senegal. A former French colony, Mali gained independence on September 22, 1960, with Bamako as its capital. Mali is composed of eight administrative regions: Gao, Kayes, Kidal, Koulikoro, Mopti, Segou, Sikasso, and Tombouctou. With a population estimated to be about 12,000,000 people (EDS/DNSI, 2004), Mali has a total area of 1.24 million sq km, of which 1.22 million sq km is land and 20,000 sq km is water (DNSI, 2005).

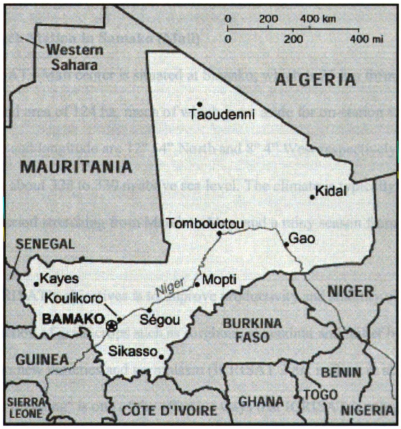

Figure 0-2: Map of Mali Republic and surrounding countries
Source : http://www.cia.gov/cia/publications/factbook/geos/ml.html

The climate is subtropical to arid; hot and dry from March to April; rainy, humid, and mild May to October; cool and dry November to February. The Niger River cuts an arc through the country.

Mali is among the poorest countries in the world, with 65% of its land area desert or semi-desert. Economic activity is largely dominated by the agricultural sector, which contributes about 45% to the GDP and ensures work for about 80% of the active population.

Malian agriculture has been focused for a long time on grain crops (millet, sorghum, maize,...) and cash crops (cotton, peanuts,...), as well as ruminants. The type of crops grown in each region depends on traditional cultivars.

ICRISAT Research Station in Samako (Mali)

The ICRISAT –Mali center is situated at Samako, which is 25 km from Bamako. It covers a total land area of 124 ha, much of which is set aside for on-station variety trials. The latitude and longitude are 12° 54" North and 8° 4" West respectively. The average altitude is about 328 to 330 m above sea level. The climate is typically Sudanean, with a harsh dry period stretching from March to May, and a rainy season from June to September.

One of ICRISAT's objectives is to improve productivity and stability of agricultural production of grain crops such as sorghum, groundnut and millet by providing access to new varieties and germplasm (ICRISAT 2002 in Siart et al., 2005). Participatory plant breeding[2] is one of the effective ways that ICRISAT is using to

[2] Participatory plant breeding is a research method in which scientists collaborate with local farmers in order to share their knowledge and to find out how ICRISAT can optimally meet their needs.

achieve this objective. This research uses ICRISAT's participatory research method to assess seed quality with farmers in two of its intervention areas: Diola and Mande.

Study zones

The research was conducted from May 2007 to September 2008 in the sorghum-based production systems of southern Mali (Siart, 2008). Southern Mali accounts for more than half of the millet and sorghum supply in Mali (ABT, 2002). The research was conducted in two zones of this part of Mali:

- The Dioila zone, located 160 km southeast of the capital Bamako, is a Malian Cotton Company (CMDT) zone.
- The Mande zone, about 60 km west of Bamako, is an "Operation Haute Vallee du Niger" (OHVN) zone

The two zones are similar agro-ecologically, but differ widely in the degree of mechanization of agriculture, market orientation, infrastructure and organizational environment (ICRISAT, 2002) as shown in table 0-1. Dioila is considered as the more developed region because of the presence of CMDT, the well structured and oldest cotton company in Mali.

The average annual rainfall is about 800- 1000 mm, and the length of the rainy season varies between 4 to 5 months, starting from May or June to September or October. As in most Sahelian countries, the starting of the rains is very uncertain in the study zones. Throughout the country, from south to north, the irregularity of the rainfall increases as well as the duration of rains, and the overall quantity of rain is decreasing (SIMPSON, 1999). This situation has contributed to marked changes observed over the recent decades in the agro-ecological conditions in the growing areas for rain-fed crops

like sorghum, millet and groundnut, including the study zones. Since the severe droughts of the early 1970s, the average rainfall in Sahel in the 30 years up to 1997 was 20- 49% lower than in the period between 1931 and 1960 (IPCC, 2001 cited by Siart, 2008). Soil fertility is also changing due to shorter fallow periods and insufficient use of fertilizers on sorghum, millet and groundnut fields. (Weltzien et al. 2006)

Table 0-1: Socio-Agro-Ecological conditions of Dioila vs. Mande

Conditions	Dioila	Mande
Distance to Bamako	160 km southeast of Bamako	60 km west of Bamako
Major extension service	CMDT: the Malian Cotton Company	OHVN: Upper Niger River Valley Development Authority
Characteristic of agriculture	• More Mechanized • More market oriented • More organized farmers • More infrastructure (road, storage places, etc...)	• Less Mechanized • Less market oriented farming • Farmers are less organized • Less infrastructure
ICRISAT partnership	ULPC : Local union of coarse grain producers	ACOD: National NGO AOPP: Association of professional organization of producers
Ethnicities	Mainly inhabited by Bambara	Mainly inhabited by Malinke
Agro-ecological characteristics	800 – 1000mm of rain/year, with a decreasing length of rainy season in the recent decades. Soil fertility is also decreasing.	Same as in Dioila, but sometimes more rains. Soil fertility conditions are similar but sometimes worse in Mande because farmers do not have access to fertilizers as they do in Dioila

Brief Overview of Agriculture in the Study Zones

Both areas are cotton-growing zones, but Dioila is one of the oldest CMDT regions in Mali. In Dioila Zone, farmers have access to inputs (cotton seeds, fertilizers and pesticides) and basic farming equipment (ox plows, planters, etc.) on credit for cotton

production. In Mande, on the other hand, the cotton production is not as important as in Dioila. It is under OHVN extension service, and farmers do not have access to credit for cotton production. As result, the level of mechanization in Mande is lower compared to Dioila (Siart, 2008).

Sorghum is the main staple crop in both zones, but other cereals like maize, millet, and rice are also grown. A typical cotton-growing household's cropping system is as follows: cotton—maize—sorghum—millet—groundnut (grown by women). If the household doesn't produce cotton, maize takes the head of the system (Weltzien et al. 2006). In this cropping system, sorghum, millet and groundnut are grown on poor soils that are not suitable for cotton and corn. However, if grown in rotation with cotton, sorghum can profit from the residual fertilizer.

In both areas, farmers grow sorghum, millet and groundnut in two types of fields: bush field and house field. The bush fields are usually far from the village. Due to transportation problems associated with long distances, these fields usually receive only a small portion of the households' manure. The house fields are located near or within the village and receive more manure because they constitute the place where animals are tied-up at night during the dry season. They also receive more attention because of their location. (Weltzien et al. 2006).

Socio-Economic and Cultural Situation of the Research Zones

Sorghum and millet are grown mainly for subsistence, more specifically in Mandé and with only some degree of commercialization in the Dioila region (Siart, 2008). The cereal producers' organization in Dioila (OPC) coordinated by ULPC (Local Union of Cereal Producers) makes this market orientation for sorghum possible in this region.

Cotton is the main cash, crop followed by groundnut for men; groundnut is the main cash crop for women in both zones.

Sorghum and millet are primarily men's crops and are grown in family fields where all able-bodied family members (expect the old women) are required to work (Weltzien et al. 2006). The lack of labor is an important limiting factor to agricultural production in both regions because more people tend to do more off-farm income-generating activities from which they can get more income than from agriculture. Children and young people attending school, which might be outside the village, also reduce the amount of labor allocated to agriculture (Weltzien et al. 2006).

The two zones are different in terms of the presence of organizational structures. Dioila has more farmers' associations than Mandé, which has practically none. This difference is due the fact some external organizations working in Dioila like CMDT and SNV have identified farmers associations as an important agricultural development factor. As a result, they helped in initiating them in their intervention areas (villages) (Siart 2008). The Mandé region, located on the upper Niger River and the border of Guinea, is seen as a heartland of the old empire of Mali (the empire led by Soundiata Keita). This place still plays a big role in the history of the country. The Mandé language group accounts for about 40 languages in West Africa (Mabe, 2001 cited by Siart 2008).

The farm households are usually extended, large families headed by one head of family with his sons' and brothers' families. All the active family members work in the fields where sorghum, millet, and maize are grown for family food and cotton for cash to support family expenses (Weltzien et al. 2006).

The traditional structure of the society is extremely hierarchical. At the village level, the head of the village *(chef de village)* is from the founder family. No individual land ownership exists; all lands belong to the community, and only the land use right is inherited (Linding, 1986 cited by Siart 2008).

CHAPTER 1

QUALITY of FARMER PRODUCED SEEDS of SORGHUM, GROUNDNUT, AND PEARL MILLET IN DIOILA AND MANDE ZONES

INTRODUCTION

Mali's economy, like that of most SSA countries, is largely dominated by the agricultural sector, which contributes about 45% to the GDP and ensures work for about 80% of the active population. Agriculture constitutes the main source of domestic food supply and ensures at least one third of foreign exchange earnings (Diakite and Diarra, 2000). Malian agriculture is representative of the path of development for SSA countries, where subsistence, extensive cropping systems still are dominant, with minimal use of improved inputs including good quality seeds (David, S. and L. Sperling. 1999). In SSA, the existence of efficient seed systems—i.e., systems where all farmers can access to good quality of seeds (improved seed, high-yielding, diseases free) of locally adapted varieties on time— is a primary determinant of productivity (Cromwell et al., 1992 and Tripp 2000).

Seed: Parts of agricultural, silvicultural, and horticultural plants used for sowing or planting purpose

The four basic seed quality aspects are:

1- Physiological quality (germination, vigor)
2- Sanitary quality (absence of seed-borne diseases)
3- Analytical quality (percentage of good seed in a particular seed lot
4- Genetic quality (varietal adaptation, varietal purity

Good quality seed: refers to seed with good germination rates, seedling vigor, absence of weed seeds or seed-borne diseases and other impurities.

Seed system: the entire complex of organizations, institutions, and individuals associated with seed program of a country comprised of the **traditional or informal system** of farmer-selected, -multiplied, -processed, exchanged and retained seeds, and a **non-traditional or formal system** of individuals, organizations and institutions involved in specialized tasks related to producing and marketing seed for sale to seed users.

Figure1-1: Definition of Key Terms

Farmers' seed sourcing in Mali

Mali as in many SSA countries, farmers get their seeds from mainly two sources: informal/local sector and formal sector as described in the Figure 1-2

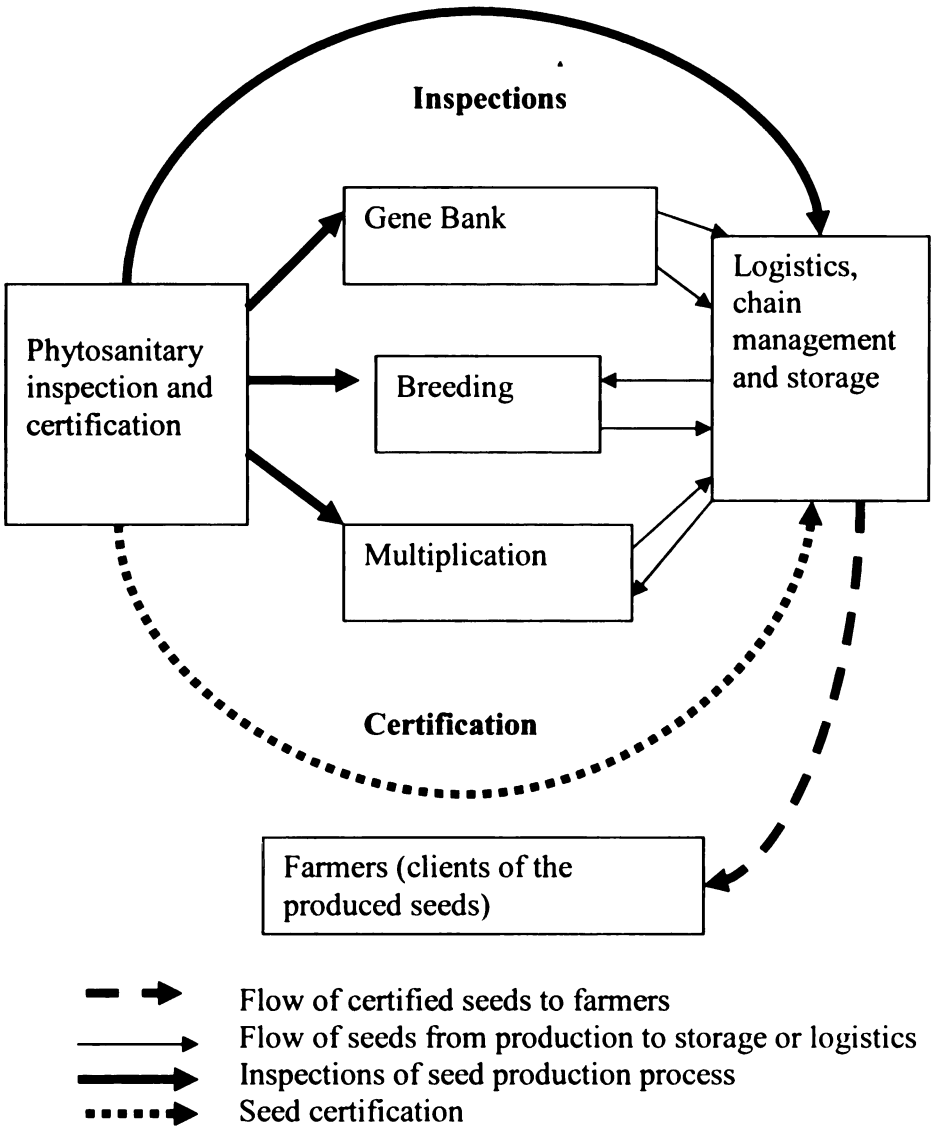

Figure 1-2: Formal seed system description adapted from Willy De Greef Biotechnology Specialist, PRODEPAM project, 2004

Formal seed system in Mali

The formal seed system is characterized by vertically organized production, storage and distribution of tested seed and approved varieties, using strict quality control (Maredia et al., 1999). In Mali, the most important formal seed channel for millet and sorghum and groundnut is the National Seed Service (SSN). SSN originated as part of the state-owned production and distribution system for seed (Minot and Smale, 2006). Today, the formal seed system is coordinated by the SSN, which has public and private components. The public components include governmental structures of research and variety development such as IER (Institut d'Economie Rural), extension (DNAMER—Direction National d'Appuis au Monde Rural), quality control (DGRC—Direction Generale de Regulation et Controle), and the SSN (Service Semencier National). The private components include private seed farms and seed producer farmers' groups (Diakité, 2003).

The formal seed system in Mali has focused on cotton, rice and maize. To a lesser extent, work has been conducted on developing a formal seed system for millet, sorghum, cowpea and groundnut (Tefft, J. 2004). The seed quality requirements recommended for these crops are to obtain >80% germination and >90% physical purity (Dembele, 2006). The use of formal system seeds is still almost nonexistent for millet, groundnut, and sorghum, which is related to many of the reasons discussed in this research. An earlier study (Yapi et al, 2000) indicated that a formal seed system is not developed because of the high cost of certification, which limits seed affordability for resource limited farmers, and because farmers can source seeds from the informal system (Maredia et al., 1999).

Informal seed sector in Mali

The informal seed system consists of farmer-to-farmer seed exchanges and farmers' own saved seeds produced from local varieties without any supervision or quality control during production (Pejuan, 2005). This system is based mostly on farmers' saved seed from their harvests, but local markets may play an important role for seed security as well. Seed and consumption grains are grown in the same field, but some farmers select and store seeds separately from the gain (Minot and Smale, 2006; Bazile, 2006; and Coulibaly, 2004).

In Mali, as in many Sub-Saharan African (SSA) countries, farmers obtain almost all their seeds through the informal sector (Siart, 2008, Almekinders and de Boef, 1999). Getting information on how small-scale farmers obtain, manage and share seed is crucial for designing appropriate mechanisms for delivering new crop varieties (David, 2003). Assessing farmers' seed quality for a range of crops (sorghum, millet, and groundnut) will help in documenting the seed quality in the study areas.

Farmers' local seed management[3] for sorghum, groundnut and millet in southern Mali

Seed production

For the most part, farmers select their own seeds in Mali. A sorghum study done by Siart (2008) in the two zones of Mali showed that 82% of sorghum seeds were selected by farmers in the field as panicles before the harvest (in Mande). In Dioila about 50% of seeds are selected after harvest. These results are similar to findings by Diakité (2003), although in Dioila the number of farmers selecting seed in the field has slightly

[3] Farmer seed management refers to the process that farmers use, to produce, to obtain, to maintain, to develop and distribute seed resources.

increased. Diakité (2003) reported that three-quarters of the farmers in Dioila were not doing seed selection in the field.

For millet, seed production at the farmers' level has not been documented in Mali, but from what we heard from farmers in a preliminary survey to this dissertation research, selection of seed usually does not occur in the field. The seed is selected from stored grain, at planting time. Only a few farmers reported selecting the best panicles of millet during harvest to save as seeds for the next planting season.

In contrast to sorghum and millet, for groundnut there is no seed selection in the field.

Seed storage

Sorghum seeds are stored by smallholder farmers in SSA in various ways, such as grains in bags, grain in granary, panicles attached together (sheaves) stored in the kitchen or outside, and inside the granary. Often panicles are stored in bags in the granary. These are the storage systems used in southern Mali as well. In Mande, the majority of sorghum seeds are stored in sheaves (71%), and about 19% are stored as grain. In Dioila, on the other hand, only 30% of sorghum seeds are stored in sheaves and 25% are stored in panicles not attached together either in bags or granary (Siart, 2008). Millet seed storage is quite similar to sorghum in both zones. The only difference is that millet is mostly stored in grain. Groundnut seeds are stored in pods (the majority) or as grain. Farmers usually store only limited quantities of groundnut in pods to use as seed because of financial and logistical reasons (Ntare et al, 2008).

Groundnut seed management by women

Groundnut constitutes the main crop for women in both zones (Broek, 2007). During the surveys, the informal discussions with old women growing groundnut revealed that almost all of them have their dominant groundnut variety since their wedding. According to them, "in our culture when a girl gets married, her mother should give her some groundnut seeds to start her field. It is her duty to multiply and maintain the seeds and provide her own daughter with seeds as wedding gift." These women have kept those seeds for more than 40 years (author's unpublished survey data, 2007) and they were still visually looking good. In the study areas, men's groundnut seeds are usually from women's production even if seeds are purchased (informal discussion with Awa Traoré of ICRISAT Mali). Thus, all these observations suggest that for a crop in which production both women and men are involved, like groundnut, women's seed quality is likely to be better compared to men's.

Biological differences between cereal crops and oilseeds

An important difference between the cereal crops sorghum and millet and the oilseed crop groundnut is that the amount of seed required to plant the former is much smaller than the later. The quantity and cost per hectare is quite small for cereals— about 4-8 kg of seed for sorghum and 3 -6 kg of seed for millet. Thus, for cereals the quantity of seed that farmers save is usually sufficient to plant their fields (Minot and Smale, 2006). It is also possible to obtain sufficient seed to plant through gifts from kin or friends, since the quantity is not large. That is one reason why seed purchases are rare for these cereals and the commercial formal seed sector has not developed for sorghum and millet in Mali, and indeed in SSA generally (Minot and Smale, 2006, Tripp, 2000).

The biology of groundnut necessitates that seed inputs are a substantial investment in production by farmers. The species is characterized by large grain size, and high oil content, increasing vulnerability to degradation during storage as well as markedly increasing the expense associated with groundnut production. The quantity of seed needed to plant one hectare is about 80-100kg/ha depending on row spacing, plant spacing, seed-mass, and percentage of germination of the seed sample used (Singh and Oswalt 1995).

Seed quality parameter assessed in this chapter

Cushman (2006) defined quality seed as varietally pure seed with a high germination percentage, free from disease and disease related organisms and with a proper moisture content and weight. Seed quality is determined by many factors, principally seed purity (physical and genetic) and physiology (level of maturity, capability to germinate) (Brick, 2004). However, many other factors, such as the presence of seed-borne disease, seed conditioning (storage, age, packaging), and size influence quality (Copeland et al. 2001). Spreading out a representative sample in a single layer on a table top provides an excellent opportunity to observe physical quality and condition of the seed. Laboratory analysis, however, is the only reliable means of determining the ability of seed to germinate, and the presence of diseases (Basra, 1995).

Seed physical purity is determined by the amount of unwanted material present in the pure seed. Seed should not be mixed with other classes or crops, especially those that mature at the same time. The best quality seed is nearly 100 percent pure (Brick, 2004).

Seed germination tests: germination is in another word the sprouting of a seedling from a seed of an angiosperm or gymnosperm. The test of germination assesses seed ability to produce new plants when placed under favorable conditions of adequate moisture, temperature, and oxygen (Copeland et al. 2001).

Seed-born diseases or health status tests assess the ability of the seed to produce a healthy plant when placed under favorable environmental conditions (Basra, 1995).

There are other factors to test seed quality such as: test weight per 100 grains, kernel plumpness, color, and conditioning (storage and handling) (Brick, 2004). For this research I will focus on the first three factors to assess farmers' seed quality, as shown in table 1-1.

Table 1-1: Seed quality parameter characteristics based on seed certification standards used by the International Seed Testing Association (ISTA) and the "Comite Inter-état de Lutte contre la Sécheresse au Sahel" (CILSS)

Parameters	Physical purity	Physiological quality		Health status	Need of seeds /ha
Crops	Weight of impurities	Germination	Weight of 100 grains	Infection	to plant 1 ha
	(%)	(%)	(g)	(%)	(kg/ha)
Sorghum	<2	80	2.8	<2	≈8
Millet	<2	80	1.2	<2	≈3
Groundnut	4	70	24	2	≈100

Source: N'tare et al., 2008 and Diakité 2003

Research Objectives

The overall objective of this research is to access seed quality of sorghum, pearl millet and groundnut used by farmers in two sorghum production zone in Mali in order to assess whether the quality of farmer produced seed is a factor contributing to low yield levels in Mali.

Specific objectives:

- Determine if high quality sorghum seed is available from the informal sector, markets and farmer production
- Evaluate seed quality traits in modern versus local varieties of sorghum
- Determine which location, Dioila versus Mandé, produces better seed quality for each crop.
- Compare farmer storage methods in relationship to seed quality, for each crop
- Determine which seed quality factors are influenced by crop species

Research Hypotheses

1)- Market-sourced seeds are better quality, i.e., having fewer impurities, less disease infection and higher germination rates compared to farmer-produced seeds

2)- Seed quality of modern sorghum varieties is better than that observed in local varieties of sorghum

3-) Seed produced in the Dioila region will be higher quality than seeds produced in Mandé, as farmers have greater access to information sources in Dioila from the long-term presence of extension, NGOs, and the CMDT (cotton company)

4-) Farmer seed stored in panicles or pods will be higher quality than seed stored in grain storage containers

5-) Groundnut will be associated with the poorest seed quality, due to the high oil content of this species, which increases vulnerability to disease and insect damage compared to sorghum and millet seed

6-) Women will do a better job in producing good quality groundnut seed than men, as this crop is traditionally a crop produced by women

MATERIAL AND METHODS

This research falls into the category of baseline studies and systems analytic description models. It will use a step-by-step approach to assess farmers' seed quality for sorghum, millet and groundnut. It will then pull together what is known about the parameters of seed quality for the three crops in Dioila and Mandé zones while identifying the problems and good aspects of farmers' seeds for these crops in Mali. To do so, it uses a descriptive approach to first assess the quality of existing seeds that farmers are planting and a comparative approach to compare seed from the two zones and different storage methods through lab-analyses of seed samples collected at farmers' level. To complete, it assesses farmers' own perceptions about seed quality, seed production and storage through two level surveys (head of households, and individual growers) and follow-up workshops.

Choice of the research areas

The fieldwork was done from May to December 2007 in eight villages and at the ICRISAT research station in Samako in the Koulikoro region in Mali. The laboratory analyses on seed samples were conducted at the research station. The seed sample collection and the surveys were undertaken in two zones: Dioila and Mandé in the Koulikoro region.

Dioila and Mandé were chosen to conduct this research. The reason for this choice is that ICRISAT's local partners in these two zones are also located in these villages. ICRISAT and IER have been working with partners in these two areas since 1999 (Siby) and 2001 (Dioila) on seed system issues. In both areas, this collaboration has led to the identification of superior varieties by farmers. Subsequently these varieties

have been inscribed in the National variety catalogue of Mali, and farmers' organizations have started the production of certified seeds of these varieties for marketing. These areas thus provide an ideal opportunity to test the mentioned hypotheses. The collaboration of ICRISAT with these organizations makes it easier to reach farmers because they are used to the surveys and others related research activities. In Mandé, we worked with ACOD, Office du Haute Vallée du Niger (OHVN) and AOPP and in Dioila with ULPC.

Four villages per zone; Keniero, Siby, Gonsolo and Siranikoro in Mandé and Seribila, Mangnambougou, Wakoro, and Wobougou in Dioila were chosen. The choice of these villages was based on the size, .i.e., the possibility to get 20 households in a village, and the accessibility of the village during the rainy season. They are also villages where ICRISAT and IER are conducting some field trials with some farmers involved in the participatory variety improvement program. Therefore, farmers in these villages are more familiar with research works, such as interviews. The choice was made with Moussa Kanoute (ICRISAT technician) and Dr. Eva Weltzien Rattunde, who know these two zones very well.

Field Activities

The field activities for this part of the research included:

- Seed sample collection
- Lab analysis on collected seed samples from farmers in the research areas.
- A Survey at the farmers' level including individual surveys of sorghum , groundnut, and millet producers and a survey of the heads of the household from which seeds sample were collected.

The data used to test the hypotheses were from the lab analyses of the seed sample collected and surveys at farmers' level. Table1-2 gives the detail of the place where the different activities were conducted.

Table 1-2: Field activities conducted in the two zones: Dioila and Mande where the research was conducted from May to December 2007

Places		Activities	Approximate dates
Dioila zone	Séribila	Seed collection	End of May 2007
	Mangnambougou	Surveys (head of households, and individual survey)	November 29 to December 10, 2007
	Wakoro		
	Wobougou		
Mandé zone	Gonsolo	Seed collection	Beginning of June 2007
	Keniero	Surveys (head of households, and individual survey)	November 18 -27, 2007
	Siranikoro		
	Siby		
ICRISAT research station (laboratory)		Seed quality lab-work	October to December 2007
Dioila		Follow-up workshops	September 11- 13, 2008
Siby		Follow-up workshops	September 17-19, 2008

Data Collection Methods Used

The data used in this research include both primary and secondary data on seed quality of sorghum, millet, and groundnut. The primary data are cross-sectional, both quantitative and qualitative, which were collected through fieldwork. Questionnaires and discussion guides were made for each group of participants according to the type of information needed at a given level of seed production and utilization. The secondary data are based on the results of previous research or studies on seeds in Mali or elsewhere and some secondary data collected at the research station.

Seed Sample Collection

Seed samples for lab analyses were collected from farmers participating in the surveys from the two zones (Dioila and Mandé). In each zone seeds were collected in four villages and from 20 households in each village. The same villages and households

were used for the field survey because I wanted to get information on seed quality from the same people to make the comparison between the information from lab analysis and farmers' points of view on seed quality.

The seed samples included all the three crop types: sorghum, millet and groundnut. In each selected household, seeds for each of the crop were collected. The head of the selected household was asked about the type of crops grown in his/her household during the previous year and those that were to be planted during the current planting season. The sampling was conducted during the period just preceding sowing, and the beginning of sowing in the two target areas. Farmers were asked to share with us samples of the seed that they were going to use for sowing in the near future. According to his/her response, the samples were collected. This way we got, for example, two sorghum samples, four groundnut samples and one millet sample from some households and in others only sorghum samples were obtained.

Appendix 1 present the number of samples collected per zone and per village for sorghum, millet, and groundnut.

Type of seeds (samples of seeds to be collected)

The seeds were collected to represent the seed being used for sowing by the farmers in these two typical regions of sorghum cultivation. In addition to farmers' own seeds, we included samples of certified seed produced by farmer seed producers and seed from crop breeders, who provide seed producers with foundation seeds.

The seeds collected represented: a) Traditional seed system seeds composed of farmers' own seeds, i.e., part of their previous harvest saved to be used as seeds, farmer-to-farmer seeds, which are seeds obtained from exchanges, as gifts, as loans and/or sales,

seeds from local markets grain sellers; b) formal-sector seeds, including improved seeds of improved varieties from researches, seed companies, para-statal seed service (governmental led seed systems), and seed from farmer seed producer cooperatives.

Lab Analyses of Seed Quality Parameters

Seed samples were assessed for the three following quality traits using lab analyses to test:

1- Physiological quality (germination, vigor)

2- Sanitary quality (absence of seed-borne diseases)

3- Physical purity (presence of good seed in a sample, no impurities such as weed seeds, pieces of wood, etc.).

There were pictures of sorghum grain infected by anthracnose; and the signs of anthracnose observed by microscope of the seed sample were assessed based of the visual appreciation of these pictures. These pictures are a reference used by ICRISAT Mali to assess anthracnose infection in sorghum seed samples before planting.

Table 1-3: The seed quality measurement parameters used for the laboratory analyses conducted over the period October-December 2007 on seed samples collected from farmers in Dioila and Mande, Mali in May 2007.

Parameters	Components	Measurement activities
Physical parameters	Physical purity: near absence of inert matters (stones, sand), absence of noxious weed seeds, and broken seeds.	Manually sort each seed sample to separate the inert matters, weed seeds, and broken seeds. Then weight each lot a part and express this weight in term of % of the total weight of the sample
Physiological parameters	Good germination for the lab work samples	Take 100 grains from the a physically good seed lot, put 50 grains in a petri-dish with paper filter in the bottom for sorghum and millet and 20 grains/petri-dish for groundnut. Let them germinate for 3 days for sorghum and millet and 5 to 6 days for groundnut then count the young plants and express them in % by adding the number per petri-dish
Phyto-sanitary parameters	Absence of visible fungi, other disease and living insect	Each sample of sorghum was observed with microscope for presence of anthracnose which is a fungal disease encountered commonly in sorghum in Mali
	Absence of infested young plant after germination	After germination the young plants presenting the sign of fungal infection (covered with a white layer) were counted for each petri-dish

Surveys

Structured surveys were conducted in eight villages (four in each in zone). These surveys included both open-ended and closed questions. My goal was to assess seed quality in a participative way; thus open-ended questions were designed to allow respondents to answer in their own words concerning what they saw as essential aspects about seed quality, from production to storage to utilization in planting.

The survey is composed of two parts: a head-of-household survey (survey instrument is in appendix 4), and a survey of individual sorghum, groundnut and millet growers if they were different from the head of the household (appendix 5).

The first part of the survey was conducted with heads of households to evaluate socio-economic information about the household: size of the farm, number of people living in the household, number of workers in the farm, farm equipment and family member's participation in local farmers' associations or organizations. We also asked about the number of people in the household individually growing groundnut, millet, and/or sorghum. This survey built a relationship with the household head and enhanced farmer interest in participating in the seed survey by reading the consent statement and asking for participant agreement first before conducting the interview. This process was somewhat new for the farmers and helped reassure them that we were interested in their participation and learning from them.

For this first part, the target was the 160 households from which we collected the seed samples; we were able to survey154 of the original 160 households from which we obtained seed. Between the seed sample collection and the survey, a few people moved to another place, and one head of household passed away, but we were able to revisit and

survey from a high percentage of the households surveyed. See appendix 2 for a description of household locations and gender of participating farmers.

A second survey was conducted with the individual sorghum, groundnut, and pearl millet growers from each household. This survey was composed of five parts addressing these following topics: seed source, seed production (if own production), seed quality parameter identification by farmers, farmers' preferred varieties, and general information about the farmer and his/her field. If seeds were sourced from the market, we asked questions to elicit information on this farmer choice, and to find out where the market was located. The final survey section addressed seed quality assessment from the farmer's point of view, which was assessed twice - before planting and after planting.

The surveys in Mande were done from November 18 to 27th 2007 and the ones for Dioila were conducted form November 29th to December 10th 2007.

Choice of the household participants

The choice of the household was made with the extension agent of the villages. Together with the agent, we went from house to house to explain the objective and activities of the research. The choice of the household was then made based on its willingness to participate in research activities. So the households in the samples were composed of farmers conducting on-farm field trials with ICRISAT/IER as well as farmers not involved in the research activities but willing to participate in this research. In all selected villages the majority of households agree to participate in the research, 20 households were randomly chosen among them. The choice of 20 households was based on the resources (times, money, and staff) available.

I used this sample method based on the agents' advice regarding previous experience of research activities conducted in the villages—i.e., they suggested households that had a good record of participating in previous research studies. The extension agents did not want me to end up with a lot of household dropping out of the study in the middle of the research.

Although the sample was from the majority of the households in the villages, the results need to be taken with caution because we don't have the opinion of the minority households who did not want to participate in the research. They might have different point of view on seed quality than the majority.

Follow-up workshops

To get the participant farmers' reactions to the results on the lab analyses of seed samples collected in 2007, on September 11 -19, 2008, follow-up workshops were conducted in two places: September 11 -13, 2008 in Dioila in Dioila zone and September 17-19, 2008 Siby in Mande zone. In each place, two workshops were conducted where farmers from two villages participated. In each village, 20 people (10 men and 10 women) from the 20 households from which the seed samples were collected were invited to attend the workshops.

Each workshop lasted two days. The first days, the preliminary results were presented and all the participants were allowed to comment on the results. The second day, the participants were divided into four groups. Each group was given questions to discuss for one hour. Afterwards, all groups were put together and each group presented its results, on which the other groups commented.

To get women to express their points of view, the groups of women and men were separated. The discussions were facilitated by ULPC, ACOD, OHVN, and ICRISAT technicians, Deborah (a helper), and me.

Data Documentation and Analysis

The seed collection and the entry of identification information for each seed sample and physical purity data were done by the driver (Sidy Dembele) and me. The surveys were conducted by four enumerators (two men and two women), closely supervised by me. I was an enumerator when needed[4] and I checked all data quality in the field and after data entry. The data collection as well as entry from the surveys, and lab analyses was conducted by one person supervised by me.

The lab analyses data included the percentage of germination, percentage of impurities (by weight), and the number of grain and seedling infected for each seed sample. An example of the survey is presented in appendix 5. The quantitative data collected in the survey included socio-economic characteristics and cropping system traits of the households. Qualitative data collected in the survey included gender, zone, seed sources, village, seed storage, and variety type.

Data were first registered on sheet of papers in the lab and on questionnaires for the surveys in villages. Then all the data was entered in Microsoft Excel spreadsheets. The reporting was done using the program Microsoft Word for reporting and the analysis was done using the programs of Excel and Statistical Analysis Software (SAS 9.1.2). Descriptive statistics were used, including frequency analysis, percentages, mean values

[4] When we found that there many farmers in the sample ready to be interviewed quickly so that they could leave for other household needs (farm work, trip, etc...) or other reasons, in order to get everybody interviewed on time I served as an enumerator. This situation was very common.

and standard deviation. The analysis of variance and other statistical tests were done using SAS Generalized Linear Model (GLM) using the CONTRAST statement for the lab analyses and survey data. The GLM PROCEDURE with CONTRASTS enables one to perform custom hypothesis tests (SAS Inc 1999).

The GLM could not be conducted for seed source data, as market sourced seed had a very small sample size compared to own production seed; instead trends were discerned through descriptive statistics. To assess significance, we used α= 20%, i.e., a 20% significance level. This is an appropriate level of significant for on-farm research, given the inherent high variability and importance of discerning trends to elucidate the complexity of seed systems (Manderscheid, 1965).

RESULTS

Surveys

Since the survey sample was chosen based on the household's willingness to participate in the research activities, the results presented here did not include the opinions of the farmers who did not want to participate. However, they are representative of the farmers interested in research activities in the villages where the research was conducted. The fact to not agree to participate in research activities, the nonparticipating households might have different opinions about research those who were willing to participate.

Socio-economic characteristics of the farmers

Consistent with the information obtained from seed collection, the survey found that groundnut is the crop that both men and women are involved in growing, In Dioila, more men (42%) seem involved in groundnut farming than in Mande (14%) (Table 1-4). The middle age (30 to 50 years old) growers' percentage is higher for groundnut, while for sorghum and millet, the majority of growers interviewed are old (>50 years old). This result can be explained by the fact that millet and sorghum are basic food crops and are grown on the family field. Usually the head of the household represents the grower of family crops.

At both sites, the majority of groundnut production is within fields managed individually (80%) rather than the family collective fields (Table 1-4). About 90% of sorghum and millet production is based in the family fields. In the majority of cases, seeds used to plant personal fields are provided by the grower him or herself. Seeds for the family field, on the other hand, are provided by the head of the household.

Groundnut field size and the number of workers per groundnut field are substantially less (0.65 ha, and 1 to 3 people per groundnut field) compared to sorghum and millet (6 to 7ha, and 3 to 4 people per field). A major portion of the farm, and family labor, is devoted to family crop production.

The proportion of growers who received some education is also low among those who grow groundnut, compared to sorghum and millet producers in both zones.

Table 1-4: General information (gender, age, information on the field) of the farmers who participated in the research in 2007 in the two zones: Dioila and Mande

	Groundnut		Millet		Sorghum	
	Dioila n=53	Mande n=79	Dioila n=25	Mande n=15	Dioila n=79	Mande n=75
Gender of growers (% in the sample per gender)						
Men	42	14	96	87	96	97
Women	58	86	4	13	4	3
Age group* of the growers (% in the sample per age group)						
Young	34	37	16	27	15	13
Middle age	36	42	40	33	39	40
Old	30	21	44	40	46	47
Field type (% in the sample per field type)						
Family field	26	14	92	93	96	88
Individual field	74	86	8	7	4	12
Responsible of seed provision for the field (%)						
Head of family	19	5	48	54	63	47
Person responsible for farm work	34	32	36	13	27	36
Grower him/herself	47	63	16	33	10	17
Average field size	0.6	0.7	3.8	3.4	6.6	5.7
(SE)	(0.1)	(0.1)	(0.8)	(0.8)	(0.7)	(0.6)
Average # of workers in the field	3	1	7	5	7	4
(SE)	(0.4)	(0.1)	(1.4)	(1.2)	(0.8)	(0.6)
Education (%)	32	28	40	73	49	45
Level of formal education reached by the growers who received some schooling						
Elementary	12	27	30	27	23	47
Middle school	29	5	10	9	16	15
Local language	29	41	60	54	51	15
Other	30	27	0	10	10	23

*Head of household less than 30 years old= young, between 30 and 50 years old = middle age, and above 50 years old = old.

Table 1-5: Information on the participating household cropping systems in Dioila and Mande

	Dioila n=80		Mande n=74	
Cropping systems	n	% sample	n	% sample
Sorghum only	15	18.7	23	31.1
Millet only	5	6.3	2	2.7
Millet & sorghum	24	30	11	14.9
Groundnut &sorghum	10	12.5	16	21.6
Groundnut &millet	2	2.5	3	4
All three	24	30	17	23
Other	0	0	2	2.7

Sorghum as a sole crop (31%) is the dominant crop planted in the family fields in the Mande zone, while the association of millet and sorghum was 30%, and similarly the intercrop of three crops was 30% of family fields in the Dioila zone (table 1-5). This result is consistent with the high proportion of millet seed samples collected in Dioila and moderate levels of millet seed collected in Mande (see table 1-6 below).

Description of the seed samples used for the test

We examined seed quality parameters in relationship to location (zone and village), variety type, gender of farmers, seed source and storage methods.

Table 1-6: Seed samples collected from farmers in Dioila and Mande on May 2007 for lab-analyses of farmers' seed quality parameters

	Groundnut		Millet		Sorghum		Total/zone	
Zones	n	%	n	%	n	%	n	%
Dioila	74	33	44	20	104	47	222	100
Mande	89	44	17	8	97	48	203	100
Total	163	38	61	14	201	47	425	100

As shown in table 1-6, more groundnut samples were obtained in Mande than in Dioila, indicating that groundnut was grown to a greater extent in Mande (53% of the total groundnut samples and 44% of the samples from Mande) compared to Dioila (47%

and 33% respectively as in Mande) . For millet, the reverse was observed, where millet was very important in Dioila (72% of millet samples and 20% of Dioila samples) compared to Mande. This is consistent with the drier conditions in Dioila, an environment that millet is adapted compared to sorghum. The two zones are almost the same in terms of sorghum production. This confirms that both zones are major sorghum producers.

Table 1-7: The number of seed samples collected in eight villages representing two zones in Mali; Dioila and Mande.

Zones/Villages		Groundnut		Millet		Sorghum		Total	
		n	%	n	%	n	%	n	%
	Seribila	23	36	17	26	25	38	64	100
	Mangnambougou	6	16	12	32	21	52	38	100
Dioila	Wakoro	20	31	4	6	40	63	64	100
	Wobougou	25	46	11	20	18	34	54	100
	Gonsolo	35	59	0	0	23	41	59	100
	Kenioro	8	22	0	0	29	78	37	100
Mande	Siranikoro	20	45	2	4	21	51	44	100
	Siby	26	40	15	23	24	37	65	100
Total		163	38	61	14	201	47	425	100

Note: %= the percentage within village per seed samples, n= number of seed samples collected

In Dioila, when we look at the percentage of seed samples collected in each of the 4 villages per crop, except for Wobougou, sorghum is the crop with highest percentage in the samples in all the villages: 63% of the samples in Wakoro, 52% of the samples in Mangnambougou and 38% in Séribila. Groundnut has the highest percentage (46%) in Wobougou and is the second crop in Séribila and Wakoro. Millet shows up in second place in Mangnambougou with 32% of the samples and in the third in the other three villages.

In Mande zone, sorghum is the first crop in Keniero (78%) and Siranikoro (51%), Groundnut is the first crop in Gonsolo (59%) and Siby (40%). In contrast to the Dioila zone, we did not get any millet samples in Gonsolo and Keniero.

Table 1-8: Number of seed samples collected per gender and per crop (groundnut, pearl millet, and sorghum) in Dioila and Mande for farmers' seed quality assessment study

Gender	Groundnut		Pearl Millet		Sorghum		Total	
	n	%	n	%	n	%	n	%
Men	57	35	61	100	196	97	314	74
Women	106	65	0	0	5	3	111	26
Total	163	100	61	100	201	100	425	100

From table 1-8, it is clear that sorghum seeds (97% from men) and millet seed (100% from men) are not crops that seeds are produced by women. Groundnut, on the other hand, is the crop where both men and women are involved in the production, but 65% of the seed samples were from women which is consistent with it being a crop produced mainly by women. This finding supports my choice of groundnut as crop to get women involved in my research and confirms why women's participation in millet and sorghum plant breeding participatory research has been limited to variety evaluation visits, and conducting culinary trials in southern Mali.

Table 1-9: Number of seed samples collected per type of varieties (modern versus local) for all three crops in Dioila and Mande

Variety type	Groundnut	Pearl Millet	Sorghum	Total
Local	151	60	159	370
Modern	12	1	42	55

Looking at the variety types, local varieties representing 87% of all seed sample collected are dominant for all three crops. Except for sorghum, where the modern varieties represent about 21% of sorghum seed samples collected, there were apparently few modern varieties of groundnuts or millet adopted in these zones. Millet had almost

no modern varieties. For testing the hypothesis about comparing modern and local varieties, I therefore chose to focus on sorghum only.

Table 1-10: Number of seed samples collected per seed sources for all three crops (groundnut, pearl millet and sorghum) in both zones: Dioila and Mande

Seed sources	Groundnut	Pearl Millet	Sorghum	Total
Own production	158	58	195	411
Market	4	2	4	10
Exchange	1	1	1	3
Gift	0	0	1	1

For seed sources, own production represented about 97%, and market sources were ~2% of the total. For hypotheses testing, I focus on two sources only--own production and market--for the comparison because the sample size for the other sources is too small. Also I want to know seed quality for market seed versus own production in anticipation of making recommendations for promoting seed marketing.

Table 1-11: Percentage of seed samples sourced in market versus farmers own produced seed per zone (Dioila and Mande) and per crop type (groundnut, pearl millet and sorghum)

	Groundnut		Pearl Millet		Sorghum		total	
	Own Pr	Market	Own Pr	Market	Own Pr	Market	Own Pr	Market
Dioila	93	5	95	3	97	2	95	4
Mande	100	0	100	0	100	0	100	0

Own Pr = farmer produced seed

Self provision of seeds was relied on for more than 90% of seeds in all three crops, thus own production was the most common source of seeds used in the study areas (Table 1-11). Market sourced seeds for groundnut (5%) was slightly higher than for the two other crops.

There were many storage methods. To make the analyses feasible, I grouped them into the following simplified categories: seed stored in grains versus seed stored in panicles or pods.

Table 1-12: Number of seed samples collected, by seed storage method for sorghum, millet and groundnut per zone

	Sorghum		Millet		Groundnut	
	Grains	Panicles	Grains	Panicles	Grains	Pods
Dioila	54	50	41	3	2	72
Mandé	17	80	11	6	0	89
Total	71	130	52	9	2	161

From table 1-12, in Dioila zone, farmers stored most of their sorghum seeds as grain (52%) rather than as panicles. In Mande, storage in panicle was the most common method: 83% of sorghum seed samples were stored in panicles compared to 17% as grain. For millet, the storage of seed as grain was the common practice in both zones. Storage in pods (unshelled) was the most common storage method for groundnut seeds across zones.

Lab analyses

The following parameters were assessed to evaluate seed quality: physical purity (percentage of the weight of impurities), physiological quality (germination percentage) and health status (% anthracnose for sorghum alone before germination test and the percentage of seedling infection with germination test) (Table 1-13).

Hypothesis 1: Market-sourced seeds were hypothesized be higher quality than farmer's own seed production.

The general descriptive statistics (mean, and standard deviation) presented allow a comparison between the two seed sources, market and own production. For sorghum and

millet, the mean level of impurities observed for all sources was below 10%. For groundnut, the mean level of impurities was slightly above 20% for own production and slightly less than 20% for market-sourced seed. In both cases, own production and market, the level of impurities was above the level allowed for certified seeds (4%) (Ntare et al., 2008).

All seed samples were found to have an 80% or greater germination rate, which is sufficient to be high quality seed (see table 1.1).

In terms of seed infection, a key difference was observed between own production and market source in groundnut (figure 1.3). Market-sourced seeds had less infected seeds (18%) compared to own production (22%).

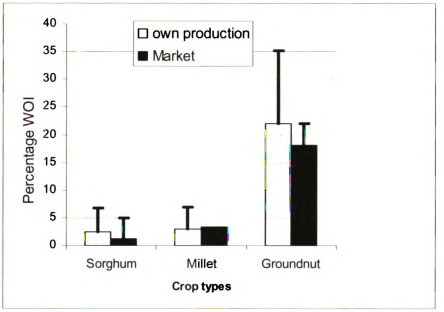

Figure 1-3: Percentage of seed impurities weight by crop for market versus farmers own produced seeds of seed samples collected in Dioila and Mande. The bars represent the average weight (means) and lines above the bars represent the standard deviation from the mean

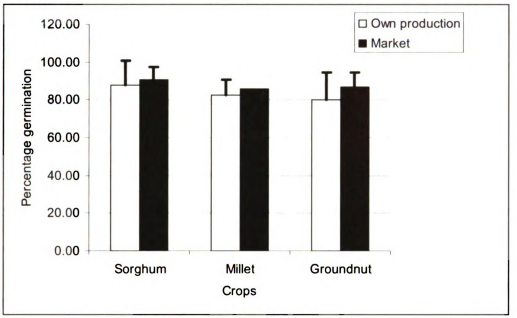

Figure 1-4: Percentage of germination by crop for market-sourced versus farmers' own-produced seeds of seed samples collected from farmers in Dioila and Mande. The bars represent the average weight (means) and lines above the bars represent the standard deviation from the mean

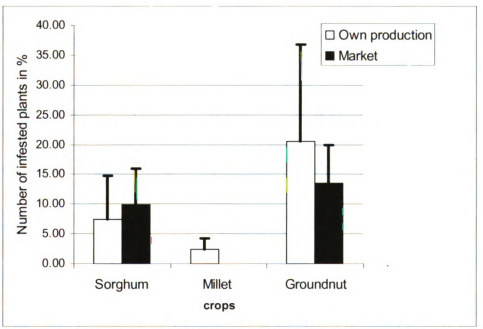

Figure 1-5: The percentage of infected seedlings for each of three crops for market-sourced versus farmers' own-produced seed of seed samples collected from farmers in Dioila and Mande. The bars represent the average weight (means) and lines above the bars represent the standard deviation from the mean

The infection of sorghum seed was the opposite of that observed for groundnut, i.e., the market-sourced seeds had the higher infection rate (figure 1-4). Overall, the infection level for sorghum was low, less than 10% for both sources.

Hypothesis #2: The table 1-13 below presents data comparing seed quality of modern varieties in sorghum to local varieties. No effect of variety was found on sorghum seed quality.

Table 1-13: Seed quality characteristics are presented for modern and local sorghum varieties, along with standard Error of the mean (SE) and a GLM contrast to test if modern versus local varieties are significantly different.

Statistic for variety types		Seed quality parameters			
		WOI	Anthracnose Infection (%)	Germination	Infection
Local n=159	Means	2.7	2.8	88	7.1
	SE	0.2	0.2	7.0	0.6
Modern n=42	Means	2.5	3.4	88.0	8.1
	SE	0.3	0.5	13.5	1.2
Contrast modern vs local	P-value	0.78	0.52	0.91	0.80

WOI refers to the percentage of the weight of impurities found in a seed sample
SE refers to standard error of the mean

These results are not conclusive due to high variability they do not provide evidence that seed quality of modern varieties is different from local varieties.

Hypothesis #3: Seed quality of sorghum samples was evaluated to determine if the seed location was an important determinant. It was found that seed from Dioila had slightly higher rates of impurities, anthracnose infection and seedling infection compared to Mande (Table1-14).

Table 1-14: Seed quality characteristics for Dioila and Mande sorghum varieties, along with standard error of the mean (SE) and a GLM contrast to test if quality characteristics of seed from Dioila are significantly different from those from Mande.

Statistic per zone		Seed quality parameters			
		WOI	Anthracnose Infection	Germination (%)	Seedling Infection
Dioia n=104	Means	3.7	3.7	88.1	9.6
	SE	0.4	0.4	8.6	0.9
Mande n=97	Means	1.5	2.1	88.2	5.9
	SE	0.1	0.2	9.0	0.6
Contrast modern vs local	P-value	0.0011	0.0569	0.95	0.0002

The seed quality response was further examined by village, where it was shown that the highest level of impurities was found in Wakoro, Dioila zone. The highest percentage of anthracnose infection (9%) and the highest percentage of general infection (16%) were found in Mangnambougou, another village in Dioila zone (table 1-15). Thus, these results are consistent with sorghum seed quality being generally better in Mande compared to Dioila.

Table 1-15: Seed quality analyses results for sorghum are presented by village of production Mean, and Standard Error presented in parentheses, to identify which villages have better quality seed

	% impurity	% Anthracnose infection	% infected plants
Mangnambougou	3.2 (0.7)	9.0 (1.9)	16.0 (3.5)
Séribila	2.6 (0.5)	2.5 (0.5)	7.5 (1.5)
Wakoro	5.0 (0.8)	1.1 (0.2)	6.3 (1)
Wobougou	2.6 (0.6)	4.6 (1.1)	12.1 (2.9)
Gonsolo	1.2 (0.2)	1.1 (0.2)	6.6 (1.4)
Keniero	1.4 (0.2)	1.3 (0.2)	4.5 (0.8)
Siby	1.1 (0.2)	4.1 (0.9)	6.7 (1.5)
Siranikoro	2.7 (0.5)	1.3(0.3)	4.7 (0.9)

To provide insight into these results, I looked at the two extreme values per seed parameter that tested significant. Table 1-16 shows this information.

Table 1-16: Factors contributing to high values in impurities observed among sorghum seed samples, including varieties and villages where seed were produced.

		Extreme value	Sample number	Variety Name	Village
		42	15	Soguerekou	Wakoro
	Dioila	40	14	Algerien	Wakoro
%WOI	Mande	10	172	Tiemarifing	Keniero
		10	126	Kendebilen	Gonsolo
%		42	61	Bandoka	Wobougou
Anthracnose	Dioila	24	79	Algerien	Magnambougou
Infection	Mande	44	130	Tieblen*	Siby
		18	110	Dorongonnikalan	Siby
% general		40	79	Algerien	Magnambougou
infection	Dioila	35	61	Bandoka	Wobougou
	Mande	27	116	SUMALEMBA*	Gonsolo
		20	113	Dorogonnikalan	Siby

The varieties with * are modern varieties.

Table 1-17: Seed quality characteristics for Dioila and Mande for pearl millet and groundnut, along with standard Error of the mean (SE) and a GLM contrast to test if seed from Dioila and Mande are significantly different.

Statistic per zone			Seed quality parameters		
			WOI	Germination	Infection
	Dioila			%	
	n= 44	Means	4.0	81.0	3.0
Pearl		SE	0.6	12.3	0.4
Millet	Mande n=17				
		Means	1.3	86.0	2.0
		SE	0.3	21.0	0.5
	Contrast Dioila vs Mande	P-value	0.0379*	0.0506*	0.0418*
	Dioila			%	
Groundnut	n= 74	Means	17.0	85.0	16.0
		SE	2.0	9.9	1.9
	Mande n=89				
		Means	26.0	76.0	24.0
		SE	2.8	8.1	2.5
	Contrast Dioila vs Mande	P-value	<.0001	<.0001	0.0046

For millet, there was evidence that seed quality varied by zone, with higher quality seeds being produced in Mande (table1-17).

In contrast to the observations on seed quality for cereals, the opposite trend was observed in groundnut. Dioila was associated with higher seed quality. Seeds from Diola had over 17% weight of impurities, 85% germination rate and 16% infection level, which were better levels than groundnut seed from Mande with respectively 26%, 76% and 23% (table 1-17).

Hypothesis # 4: Comparing storage methods

For sorghum, comparisons were made in relationship to three important methods of storage: grains, sheaves, and panicles not attached together.

Table 1-18: Seed quality characteristics per storage methods commonly used by farmers for each crop, along with Standard Error (SE) and a GLM contrast to test if quality measures for seeds stored in panicles, sheaves, and grain are significantly different.

		Seed quality parameters			
		WOI	Ant Infect	Germ	Infection
Grain n=72			%		
	Means	3.9	2.3	90	8.4
	SE	0.4	0.3	10.6	1.0
Sheaves n= 64					
	Means	2.5	5.2	87	10
	SE	0.3	0.6	10.9	1.2
Panicles n=65			%		
	Mean	1.4	1.4	88	5.1
	SE	0.2	0.2	10.9	0.6
Contrast grain vs. sheave and panicle	P-value	0.0089	0.19	0.180	0.38
Contrast sheave vs. Panicles	P-value	0.191	0.0001	0.72	0.0001

Ant Infect refers to Anthracnose Infection, Germ refers to Germination rate
Sheave is a sorghum storage method where farmers select the good panicles during or before harvest and attach them together to form a sheave that they hang inside the granary or the kitchen and/or hang it on a tree in the courtyard.

The results for sorghum show that the difference between seeds stored in grains and those stored in panicles (sheaves and single panicles) is highly significant for WOI only. Seed stored as grain, with about 4% WOI, has significantly more impurities than

seed stored as panicles (2%). For anthracnose, the trend was reversed: seeds stored as grain had 2.0% infected grains, whereas seed stored in the panicles had 3.3% infected grains. The same trend appears with germination rate: seed stored as grain has a 90% germination rate, compared to seed stored in panicles with 87.5%. The comparison between sheaves and single panicles also showed the all quality parameters were influenced by storage method, with the exception of germination rate (Table 1-18). Seeds stored in single panicles had higher quality parameters (1.4% WOI, 1.4% Ant-infection, and 5.1% total infection) compared to seeds stored in sheaves (with 2.5%, 5.2 and 10%, respectively).

Groundnut seeds stored in pods, in a bag, had slightly lower impurities, with 20% WOI, compared to 25% in pods stored in a granary (table 1-19). Seeds stored in pods in a bag had an 83% germination rate and 18% infection rate, compared with a 73% germination rate and 25% general infection for seeds stored in pods in granary

For millet, there was no significant difference between seeds stored as grain and seed stored as panicle, for all quality parameters assessed (table 1-19). However, the sample size for panicle storage was low.

Table 1-19: Seed quality characteristics per storage methods mainly used by farmers for groundnut and pearl millet, along with standard error of the mean (SE) and a GLM contrast to test if seeds stored by different method are significantly different.

			Seed quality parameters		
			WOI	Germination	Infection
	Pods in bags n=97			%	
		Means	20.4	83.0	17.7
		SE	2.1	8.5	1.8
	Pods in granary n=64				
Groundnut		Means	24.0	75.0	25.0
		SE	3.0	9.4	3.1
	Contrast pods in bags vs. pods in granary	P-value	0.0925	0.0002	0.0068
	Panicles n=9				
		Means	2.0	84.0	2.4
Pearl		SE	0.7	28.0	0.8
Millet	Grain n=52				
		Means	3.8	82	2.5
		SE	0.5	11.4	0.3
	Contrast Panicles vs grain	P-value	0.354	0.5324	0.898

Hypothesis # 5: Comparing groundnut versus millet and sorghum seeds

Table 1-20: Seed quality characteristics are for sorghum, pearl millet and groundnut seed samples along with standard error of the mean (SE) and a GLM contrast to test if seed of the three crops are significantly different from each other.

		Seed quality parameters		
		WOI	Germ	Infection
			%	
Sorghum	Means	2.7	88.0	7.8
n= 201	SE	0.2	6.2	0.5
Millet n=61	Means	3.6	82.4	2.5
	SE	0.5	10.7	0.3
Groundnut n=163	Mean	21.8	80.4	20.4
	SE	1.7	6.3	1.6
Contrast groundnut vs Millet & Sorghum	P-value	<.0001	0.0005	<.0001
Contrast Millet vs and Sorghum	P-value	0.5	0.0026	0.0011

To evaluate biology of crop effect on seed quality, the effect of legume versus cereal crop types was tested by comparing seed quality in groundnut, a legume crop, to that in sorghum and millet, cereal crops. A second comparison was done between the two cereal crops. The results of the first comparison showed that there were highly significant differences between legume and cereal species (P-values for the three parameters were respectively <0.0001, 0.0005, <0.0001). Groundnut had 22% WOI, an 80% germination rate and a 20% seed infection rate. This is indicative of considerably more seed quality concerns for groundnut than sorghum and millet with 3%, 85%, and 5% respectively of WOI, percentage germination and infection.

The second comparison between sorghum and millet showed that germination level for sorghum seeds was better at 88% compared to millet at 82% (P-values for the germination rate was 0.0026). However, millet had a 2.5% infection level and thus much less seedling infection potential compared to sorghum seeds at 7.8% infection (P-value for infection was 0.0011).

Hypothesis # 6: The influence of gender on seed quality could only be assessed for groundnut, which was grown by both men and women.

Table 1-21: Seed quality characteristics per gender for groundnut seeds collected from farmers in Dioila and Mande zones along with standard error of the mean (SE) and a GLM contrast to test if seed from men and women are significantly different.

			Seed quality parameters	
		WOI	Germination %	Infection
Women n=106	Means	24.0	78.0	23.0
	SE	2.3	7.6	2.2
Men n= 67	Means	17.0	85.0	16.0
	SE	2.1	10.4	1.9
Contrast Men vs Women	P-value	0.0006	0.0007	0.0101

The results of these comparisons showed that there are significant differences between men and women in term of groundnut seeds management. For all three quality parameters tested: WOI, germination rate and infection, men's seed samples showed to be better quality than women's seed samples.

Farmers seed storage from survey

The survey results show that storage in pods and panicles is the most common seed storage practice for all three crops; and this was consistent across zones (table 1-22). Comparing the two zones, the amounts of seeds stored in pods/panicles in Mande are higher for all three crops (82%, 67% and 81% respectively for groundnut, millet and sorghum).

Table 1-22: Seeds storage method used by farmers in Dioila and Mande, for groundnut, millet, and sorghum observed during farmers seed quality assessment study done from May to December 2007 in southern Mali

	Groundnut		Pearl Millet		Sorghum	
	Diola n=53	Mande n=79	Diola n=25	Mande n=15	Diola n=79	Mande n=75
Storage method (% in the sample of the survey)						
In grains	6	0	44	33	24	11
Pods/panicles	77	82	48	67	75	81
No Response*	21	18	8	0	1	8
Pods/panicles storage method (% of people who stored in pods/panicles)						
In bulk in granary	34	34	24	13	25	23
In bags stored in granary	13	16	12	20	7	14
Sheaves stored outside	0	0	20	20	22	34
Sheaves stored in granary	0	0	20	40	22	29
No Response*	53	50	24	7	24	0

* The survey participation consent statement allowed the respondent to not answer questions if she/he doesn't have answer for or doesn't fell comfortable in answering.

Bulk pods or pods in bags within a granary are common practices for groundnut storage in both zones (table 1.22). Millet panicles are stored equally outside and in granaries in Dioila, while in Mande sheaves are in the main stored in granaries (40%).

Farmer seed storage issues

As presented in the table 1-23 below, during storage, farmers are concerned about different issues depending on the crop type. For groundnut, farmers worry mostly about insect attack on seeds. In Dioila, 57% of groundnut growers were concerned about insect attack, whereas 68% of farmers in Mande were concerned. Insect attack is often followed by further degradation, a concern of 32% of farmers in Dioila, and a related concern about humidity was expressed by 10% of farmers in Mande. During millet storage, farmers worry mostly about temperature because very high temperature can kill the embryo, and more so in Dioila (76%) than in Mande (40%). For sorghum, insect attack is a critical factor of concern during seed storage; 76 to 80% expressed this concern at both sites. Other physical damage following insect attack was also of concern in sorghum seed storage, along with being an issue in groundnut.

Table1-23: Factors of concern for farmers during seed storage of the groundnut, millet, and sorghum in Dioila and Mande identified during the farmers seed quality assessment study done from May to December 2007 in southern Mali

	Groundnut		Pearl Millet		Sorghum	
	Diola n=53	Mande n=79	Diola n=25	Mande n=15	Diola n=79	Mande n=75
Factors of concern during seed storage						
Temperature	2	6	76	40	4	15
Humidity	2	10	0	8	6	17
Insect attack	57	68	0	0	76	80
Other physical degradation	32	8	40	33	13	29
Prevention of seed loss during storage						
keep seed in pod/panicles	28	1	4	0	6	4
Chemical treatments	0	63	44	13	47	15
Regular checking during storage	13	2	8	20	11	21
Other	21	5	20	27	16	12

The percentages (%) in this table indicate the frequency with which a quality parameter was cited by farmers.

To address the concerns described, farmers use different methods. For groundnut, the most popular practice was to store seed in pods (unshelled) in Dioila (28%); while in Mande seed treatment was the key practice for seed protection by groundnut famers (63%). In Dioila, both millet and sorghum are protected using seed treatments, reported by 44 to 47% of farmers respectively. In Mande, other prevention practices were reported by 27% of farmers for millet, and regular checking during storage was reported for sorghum (21%).

3-3-2 Seed treatment during storage at farmers' level

Table 1-24: Seed treatment used by farmers in Dioila and Mande during seed storage for the groundnut, millet, and sorghum documented during farmers seed quality assessment study done in 2007 in southern Mali

	Groundnut		Pearl Millet		Sorghum	
	Diola n=53	Mande n=79	Dioila n=25	Mande n=15	Diola n=79	Mande n=75
Treatments during storage (Yes)	28	**77**	44	27	34	19
No	51	6	44	40	42	45
No response	21	38	12	33	24	36
Type of treatment (% of people who treated seeds during storage)						
	n=15	n=61	n=11	n=4	n=27	n=14
Spraying insecticide liquid	7	3	36	25	7	0
Use of insecticide in small pieces	53	87	36	25	67	36
Use of insecticide in powder	27	2	18	25	18	28
Traditional treatment	7	2	0	0	0	0
Others	6	6	10	25	8	36
Time of the treatment						
Beginning of storage	67	84	64	25	81	28
In middle of the storage	0	0	0	0	4	36
Others	33	16	36	75	15	36
#of treatment						
One treatment	73	74	45	50	74	78
More than one	7	8	19	25	4	14
No Response	20	18	36	25	22	8

Seed treatment during storage is not common practice for millet and sorghum in both zones. For groundnut, 77% of the farmers interviewed in Mande said that they treated their seeds during storage, while only 28% did in Dioila zone. Of the people who did treat their seeds, most used insecticide in small pieces for all three crops. Here again, 87% of Mande farmers have used this product for groundnut and 67% in Dioila did for sorghum. Except for millet in Mande, most of the treatments were done at the beginning of the storage.

Farmers' assessment of seed quality

Table1-25: Farmers' seed quality evaluation as assessed through survey questions conducted before and after planting on December 2007 in the eight villages representing Dioila and Mande zones in Mali

	Groundnut		Millet		Sorghum	
Quality parameters	Dioila n=53	Mande n=79	Dioila n= 25	Mande n=15	Dioila n=79	Mande n=75
Before planting						
Appearance	72	90	52	60	63	77
Past experiences	17	27	4	0	21	28
Information from other growers	28	25	20	20	33	28
Seed coat integrity	53	78	56	67	40	76
% impurity	40	46	32	40	34	37
Seed shape	57	54	28	60	37	53
Seed color	41	37	24	33	30	29
Seed size	55	35	32	47	27	47
Insect attack	62	44	56	53	48	56
Presence of other grains	4	16	0	7	4	1
After planting						
Germination rate	77	66	72	80	71	83
Vigor of seedling	9	24	4	40	11	24
#of healthy plants	6	35	4	20	5	39
Others	0	4	4	0	4	4

The percentages (%) in this table indicate the frequency with which a quality factor was cited, where farmers could report more than one seed quality attribute

The results in this table show that farmers put different weight on quality parameters depending on the crop type. Before planting, appearance is the most important quality parameter for groundnut and sorghum in both zones (table 1-25). In Mande, almost all farmers (90%) surveyed prioritized the appearance of groundnut seed before planting. For both sorghum and groundnut, appearance was followed by insect attack (48% sorghum and 62% groundnut) in Dioila, and seed coat integrity (76% for sorghum and 78% for groundnut) in Mande. For millet, the most important quality parameters before planting were seed coat integrity and insect attack (56%) in Dioila and seed coat integrity (67%) followed by appearance and seed shape (60%) in Mande (table 1-25). This changed after planting. The percentage of germination was the most popular seed quality factor later in the season and was reported by ~ 75% of farmers for all three crops, across zones.

DISCUSSION

In Mali, it is a general assumption by researchers and policymakers that farmer-produced seed is of inferior quality compared to formal sector and research produced seed (Diakité, 2004, Yapi et al., 2000). According to Diakité (2004), the wide use of local sector seeds constitutes one of the major challenges facing sorghum production in Mali. My research tested this assumption for different seed sources, storage types and crops.

Cropping system characterization

As expected, cropping system patterns followed agroecological zones: millet was grown primarily in Dioila, which has a drier climate than the Mande region, reflecting the adaptation of millet to low rainfall conditions. A majority of the groundnut samples were also found in Mande, about 55% more of the sample compared to Dioila (table 1-6). This finding is somewhat surprising, as groundnut generally requires more rainfall than is typical of Dioila. The higher prevalence of groundnut in Mande may also reflect the role of alternative cash crops in Dioila, as cotton has been grown for decades in this zone supported by the Malian cotton company (CMDT) , and this may reduce farmers' incentives to grow groundnut as a cash crop (Boughton, 1994; ICRISAT, 2002).

There are also socio-economic factors that influence cropping patterns. According to Malian tradition, the male head of the household is responsible to ensure the staple grain food of sorghum and millet (Becker, 2000), whereas women are expected to take care of the ingredients of the sauce, including groundnut. As a result, men usually grow millet and sorghum, while married women grow sauce crops such as groundnut and okra (Broek 2007). The data from our survey on field size, the age group of the grower, the

field type and the number workers per field all were consistent with the importance of sorghum and millet as family staple crops (table 1-4).

The literacy rate for producers of groundnut was lower than the rate for farmers that primarily produced millet and sorghum; this is presumably due to the vast majority of cereal producers being men, who have a higher literacy than women who made up about half of the groundnut producers. Based on these results, we are not surprised that on-farm research in this area, which has focused primarily on cereals, has had low participation of women (Broek, 2007).

Farmers' seed sourcing

The informal seed sector, particularly the 'own-produced seed,' is the most important seed source for all three crops. As shown in table 1-11, own-produced seeds represented more than 90% of seed samples collected. This result reflects the trend of seed provision in the research areas. Siart (2008), in her research on strengthening local seed systems conducted in the same zone, found similar seed source results. Diakité (2003), in his study of promoting improved varieties diffusion through seed sale, showed that seeds, particularly sorghum seeds, in the research areas have more social values than market value. Seeds are there to consolidate the deep social relationships within a community, not to be sold in much of Mali (Siart, 2008, Broek, 2007, Diakite 2003). And he concluded that any sustainable and efficient action toward improving farmers' seed provision in these two zones should take into account the realities of the informal seed sector.

Farmers reported in Mande that no seed was sourced from the market (Table 1-11). This was surprising, as NGOs and researchers have been promoting seed fairs in this

region, and this should have augmented availability of seeds in the samples from a range of sources. For example, Siart (2008) documented seed fairs held in 2005 in Mande where more than 90% of the participants were happy with the seed quality and about 80% found that the prices were affordable. We have not found an explanation for this absence of market-sourced seed in our sample, although it should be taken into consideration that purchasing seed of staple crops is not culturally seen as appropriate behavior (Siart, 2008; Broek, 2007; Diakite, 2004). Farmers may be unable to produce sufficient seeds, but for socio-cultural reasons, they do not want to be seen buying them.

Groundnut seed was sourced to a limited extent (5%) from markets, higher than the other crops. This result is not surprising because the biology of groundnut is characterized by high germination and infection rates, as well as a high oil content, which leads to spoilage and makes seed storage difficult (N'tare et al., 2008). In addition to biological reasons to purchase seed, farmers sometimes grow groundnut as a cash crop and thus may be interested in expanded access. Further, groundnut seed if often lost through consumption (e.g., during a social event such as a wedding) or due to emergency cash needs (N'tare et al., 2008). These findings in groundnut are similar to research on bean seed systems in Eastern Africa that indicated farmers often face multiple losses of legume seeds, and intermittently rely on seed purchases to renew bean varieties (David and Sperling, 1999).

Seed storage

A consequence of widespread reliance on own-seed production is that farmer storage conditions are important determinants of seed quality at planting. Farmers have

developed specific storage techniques and practices that vary with culture and crop type (Christinck et al., 2006).

Seed stored in panicles (or pods for groundnut), or as grain, were the two most important storage methods used. Storage as grain was mostly used for millet. Farmers report that they store sorghum seeds in pods/panicles to prevent damage caused by insects and mice (N'tare et al, 2008, Siart, 2008, Diakite, 2003). Similarly, all groundnut samples were stored in pods to protect against pest damage (author's survey data 2007). Sorghum storage in the Mande zone involved substantial storage in panicles, much more so than in Dioila (table 1-12). This result agrees with a Siart (2008) study conducted on sorghum in the two zones. It also provides evidence that improved, local practice and traditional knowledge is widely understood and used in Mande but much less so in Dioila, where there are many extension services (ICRISAT, 2002).

Seed Quality

Farmers want seeds of good quality and with the characteristics they need for their particular agro-ecological conditions and objectives (ICRISAT, 2000; Diakite, 2004, Chakanda, 2000). However, the key aspects of seed quality such as capability to germinate, age, health status, and the effect of storage can be difficult to judge when acquiring seeds. In other words, seeds are not transparent in term of quality (Badstrue, 2007). The only way to evaluate seed quality parameters is through testing. The three seed quality parameters measured in our study - physical purity, germination rate, and health status – were found to be high for all farmer produced seed. This held true for the three crops studied, all of which met the seed quality standards set by the SSN and the Harmonized Standard of "*Comite Inter-etat de Lutte contre la Secheresse au Sahel*"

(CILSS) countries for groundnut (N'tare et al., 2008, Diakite, 2003, Almekinders and Louwaars, 1999). The only exception of was infection level, which was higher than the recommended 0%, but we note that infection was less than 5%, which is on a practical level what is achievable in seed production in Mali.

Seed quality for purchased versus farmers' own-produced seeds

Seed physical purity for sorghum and groundnut from purchased source seeds was higher than that observed for farmer-produced seeds. This result was not surprising because sorghum seed from a purchased source in the Dioila zone was from the organization of cereals producers - OPCs (author's survey data 2007), and the members of these farmers organization receive training on seed production from ICRISAT and IER (Siart, 2008). In addition, during the meetings with farmers, they attested that appearance of market seeds is better than own-produced seeds because sellers pay attention to producing clean seed that to attract buyers. One farmer (from Keniero Mandé) said: "*the sellers do all they can to attract buyers whose only quality appreciation parameter is the appearance at that very moment. They clean the seeds well and put them in clean bags or boxes*" (meeting with farmers, September 18th 2008).

In terms of germination rate and seed infection level, this study documented that market-sourced seed was slightly better quality than farmer-produced seed for millet and groundnuts (figures 1-3 and 1-4). This result for groundnut is not a manual by N'tare et al., 2008 concerning groundnut seeds from different sources. For millet, the results have to be taken with caution because the sample size was too small.

For sorghum, in all cases the farmer-produced seed quality was high, with only moderate or no reduction in quality compared to market-produced. The moderately

higher levels of infection in the market-sourced sorghum compared to farmer-produced seed may be indicative of a major problem. Through the survey comments I found that farmers report that market seeds of sorghum are varietally pure, but are often infected, which leads to diseased seedlings (author's follow-up workshops 2008). A farmer from Gonsolo (Mande) said: *"If we are running out of seeds, and cannot get it with a friend or relative, that is when we use the market source, but seeds from market are infected and we cannot tell at the time we buy them. When the infection starts, it is too late to replant and we don't know what to do."* Another farmer from Siby said *"Even if they look good (clean), we don't like market seeds because we don't know the variety"* (meeting of September, the 17th 2008).

This result should take seriously because it shows one of the obstacles to the promotion of seed markets and the diffusion of modern varieties in Mali (Yapi et al., 2000; Diakite, 2004). However, this finding is consistent with ICRISAT (2000) statement that "*farmers have selected seed from their crops for the next season. Their knowledge has been accumulated over generations, and nobody is in better position than they are to choose seed for them*".

To summarize, the results suggested that farmers are producing high quality seed, which may reduce the incentive for farmers to purchase seed. There may be other considerations beyond quality that influence the very low percentage documented here of farmers sourcing seed from market. There are other factors than seed quality that could explain reluctance to purchase seed.

- The cultural view of seeds as a non-market good, as mentioned by Diakite, 2004, in his study on the use of sale as way to promote the diffusion of

improved varieties in Dioila, and Broek, 2007, field work paper on sorghum production by women in both zones.

- The lack of information on market seeds, as suggested by Sperling et al., 2006 in assessing seed security in northern Mali, and Badstrue, 2007, in her paper "The role of trust in the acquisition of seeds".

Seed quality for modern varieties versus local variety seeds

The analyses of the three quality parameters for sorghum modern and local varieties showed that there was no significant difference between modern and local varieties with respect to these quality parameters. The study by Siart (2008) on strengthening local seed systems in Dioila and Mande zones showed that under different conditions (soils, rainfall, and temperature), farmers 'local seeds achieve high germination rates (>80%) and high physical purity (<2%)'. Yapi et al. (2000) also showed that one of the reasons for low adoptions of modern sorghum varieties was because they were not superior (adaptation, yield and taste) to local existing varieties. Our findings suggest that the low yield potential of local sorghum varieties,, which Diakite, 2003, attributed to the wide use of farmers' seeds, might be due to reasons other than seed quality.

Seed quality by zone (Dioila versus Mande)

Farmers in Dioila are provided technical information from such organizations as CMDT and many development NGOs such as ULPC, Netherlands Development Organization (SNV) projects and others. Thus they have significantly more access to information and training than in Mande (Siart, 2008), and we expected that Dioila farmers would have access to and produce high quality seed. Surprisingly, sorghum seed

samples from Mande showed better quality characteristics compared to samples from Dioila (table 1-14). This indicates that traditional seed production and storage practices (storage in sheaves) – which are practiced widely in Mande— are conducive to producing high quality seed, at least in sorghum (table 1-12).

Another important factor may be the prominent presence of modern variety *SUMBA* in Dioila compared to Mande. The improved variety called *SUMBA* was a major source of infection in Dioila, more particularly in Mangnambougou collected seeds (table 1-15). According to farmers, the high infection of "*SUMBA*" is related to its early maturity, which leads to it being harvested when it still raining and being stored at high moisture content (unpublished data from follow-up workshops in Dioila, September 2008).

Overall, groundnut showed that reasonably high quality seed could be produced by farmers, although physical purity and infection was higher (>10%) compared to the CILSS harmonized groundnut seed quality standards, which are respectively 4% and 2% (N'tare et al., 2008). Overall, groundnut seed samples from Dioila were of better quality than those from Mande (table 1-17). The germination rate was high from both zones, in almost all cases greater than the CILSS standard of 70% for groundnut. This is surprising in view of the high oil content and vulnerability to pests often found with this crop (Tripp, 2000; N'tare et al., 2008, Nigam et al., 2004).

Seed quality by storage methods

Consistent with earlier studies conducted by ICRISAT in the research areas, we found three major sorghum seed storage methods: grains, sheaves and single panicles (Diakite 2003, Siart, 2008). Across a wide range of storage methods, the level of general

infection was above the SSN standard (>5%). However, our research indicated that seed stored as panicles and sheaves had better seed quality than seed stored as grain. Siart (2008) found similar results, that seeds stored in the sheaf had better quality than seeds stored as grain. However, there are tradeoffs in terms of storage methods. When we compared the two storage methods for panicles (sheave and single panicles), we found that single panicle seeds have fewer impurities (<2%), less anthracnose infection (<2%), and less general infection (<6%) than sheaves. These results are opposite to the common farmer assessment that sheaves were the best storage method for sorghum seed (author's informal discussion with farmers 2007). However, they were not surprising to farmers, as they commented, when we returned to discuss initial laboratory analysis findings, that the panicles of the sheaves are attached together just after harvest (not dry); thus, the chance of infection and contamination is relatively high compared to single panicles, which are dried out before storage (author's follow-up workshop in Dioila 2008) .

For groundnut, pods stored in bags were associated with higher quality than pods stored in the granary (Table 1-19). Again, the comments of farmers were instructive, from our follow up visit to share the initial results. Farmers indicated that they check regularly groundnuts in bags, removing damaged pods, and that bags are stored in a chemically-treated place. The pods stored in granary, by contrast, are closed hermetically from the beginning to the end of the storage period. The farmers open the granary only when it is time to prepare seed for planting at the beginning of the growing season.

Seed quality in relationship with crop biology

A review by Tripp (2000) indicated that the ability of a crop to be maintained as seed depends on seed characteristics; the biology of the species. N'tare et al., (2008)

pointed out that groundnut seed storage and handling are issues are of critical importance due to the biological characteristics of the crop. In agreement with these reviews, my data showed that groundnut samples had the poorest quality traits among the three crops studied. Groundnut seed is characterized by high oil content, and is large sized, with an easy detachable seed coat enhancing vulnerability to many post-harvest pests, and to storage damage (N'tare et al., 2008).

Gender and seed quality in groundnut

Overall, higher quality was associated with groundnut seed collected from men compared to women. This was not expected, considering the literature which indicates women tend to be more knowledgeable about a crop that they are primarily responsible for, such as groundnut (Saito et al., 1990). However during the follow-up workshop the women told me that they did not give me their true groundnut seed because they did not know that my research was important to them. Thus our research hypothesis could be true if the women had provided their real seed during the seed collection.

This behavior of women can be a consequence of their weak participation in research activities because they had no idea of what I was going to do with the seed compared to men. At the workshop, they felt kind of sorry of not having given the good seeds.

CONCLUSION

The results showed that farmers have similar concerns about seed quality as researchers do, but the ways concerns were addressed were quite different. From the lab analyses, we found that seed quality of farmer-produced seed was high, meeting CILSS standards in almost all cases. The level of impurities was less than 10% for all sorghum and millet seed sampled. The germination rates of sorghum and millet were over 80% in all cases. Even for groundnut, which is known to be vulnerable to decay and poor quality seed problems, the germination rate was consistently above the CILSS standard of 70%.

There were some concerns about physical purity and health status of groundnut seeds, as some of the farmer-produced seed that was below the recommended certification standards. These problems were serious in groundnut, particularly from the Mande zone in farmers' own-produced seeds. Since women are the most involved in groundnut production, education of women on seed quality could help address this problem. That will prevent them from doing the same thing of giving the bad seed as they did in this research. Further, involvement of more women in participatory breeding and research activities could provide long-term benefits for crop improvement in Mali.

The result of the comparison between modern local varieties showed that modern sorghum varieties have lower seed quality compared to local varieties. Malian plant breeders have developed new sorghum varieties that have high yield potential and are early, but the negative traits related to seed quality need to be fully considered. Under a system where farmers are saving seed, the fact that a variety is highly susceptible to infection needs to be fully considered.

CHAPTER 2

IMPACT OF FARMERS' SEED RECYCLING ON UNIFORMITY OF SORGHUM VARIETIES IN SOUTHERN MALI

INTRODUCTION

Maintaining varietal purity is associated with maintaining varietal identity and thus the performance level of the variety. Degeneration of varietal purity after farmers recycle seed for some time has been shown to be associated with a reduction in yielding ability and productive potential of such recycled seed (Fehr, 1987). It is thus a generalized recommendation that farmers should regularly use new, certified seed of open pollinated varieties at least every third year (Diakite and Diarra 2000). Research upon which such recommendations are based has been primarily conducted within the context of commercialized farming systems of Europe or North America, where farmers themselves normally do not invest their own efforts in selecting plants or grains specifically for use as seed (Brick, 2004).

As highlighted by recent reviews, such as Jarvis et al., (2003), and by the seminal work by Dr. Vavilov on centers of origin (Harlan, 1971), farmers play a crucial role in conserving crop genetic variation and protecting the world's agricultural heritage.

Farmers observe and select crops and crop varieties[5], saving and managing seeds for the next season. Thus, the traditional seed system has been the foundation of conservation of biodiversity, and sources of resistance to abiotic and biotic stresses (Almekinders and de Boef, 1999; Jarvis and Campilan, 2006).

Biodiversity and farmer's selection criteria

Farmers maintain a set of crop populations that they keep as separate groups, which are generally referred to as 'varieties' (Bellon, 1996). By maintaining and continuing to select for varieties with specific sets of traits[6], farmers influence the conservation of genetic diversity[7] around the world, and the degree of biodiversity on their farm (Jarvis, et al., 2008).

Using grains from their own harvest as seed (seed recycling), often combined with selection of individual plants, inflorescences or grains are some of the means by which farmers maintain seed stocks and thus genetic variation. The heterogeneity and unpredictability of the environment that smallholder farmers face, the limited resources which they can draw upon to manage shocks from pests and drought, are some of the reasons that farmer's maintain diversity (Rice et al., 1998). In addition, farmers select for grain quality traits associated with multiple uses of crop products, including but not limited to grain cooking characteristics, color, size and storability (Christinck et al., 2005).

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[5] Variety: a plant grouping which is distinct in one or more forms or functions from other such groups of a plant of the same species and which maintains these distinctions when reproduced (Almekinder and Louwaars, 1999).

[6] A trait is a distinct variant of a phenotypic character of an organism that may be inherited, environmentally determined or somewhere in between (http://en.wikipedia.org/wiki/Trait_(biological))

[7] Genetic diversity is a level of biodiversity that refers to the total number of genetic characteristics in the genetic makeup of a species (http://en.wikipedia.org/wiki/Genetic_diversity)

Seed industry requirements for uniformity

Uniformity of crop varieties is usually achieved by genetic homogeneity of the genotypes constituting the varieties, so that varieties will have few off-type[8] plants and the plants are uniform for plant height, morphological traits, such as glume color, presence of leaf hairs and flowering date (Almekinders et Louwaars, 1999). Genetic homogeneity is an important factor in obtaining pure stands of a specific variety (Brick, 2004). Variety uniformity is important when crops are produced for specific markets or uses, e.g., for malting, sorghum grains need to be of uniform grain size, and have similar germination times (Almekinders and Louwaars, 1999). Regulations for variety registration and seed certification require specific levels of uniformity for each crop, based on the biology of the crop.

In formal seed production processes, variety purity is crucial for seed lot certification. It is assessed by field visits of the certification agents during critical stages of crop development, usually just before flowering, especially for allogamous crops, and just before harvest (Copeland and McDonald, 2001). Since varietal purity usually cannot be determined by looking at the seed, seed certification programs and many seed companies rely heavily on field inspection during seed production. Fingerprinting with molecular markers is also used by practitioners to assure genetic homogeneity of seed lots. Field inspection activities include: observation of plants' agronomic performance, the phenotypic uniformity (plant height, number of off-type plants), and observation of flowering date. The laboratory test for variety uniformity generally includes observation

[8] Off-type plant refers to a plant differing from the variety in morphological or other traits as a result of mutation or cross-pollination

of grain uniformity through weight and size assessment, and grain vitrosity (Copeland and McDonald, 2001).

Sorghum

Sorghum is used here as a case study to understand the impact of farmer seed saving practices on variety purity. Sorghum is an important dietary staple crop in West Africa, particularly in southern Mali (Koulikoro region) (Yapi et al., 2000). In Mali, sorghum is a subsistence crop for most of the population, and the area it occupies is higher than that of rice and maize (FAOSTAT 2007). Despite its importance to Malian food security, sorghum faces some obstacles that are restraining its productivity. The average yield on-farm in sorghum in Mali from 2000 to 2007 is about 1000 kg/ha (FAOSTAT 2008) compared to 1.3t/ha in Ethiopia (Mekbib, 2005) and the 1.12t/ha average yield in developing countries (FAOSTAT, 2005).

Sorghum (*Sorghum bicolor*) is a diploid (2n= 20), cereal crop and largely self-pollinated (2-20% outcrossing[9]) (Minot et al., 2006, Almekinders and Louwaars 1999). Based on this level of out-crossing, sorghum varieties are expected to be rather uniform compared to millet (75 to 80% outcrossing) (Minot et al., 2006) and maize, which are cross-pollinated crops (Almekinders and Louwaars 1999).

In Mali, local sorghum varieties collected from farmer sources have shown variability among varieties for some traits, particularly for grain yield components in a field study conducted by Chakanda (2000). This study was conducted in Mande zone Koulikoro region of Mali. It was observed that a rather low level of variation occurred within farmer varieties for traits studied such as date of flowering and panicle weight. Chakanda

[9] Outcross or cross-pollinate occurs when pollen is delivered to a flower of a different plant under natural or artificial conditions (http://en.wikipedia.org/wiki/Cross-pollinated#Mechanics)

concluded that these variations were probably caused by the way farmers manage their fields and varieties. Almekinders (2001) as well as vom Brocke et al. 2003, found that intra-varietal diversity of farmers' local varieties usually has a purpose. Sometimes farmers use intra-varietal diversity to assure yield stability in highly unpredictable production environments or to cope with variable or unpredictable pest and disease dynamics (Diakite, 2003; ICRISAT, 2004; Almekinders, 2001). For sorghum in West Africa, such studies are rare.

Sorghum seed production by farmers in West Africa

Seed recycling is common among smallholder farmers in West Africa (Almekinders and Louwaars, 1999). Diakité's (2003) and Siart's (2008) research on local seed systems in Mali documented that seed recycling is a common practice among farmers. From Diakité's results, almost 50% of farmers in Mande zone have changed (replaced) the sorghum varieties they grow only once, and about 16% never changed varieties. The results of the same research in the Dioila zone showed that 35% of the farmers interviewed changed their dominant sorghum varieties only one time and 6% never changed theirs.

With regards to modern varieties[10], recycling is also common, at least among Malian farmers. Siart (2008) reported from her field survey that more than 30% of modern varieties grown in Dioila zone of Mali were recycled over 6-10 years and more than 50% were recycled for 1-5 years. In this farm-level survey by Siart, in the Mande zone similar if slightly lower levels of recycling were observed: 25-30% (6-10 years recycling) and 30- 45% (1-5 years recycling).

[10] Modern variety is a variety developed by trained breeders working through targeted generation of diversity, through crossing or other bio-technology tools, and selection (Almelinders and Louwaars, 1999)

Objectives

The objective of this research is to examine whether the seed selection practices used by farmers in southern Mali for sorghum prevent degeneration, i.e. maintain the productivity of the variety and maintain varietal purity, and thus intra-varietal homogeneity. In this study, we use the opportunity to quantify genetic purity of seed lots for four sorghum varieties that have been "recycled" for different amounts of time by farmers who have been participating in variety selection research over several years and have contributed to the identification of these varieties. The four sorghum varieties (SAKOYKABA, SUMALEMBA, SUMBA, and TIEBLE) were developed jointly by IER and the ICRISAT/CIRAD sorghum breeding groups and have been in seed production with farmers since 2003.

MATERIALS and METHODS

Research Activities

The field activities for this part of the research included:

- Seed sample collection in the villages: 194 seed samples of four modern sorghum varieties: TIEBLE, SUMALEMBA, SUMBA, and SAKOYKABA
- Field trials with four modern ICRISAT sorghum varieties in production at the farmers' level

Table 2-1 : Places and approximate dates of the different activities undertaken to conduct the field trial assessing the impact of farmers' seed recycling on sorghum variety trait uniformity from May to December 2007 in ICRISAT-Mali research station

Places		Activities	Time frame
Dioila Zone	16 villages including Seribila Mangnambougou Wakoro Wobougou	Seed sample collection Farmers survey	End of May, 2007
Mande zone	14 villages including Gonsolo, Keniero Siranikoro Siby	Seed collection Farmers survey	End of May, 2007
ICRISAT research station (Samako experiment fields)		Seed quality Field Trial	From July to December, 2007

Surveys

Seed sample collection

In May 2007, the seed samples were collected from farmers. At the same time, we conducted a short survey. The village, the varieties and the number of seeds to be collected per zone were determined in collaboration with ICRISAT researchers according to their records of a survey conducted by village farmer facilitators during the 2005/6 dry season. They had recorded in their specific villages who was growing which improved variety since when (2003, 2004, or 2005) (Christinck and Weltzien, unpublished data). Seed samples from 33 villages in the two zones were collected. The samples were from

farmers who had received one of the varieties for a trial or who had purchased seeds of at least one the four varieties chosen for this trial. The seed collection was done along with a short survey to get information about the seeds lot, such as first year of planting, seed source, seed production and storage. The survey instrument is in Appendix 4.

The sample size of the seed sample collection was a function of the number of seed lots of the different recycling categories we were studying. In Dioila zone, seed samples were collected from 48 farmers in 16 villages, while in Mande zone there were 25 farmers in 14 villages. In the whole sample, there were only 9 women (7 in Dioila zone and 2 in Mande). Almost all the farmers targeted (100%) were found.

Farmers' survey

During the general survey conducted at the farmers' level for seed quality assessment in December 2007, there was a part focused on farmers' preferred dominant varieties. This part of the survey aimed to assess, in addition to farmers' preferences for sorghum varieties, the genetic diversity at their level, i.e., the number of sorghum varieties they were planting. The data collected on genetic diversity included the number of varieties, the number of years of growing the same variety (recycling the seed), the number of times farmers changed their preferred variety and the reason for this change.

The details of the survey i.e. the sample size, the villages where it was conducted etc., are presented in Chapter 1 in the "Methods" section.

Assessment Varietal Purity or Homogeneity: Field Trial

A field trial was conducted at the ICRISAT research station with a range of different seed lots of four sorghum varieties: TIEBLE, SUMALEMBA, SUMBA, and

SAKOYKABA, all developed through Participatory Plant Breeding (PPB) program and in seed production at farmers' level since 2003.

Experimental design

The split-plot design was used in the field trial, where the mean treatments were the varieties and the sub-treatments were the seed lots (recycling), in the three replications. The number of entries was 64, 16 seed lots for each variety X 4 (number of varieties in trial) = 64 entries per block. These were replicated three times for a total of 64*3 = 192 plots. One hundred ninety-two (192) seeds lots split into three recycling (foundation seeds, seed held by farmers for less than 3 years and seed held by farmers for more than 3 years) were used .

Each plot was composed of 6 rows. The length of each row was 3 m, the space between rows was 75 cm, and the space between sowing hills was 30 cm. On each row, we had 11 sowing hills. The field was sown on July16· 2007. The field was thinned to two plants per sowing hill on August 1, 2007, and the space between blocks was 1 m.

Material

Table 2-2: Description of the four sorghum varieties used for the field trial from the catalog of sorghum varieties in Mali obtained with ICRISAT research technician

	SAKOYKABA	SUMBA	SUMALEMBA	Tieble
Origin	Katibougou near Samanko	CEM 326/11 CIRAD	Cameroun from the collection IS 15401 ICRISAT/CIRAD	CSM 335 from Malian sorghum collection ICRISAT /IER
Botanic Race, flowering group	Guinea, medium duration, loose, drooping panicle	Caudatum, short duration, erect panicle	Guinea, late flowering, erect panicle	Guinea medium cycle loose, drooping panicle
Plant Height (cm)	350- 400	150 - 250	440- 500	460
Plant Color	Anthocyanee	tan	Anthocyanee	Anthocyane e
Panicle Shape	Lax	Elliptic semi-compact	Elliptic semi-compact	Lax
Panicle length (cm)	42	-	-	37 cm
Photosensitivity	Photosensitive	Not photosensitive	Very photosensitive	Photosensitive
Growing cycle	90 days	90 to 100 days	115 days	90 days
Grain	Big and translucent	tan	Large grain size White	Big and translucent
Rain-fed crop	Yes	Yes	Yes	Yes
Preferred rainfall	800- 1000 mm	700-900 mm	900 to 1200mm	800 to 1000mm
Average yield/ha of grain	2000-2500 kg	2000 – 2300kg	2000 – 2300kg	1800 kg
Cooking characteristics	Very good in *To*	Not good for *To*	-	Very good in *To* and other local dishes

We focused on seeds of improved varieties in production at the farmers' level since 2003: SAKOYKABA, SUMALEMBA, SUMBA, and TIEBLE. We tested 47 seed lots from farmers produced without supervision, 13 seed lots from supervised seed producers, and 4 breeder seed lots or foundation seeds (FS). Among the 47 seed lots produced by farmers without supervision, there were four sub-lots composed of ES (ICRISAT on-farm trial on 2003 seed), FSSP (farmers supervised seeds purchased) 2006, FSSP 2005, and FSSP 2004. The 12 seed lots from farmer-supervised seeds (FSS) include FSS 2006. For analysis purposes, I grouped all seeds into three groups: FS, seed held by farmers for less than 3 years (SHF<3), and seed held by farmers for more than 3 years (SHF>3).

Table 2-3: Number of seed samples (recycling categories and seed categories according to the source) used in the field for each of the four varieties. Field trial conducted on ICRISAT-Mali research station on 2007

Recycling categories	Seed lots collected	Number of seed lot collected per variety used in the trial			
		Sakaykaba	Sumalemba	Sumba	Tieble
Category 1	FS	1	1	1	1
	FSS 06	4	2	1	3
Category 2	FSSP 06	3	3	3	3
	FSSP 05	1	3	2	3
Category 3	FSSP 04	4	3	4	4
	ES 03	3	4	5	2

Field Monitoring

The emergence rate was evaluated by counting the number of empty sowing hills seven days after planting. A score of 0 to 5 was given to each plot, 0 meaning excellent germination and 5= poor germination. The seedling vigor was evaluated on the 15th day after sowing by observing the height, width, and number of leaves on the plants, using the same score. Thirty days after planting, the early vigor or plant growth was evaluated

through the height, width, and number of leaves on the plants. For both seedling and development vigor, a score of 1 to 5 was given to each plot, 5 meaning excellent and 1= poor.

Phenotypic uniformity of each plot was evaluated by counting the number of off-type plants in each plot, after flowering, just before harvest. A plot with no off-type plants was considered to be uniform phenotypically and a plot with more than 5 off-type plants was not uniform.

The heading date = the day the panicle emerges from the sheath, was recorded very carefully by observing the date when the first 5 plants headed per plot, the 20%, the 50%, the 80% and the last 5 plants. The duration of the heading period was calculated as the difference between the dates of the first 5% plants to the last 5% plants headed. The height of 10 plants randomly chosen from the four central rows of the plot was measured in centimeters 15 days after complete flowering. At harvest, the number of sowing hills to be harvested was counted, and the number of panicles harvested was counted after harvest. All six rows were harvested. The panicles were weighed before threshing, and the grain was weighed immediately after threshing.

Data documentation and analysis

Surveys

Data were first registered on questionnaires for the seed sample collection surveys in villages, in a field book for the field trial. We subsequently entered the data into a Microsoft Excel spreadsheet. Excel was used to generate the frequencies and descriptive statistics (means, standard deviation).

Field trial

For the analysis of variance and Least Square Means (LSM) comparisons, I used the Linear Mixed Models (PROC GLIMMIX) components of SAS. I had two fixed factors (Varieties and recycling) in a split plot design, with the whole plot factor being varieties (SAKOYKABA, SUMALEMBA, SUMBA and TIEBLE) in RCB (Randomly Complete Block) fashion. The sub-plot factor was the seed recycling category or level of recycling (foundation seed= 0, seed held by farmers for less three years <3, and seed held by farmers for more than three years >3). We checked the homogeneity and normality of the residuals of varieties and recycling categories using PROC Univariate and we found tremendous heterogeneity of residuals in both varieties and recycling categories. Thus, we decided to use heterogeneous GLIMMIX models for the varieties and recycling.

To assess the effect of recycling categories within a given variety, we compare Least square Means (LSM) for the interaction between variety and recycling categories (variety*recycling).

Table 2-4: Description of the GLIMMEX model the statistical model used to analyze the field trial data

Class information		
Class	Levels	Values
Replication	3	1st 2nd 3rd
Variety number	4	1- Sakoykaba 2- Sumalemba 3- Sumba 4- Tieblen
Category number	3	1- Foundation seeds 2- Seed held by farmers for more than 3 years 3- Seed held by farmers less than 3 years
Number of observation read		192
Number of observation used		192

RESULTS

Results from surveys

For this chapter, only the data from the farmers' survey on varietal diversity for sorghum were used for the analyses. Table 2-5 shows the number of seed samples collected, the number of villages where the samples were collected, and the gender of the growers surveyed by zone.

Table 2-5: Number of seed samples collected from farmers in Dioila and Mande zone for the field trial conducted on the ICRISAT research station from July to December 2007 in Mali

Zones	#of seed growers	# villages	# women	Varieties
Dioila	48 (66%)	16	7 (15%)	All four varieties*
Mande	25 (34%)	14	2 (8%)	All except SUMBA
Total	73	30	9	-

*The four varieties in the field trail were: SAKOYKABA, SUMALEMBA, SUMBA and TIEBLE

From the seed sample collection exercise, we documented a difference between the two zones in terms of participation in research (twice as many farmers in Dioila than in Mande) (Table 2-5). Sixty-six percent of the seed samples collected were from Dioila and 34% from Mande. This is because Dioila zone is much bigger than Mande.

Another important finding was that in the whole sample there were only 9 women (7 in Dioila zone and 2 in Mande). This reflects the weak involvement of women in farmer participatory sorghum research in both zones and the fact that sorghum is not a crop that women are responsible for in this region.

Table 2-6: Number of sorghum varieties grown by farmers from farmers' survey conducted on December 2007

	≥to 3 varieties (%)	Two varieties (%)	One variety (%)
Dioila n= 79	8	38	54
Mande n=75	8	52	40

The information in table 2-6 was needed to document the varietal diversity at farmers' level in the study zones. Table 2-6 shows that 8% of farmers in each zone grew at least 3 varieties. However, a higher proportion of farmers in Mande (52%) grew two varieties compared to Dioila (38%). More farmers in Dioila (54%) planted only one sorghum variety (either local or improved variety) in their fields in 2007 than did farmers in Mande (40%).

Field trial

The results from the field trial were grouped into three types of characteristics: the heading (beginning, end and duration), the morphology of the plants (number of off-types and plant height) and yield estimates (weight of harvested panicles and weight of the grains).

Test of uniformity based on flowering

Table 2-7 presents results for different characteristics of flowering: the date of heading of the first 5 plants to indicate the beginning of flowering (Ep5), the end of heading (Epfin) and duration of heading (TEP).

Table 2-7: Results of GLIMMIX Procedure for flowering characteristics of the field trial data, including the fixed effects of varieties, recycling categories and recycling categories within variety and LSM comparisons among varieties and recycling categories, presented as Julian days

		Ep5		Epfin		TEP	
Response variables		F	P-values	F	P-values	F	P-values
Varieties		84.25	<0.0001	61.2	<0.0001	0.9	0.46
Recycling		1.41	0.257	0.47	0.629	1.42	0.24
Variety*Recycling		1.23	0.46	1.47	0.29	1.82	0.10
		Mean (SE)	letter	Mean (SE)	letter	Mean (SE)	letter
Variety	SAKOYKABA	273 (1.7)	b	281 (1.6)	b	8.3 (1.2)	a
	SUMALEMBA	286 (1.0)	a	293 (1.3)	a	6.7 (1.0)	a
	SUMBA	268 (0.9)	c	274 (1.3)	c	6.8 (0.8)	a
	TIEBLE	271 (1.1)	b	279 (1.5)	b	8.1 (0.9)	a
		Means (SE)	letter	Means (SE)	letter	Means (SE)	letter
Recycling category	Foundation seed =1	274 (1.3)	a	281 (1.3)	a	7.2 (1.0)	a
	SHF <3= 2	275 (0.7)	a	282 (1.0)	a	7.2 (0.6)	a
	SHF ≥3 =3	274(0.7)	a	281(1.0)	a	7.9(0.6)	a

The letters indicating the difference among varieties or recycling categories are read in this table by column. Varieties and recycling categories with the same letter are not statistically at 95% significance level different from each other.

The results from analyses of variance (table2-7) showed that variety had a significant effect on Ep5 and Epfin levels (P-value <0.0001), but that recycling category had no significant impact on any of the flowering variables. For TEP, only the interaction variety *recycling category presented a mild significance (P-value= 0.10).

The LSM comparison results show that varieties SAKOYKABA and TIEBLE are not significantly different in terms of beginning and end of flowering. These results agree with the researcher's assumption of variety description presented in table 2-1 that SAKOYKABA and TIEBLE have the same growing cycle. The results of the comparison among recycling categories within varieties are presented in table 2-8.

Table 2-8: Results of LSM comparisons of recycling categories within varieties for flowering response variables (means, with standard errors in parentheses)

	Varieties	Recycling 1		Recycling 2		Recycling 3	
		Mean (SE)	letter	Mean (SE)	letter	Mean (SE)	letter
Ep5	SAKOYKABA	274 (4.1)	a	271 (1.7)	a	271 (1.7)	a
	SUMALEMBA	286 (1.7)	a	286 (1)	a	286 (1)	a
	SUMBA	268 (1.4)	b	268 (0.9)	b	268 (0.9)	b
	TIEBLE	269 (2.2)	b	271 (1.1)	b	271 (1.1)	b
Epfin	SAKOYKABA	281(3.1)	a	281 (1.6)	a	281 (1.6)	a
	SUMALEMBA	293 (1.7)	a	294 (1.3)	a	294 (1.3)	a
	SUMBA	274 (1.6)	a	275 (1.2)	a	275 (1.2)	a
	TIEBLE	277 (2.6)	a	279 (1.4)	a	279 (1.4)	a
TEP	SAKOYKABA	7 (2.4)	b	9.9 (1.2)	a	9.9 (1.2)	a
	SUMALEMBA	7 (1.9)	b	7.5 (1.0)	b	7.5 (1.0)	b
	SUMBA	6.7 (1.2)	b	6.6 (0.8)	b	6.6 (0.8)	b
	TIEBLE	8.3 (1.6)	a	7.7 (0.9)	b	7.7 (0.9)	b

The letters indicating the difference among varieties or recycling categories are read in this table by row. Recycling categories with the same letter are not statistically different from each other.

Table 2-8 shows that researcher seeds (recycling category 1) have more variation in the beginning and end of flowering than do farmer seeds. This variation is higher with SAKOYKABA recycling 1 than the other three varieties. The results for Ep5 and Epfin show that these variables did not differ significantly among recycling categories within varieties, except for TEP of Tieble.

And for TEP, the results show that recycling 1 of SAKOYKABA was significantly different from recycling 2 and 3. The flowering time for recycling 2 and 3 ($\approx$10 days) was long compared to recycling 1 ($\approx$7). For variety TIEBLE, recycling 1 was significantly different from recycling 2 and 3. Recycling 1 had a longer flowering duration (8.3 days) compared to recycling 2 and 3 (7.7 days), but only half a day, which in fact has no practical relevance..

Test of uniformity based on plants morphology (appearances)

For this part, the analyses were done using the following two response variables: plant height and the number of off-type plants in the plot.

Table 2-9: Results of GLIMMIX Procedure for plant phenotypic traits (plant height (cm) and number of off-type plants for varieties, recycling categories alone and recycling categories within variety and LS mean comparisons among varieties and recycling categories

		Plant height in centimeters (cm)		#of off-types plants/plot*	
Effect		F-values	P-values	F-values	P-value
Varieties		42.61	<0.0001	3.24	0.04
Recycling		1.32	0.26	2.06	0.13
Variety*Recycling		0.73	0.85	1.12	0.42
		Mean (SE)	letter	Mean (SE)	letter
Varieties	SAKOYKABA=1	391(18.7)	a	0.38(0.2)	c
	SUMALEMBA=2	403(8.1)	a	2.11(0.8)	a
	SUMBA=3	233(13.9)	b	2.53 (0.9)	a
	TIEBLE=4	388(9.7)	a	0.77 (0.3)	b
		Means (SE)	letter	Means (SE)	letter
Recycling	Foundation seed=1	352 (15.6)	a	1.5 (0.8)	a
	SHF<3= 2	349 (7.2)	a	0.99 (0.3)	a
	SHF ≥3 =3	361 (7.1)	a	1.87 (0.3)	a

*With the plot of 6 lines, there were 11 sowing hills on each line and the field was thinned to 2 plants per sowing hill. Thus the number of plants per plot was 11*6*2= 132.
The letters indicating the difference among varieties or recycling categories are read in this table by column. Varieties and recycling categories with the same letter are not different from each other.

Table 2-9 shows that the varieties effect for plant height and number of off-type plants (P-value= 0.0001 & 0.04) was significant at the 95% confidence level. Recycling had a marginally significant effect on the number of off-type plants (P=0.13) and none on plant height.. No interaction of varieties* recycling categories was significant.

LSM comparisons for plant height for varieties showed that variety 3 (SUMBA) was significantly different from the other three varieties (table2-9). SUMBA, with

average height of 233 centimeters, was shorter compared to the three other varieties, which averaged about 400 centimeters in height.

The LSM comparisons for number of off-type plants showed that varieties SUMBA and SUMALEMBA had more off-type plants (average 2 plants/plot ≈1.5%) compared to TIEBLE (about 1 plant/plot ≈1%) and SAKOYKABA (almost zero off-type plants observed).

Table 2-10: Results of LSM comparisons of recycling categories within varieties for plant phenotypic response variables (plant height and number of off-type plants) (Means, with standard errors in parentheses).

Resp. Var	Varieties	Recycling 1 Mean (SE)	letter	Recycling 2 Mean (SE)	letter	Recycling 3 Mean (SE)	letter
Plant height (cm)	SAKOYKABA	384 (46.5)	a	388 (17.7)	a	402 (18.8)	a
	SUMALEMBA	415 (12.7)	a	396 (8.0)	b	397 (8.2)	b
	SUMBA	217 (32.4)	b	227 (14.8)	b	254 (12.7)	b
	TIEBLE	391 (19)	a	382 (9.7)	a	390 (9.5)	a
# of off-type plants	SAKOYKABA	0.33 (0.6)	a	0.29 (0.2)	a	0.52 (0.2)	a
	SUMALEMBA	1.00 (2.2)	c	1.50 (0.8)	b	3.85 (0.8)	a
	SUMBA	3.00 (2.3)	a	1.94 (0.9)	a	2.66 (0.8)	a
	TIEBLE	1.66 (0.7)	a	0.23 (0.3)	b	0.41 (0.2)	b

The letters indicating the difference among varieties or recycling categories are read in this table by row. Varieties within recycling categories with the same letter are not different from each other.

Table 2-10 shows that plant height for SAKOYKABA and SUMBA increases with the duration of recycling. Here also the SEs for recycling category 1 are higher than for recycling 2 and 3, with the higher SEs observed with SAKOYKABA and SUMBA for plant height and SUMALEMBA and SUMBA for number of off-type plants.

The results of LSM comparisons of the effects of recycling within varieties on the number of off-type plants revealed that recycling 3 of SUMALEMBA was significantly different from recycling 1 and 2. Seed held by farmers for more than 3 years had more off-type plants (average 3.8 plants/plot ≈3%) compared to researchers' seeds (1.2

plants/plot ≈1%) and seeds held by farmers for less than 3 years (1.5 plants/plot ≈1.1%). These results agree with the research hypothesis 2 that varietal uniformity declined with the duration of recycling.

For the variety TIEBLE, the results were the opposite of the research hypotheses because recycling category 1 (researchers' seeds) had more off-type plants than farmers' seeds. This is interesting because it shows that farmers are reducing the heterogeneity within the variety beyond that of the foundation seed.

Test of uniformity based on yield estimates

Two response variables, weight of harvested panicles (normally called panicle yield) and the weight of their grains, grain yield, were used for this part. Table 2-9 presents the results of the LSM analyses.

Table 2-11: Results of GLIMMIX Procedure for plant yield components (panicle yield and grain yield (fixed effects) of varieties, recycling categories alone and recycling categories within variety and LS mean comparisons among varieties and recycling categories

		Weight of harvested panicles (g/ $m^{2)}$		Weight of grains (g/ m^2)	
Effect		F-values	P-values	F-values	P-value
Varieties		3.83	0.046	4.09	0.036
Recycling		2.23	0.11	2.72	0.069
Variety*Recycling		2.42	0.037	2.31	0.042
		Mean (SE)	letter	Mean (SE)	letter
	SAKOYKABA	346 (27.2)	a	260 (20.8)	a
Variety	SUMALEMBA	267 (25.7)	b	198 (19.2)	b
	SUMBA	299 (26.3)	c	238 (20.0)	c
	TIEBLE	360 (30.6)	a	280 (23.6)	a
		Means (SE)	letter	Means (SE)	letter
	Foundation	340 (26.8)	a	263 (20.6)	a
Recycli	seed=1				
ng	SHF <3= 2	312 (19.8)	a	241 (14.4)	a
	SHF ≥3 =3	300 (19.7)	a	228 (14.4)	a

The letters indicating the difference among varieties or recycling categories are read in this table by column. Varieties and recycling categories with the same letter are not different from each other.

The results of the analyses of variance showed that varieties in general and the recycling categories for specific varieties differed significantly for both the weight of harvested panicles and grains at the 95% level of confidence. For recycling categories, there was trend towards lower yields as recycling increased, at an 80% level of significance. The weight of panicles for TIEBLE and SAKOYKABA were not significantly different from one another. Their harvested panicles weighed on average about 346 and 360 g/m^2. They were significantly different from SUMBA and SUMALEMBA, whose harvested panicles weighed respectively 299 and 267 $g/ m.^2$ Based on these results, we conclude that SUMALEMBA panicles weighed less than those of the other three varieties.

In terms of grain yield, all four varieties had about 2 t/ha. The results for grain weight were similar to panicle weight. TIEBLE and SAKOYKABA had consistently higher yields than did varieties SUMBA and SUMALEMBA (Table 2-9).

The results of the interaction of varieties*recycling for harvested panicles and grains weight are shown in table 2-12.

Table 2-12: Results of LSM comparisons of recycling categories within varieties for plant yield response variables (panicle yield and grain yield) (Means, with standard errors in parentheses)

Resp. Var	Varieties	Recycling 1 Mean (SE)	lett er	Recycling 2 Mean (SE)	letter	Recycling 3 Mean (SE)	letter
Weight of Panicles (g/ m^2)	SAKOYKABA	348 (44.2)	b	374 (26.7)	a	315 (27.2)	c
	SUMALEMBA	294 (37.3)	a	271 (25.4)	a	236 (25.7)	b
	SUMBA	305 (40.0)	a	302 (26.7)	a	289 (25.6)	a
	TIEBLE	415 (57.9)	a	303 (30.7)	c	360 (29.8)	b
Grains Weight (g/ m^2)	SAKOYKABA	262 (35.4)	b	285(20.4)	a	234(20.8)	c
	SUMALEMBA	219 (28.6)	a	202 (19.0)	a	173 (19.3)	b
	SUMBA	244 (31.9)	a	242 (20.4)	a	229 (19.4)	a
	TIEBLE	328 (46.4)	b	236(23.7)	a	276 (23.0)	c

The letters indicating the difference among varieties or recycling categories are read in this table by row. Varieties and recycling categories with the same letter are not different from each other.

From table 2-12, the weight of harvested panicles of recycling groups 1, 2 and 3 of SAKOYKABA are all different from each other, with recycling 2 category weighing more (374g/ m^2) than the two others. For SUMALEMBA recycling 1 and 2 are not significantly different from each other, but they are different from recycling 3. The panicles of SUMALEMBA recycling 1 and 2 weighed 294 and 271g/ m^2, respectively, while recycling 3 panicles weighed only 236 g/ m^2. For variety SUMBA, there is no significant difference among the three recycling categories in terms of the weight of harvested panicles. For variety TIEBLE, the harvested panicles of recycling category 1 weighed more (415 g/ m^2) than that of recycling category 3 (360 g/ m^2), which also weighed more than that of recycling category 2 (303g/ m^2).

Yield of grains showed an overall pattern of response similar to that of panicle weight.

Farmers' surveys

The farmers' survey documented how long farmers grew the same variety, and if they happened to change varieties, how many times they changed and why (table 2-13).

Table 2-13: Farmers genetic diversity management for sorghum assessed by recording the duration of farmer growing the same variety and the percentage of farmers who reported of having change their preferred dominant variety at least one time during farmer general surveys conducted in Dioila and Mande zones

	Dioila n=79		Mande n=75	
Duration of growing (# of years)	Mean	SE	Mean	SE
	10	(1.1)	10.3	(1.2)
Change of the preferred variety (%)	8		17	
Reason of change	n*=6		n*=13	
Decrease in yield			2	
Rain irregularity	1		6	
Soil fertility problem	2			
No response	3		5	

* n =number of farmers in survey sample who changed their preferred sorghum variety at least once in both zones, where the research was conducted in December 2007.

As shown in table 2-13, farmers in both zones have been growing the same dominant sorghum variety for 10 years on average. Seventeen percent of farmers in Mande have changed their preferred sorghum variety at least one time against 8% in the Dioila zone. In the Dioila zone, the most popular reason for change was No response (50%), while in Mande the irregularity of rains was the most frequent reason for variety change (6 of the 13 farmers who changed varieties).

DISCUSSION

Farmers' diversity management

The analysis of farmers' management of varietal diversity in this study showed that farmers in both zones grew the same dominant preferred varieties for more than 10 years on average (table 2-13). This recycling duration is even longer than the one in Siart's (2005) survey results in the same zones.

In 2007, about 60% of farmers from Mande had at least two sorghum varieties in their fields, compared with 46% in Dioila (table 2-6). This suggests that despite the availability of research and extension services in Dioila, the farmers Dioila remain relatively closed to sorghum variety diversity. Siart (2005 survey reported in 2008) found that the majority of households in Dioila (56- 69%) and in Mande (57-62%) grew more than one variety. From her findings, Dioila farmers had more varietal diversity than Mande farmers. However, she noted that these numbers varied from year to year.

Variety Mixture or Misidentification by Farmers

The same varieties that are cultivated by different farmers over many years are likely to lose their identity for certain traits (Chakanda, 2000). The data analyses from the field trial revealed the influence of farmers' seed management and variety saving on modern sorghum varieties in production on-farm since 2003.

Chakanda (2000) also found in a Mali seed survey that despite the effectiveness of annual selection of panicles, there was a high level of variation for traits within farmers' varieties. Most of the time, due to the visual resemblance in all other traits, farmers believe that they have maintained purity of varieties and are growing a specific variety. This was noticed in the field trial with the fake TIEBLE variety we had, as all the

other varietal traits were the same as TIEBLE except the grain appearance. There might be both negative and positive aspects of "renaming" a new variety by farmers.

Field Uniformity Experiment

Even though sorghum is largely self pollinated, especially in guinea race varieties we tend to get 20 sometime 25% outcrossing (Minot et al., 2006). This also means that we get actually fairly high levels of heterozygosity in these varieties after some years of recycling. One of the consequences of keeping too much homogeneity is that it may entail inbreeding, and thus a reduction in yielding ability. For these sorghum varieties it is thus important to maintain some level of diversity, for some traits. Actually the Tieble results show this tendency: with more variability higher yield (recycling 1, than with reduced variability, lees yield.

In the field trial, we found that although there was some variation in variety traits, overall there was generally uniform expression of traits across different recycling categories within varieties. Thus, despite occasional "renaming" of a variety such as seen with TIEBLE case, overall farmers were selecting and maintaining pure varieties.

Flowering11

The results of the uniformity assessment based on the timing of flowering showed that no significant difference existed between researcher seeds (recycling 1) and farmers recycled seeds (recycling 2 and 3). The flowering time of varieties SAKOYKABA and TIEBLE were not significantly different from each other, but they were different from SUMALEMBA and SUMBA. This is consistent with the descriptions of SUMBA as an early maturing variety and of SUMALEMBA a late maturing variety (as its name

[11] This is the first study we are aware of that examined the impact of the duration of farmer-recycled seeds versus researcher-produced seeds on uniformity of flowering traits.

indicates in the local language Bambara), while TIEBLE and SAKOYKABA are intermediate cycle (table 2-1) (ref Mali National Seed Service variety catalog).

Examining the results in more detail, although we note no significant difference among the interaction of recycling category*variety, a trend suggests that researcher seeds (recycling1) of TIEBLE flowered earlier compared to seed held by farmers (recycling 2 and 3). And for Epfin, recycling1 and seeds held by farmers for less than 3 years (recycling 2) were apparently different from seeds held by farmers for more than 3 years (recycling 3). Our research hypothesis was that recycling 1 seeds have more uniform varietal traits compared to farmers' seeds and that trait variation increases as seeds are recycled more (Chakanda, 2000). For flowering traits, Ep5 and Epfin, variations observed in variety TIEBLE may have been due to seed recycling.

When considering the duration of the flowering period (TEP), only the interaction of varieties*recycling was significant (Table 2-7). The LSM analysis of varieties*recycling showed that the recycling categories within SAKOYKABA were different. For SAKOYKABA, researcher seed had the shortest flowering duration (7 days) (table 2-8). Thus, the TEP for SAKOYKABA increased with increasing time of recycling by farmers. For TIEBLE, recycling 1 had longer flowering duration (8 days) than farmers' seeds. These results show that even researchers have some uniformity problems with TIEBLE, and to some extent one can say that farmers did a better job maintaining flowering uniformity (table 2-8).

The TEP conveys information about the uniformity of maturity and to some extent variety uniformity. Thus, the shorter the flowering duration is, the more uniform is

the maturity, making the harvest easier for farmers because a longer period over which maturity will occur will stretch out harvest duration (Rasabandit et al., 2006).

Morphology

The test of uniformity based on plants' morphological traits (height and number of off-types) showed an effect of variety on plant height. Varieties SUMALEMBA, SAKOYKABA and TIEBLE were not different from each other, but they were all taller than SUMBA. This result is consistent with the researcher description of SUMBA.

The standard error for plant height is consistently higher among researcher-produced seeds (table 2-10). Also, the height of SUMBA increases with the recycling duration (table 2-10). This result suggests that farmers may be selecting SUMBA for taller height. As in many developing countries, in Mali, sorghum stover is often used to feed cattle (de Vries and Toenniessen 2001 cited by Folkentsma et al., 2005), and farmers plant a variety for multiple uses to meet their needs (Diakite, 2003).

The test for off-type plants showed that both varieties and recycling were significant, although recycling was significant only at the 13% level of significance (table 2-9). The varieties varied markedly in terms of number of off-type plants. SUMBA and SUMALEMBA had more off-type plants than TIEBLE and SAKOYKABA. This finding is consistent with earlier reports by researchers. However, the good news is that the number of off-types in all varieties was less than 5% (the critical number of off-types) The seeds in the longest recycling category showed more off-types for SUMALEMBA (table 2-10). However, with TIEBLE (excluding the "fake" TIEBLE), the trend was for researcher seeds to have more off-types than farmers seeds. This result shows that farmers are doing a better job in selecting TIEBLE seeds than are researchers.

Yield

The analyses of recycling effects on yield components showed that both varieties and recycling had significant influence on grain and panicle weight. The varieties TIEBLE and SAKOYKABA had the highest weight of harvested panicles and grains. This is not consistent with the description of the varieties in table 2-2, where TIEBLE at (1800kg/ha) was the lowest yielding of the four varieties. The yield observed in my field trial was very high (example of TIEBLE ≈3000 kg/ha). This yield may be due to favorable management and weather conditions of the trial.

The analyses of the interaction of varieties*recycling showed the overall yield was not affected by recycling. Especially for TIEBLE, recycling 3 had higher panicle and grain weight compared to recycling 2. The duration of recycling was not associated with low yield.

CONCLUSION

The field trial analyses showed that there are no significant differences between seeds of modern varieties produced by farmers without supervision and foundation seeds in terms of flowering (beginning and end), number of off- types, and panicle weight. That means that farmers are producing seeds with good level s of varietal purity, and that varietal identify is well maintained even for varieties that individual farmers have maintained for four consecutive years. Since this field trial was conducted on the research station only, for more comparisons it will be good to have some trials at the farmers' level in the future research.

In conclusion, farmers' seed recycling does affect some varietal traits of sorghum, but the effects are not serious enough to worry about them.

CHAPTER 3

SORGHUM VARIETY TRAIT EVALUATION WITH FARMERS IN SOUTHERN MALI

INTRODUCTION

Sorghum (*Sorghum bicolor (L)* is the fifth most important cereal crop worldwide (Mekbib, 2006) and the third most important cereal crop in Mali (Chakanda, 2000). Since sorghum is a C4 plant, it shows a greater efficiency of dry matter production relative to water use than rice and wheat (Downess, 1970). It can also endure short periods of waterlogging (Dogget and Jowett, 1966) and has considerable tolerance to drought and heat stress (Downess, 1970). This is why it is grown mainly in the drier regions of West Africa (Chakanda, 2000).

In Mali, sorghum is the staple food crop in the 700 - 1200 mm rainfall zones (Almekinders et al., 2007) such as the Koulikoro region investigated in this study. It is mainly a subsistence crop for most of the population in the Sudanaan zone of Mali (Byth, 1993), and the number one food crop in the two study zones (Dioila and Mande). In addition to food production, sorghum is used in local beer production, and its stalks are used for animal feed, for construction, or as fire wood (Mburu, 1986).

Despite its importance, sorghum productivity is still very low in Mali: the average yield is 1.0 t/ha (FAOSTAT, 2008) compared to an average yield of 1.12 t/ha in developing countries and a country-wide yield of 1.3t/ha in Ethiopia (Mekbib, 2005). Researchers associate this low yield of sorghum with the very low levels of fertilizers applied in general (8 kg/ha), and to sorghum in particular, and to the use of local varieties

(Diakite, 2003). In Mali, as well as many part of Africa, traditional varieties are often preferred by farmers and have been shown to be well adapted to biotic and abiotic stress factors and exhibit superior grain quality traits for the production of local dishes. These are still the main varieties cultivated in southern Africa (Shargie and Wenzel 2008) as well as in Mali (Siart, 2008).

In the past, agricultural research in Mali has often focused on cash crops such as cotton and rice (Tefft, 2004). Recent problems of food insecurity in Mali have encouraged research institutions and the government to focus on agronomic performance of staple grain crops (sorghum, millet, corn, etc.). Just after Mali's independence, the Institute of Rural Economic (IER) was created to find ways to improve the productivity of food crops (Yapi et al., 2000). Malian researchers collaborate with sorghum breeders from international institutions (such as ICRISAT), and have recently developed varieties with high yield potential to increase food security for the majority of the Malian population (Chakanda, 2000). Because of the importance of the seed sector in agricultural productivity, researchers have tried to improve the seed sector by promoting multiplication and distribution of improved variety seeds (Diakite, 2003, Maredia et al., 1999). A number of improved sorghum varieties such as SUMBA, TIEBLE, and SUMALEMBA have been developed and disseminated in the country through the IER/ICRISAT Participatory Plant Breeding program (PPB)

The formal seed sector in Mali does not function well for subsistence or modestly valued crops such as a sorghum. This is common among SSA countries, which have failed to improve farmer access to high quality seeds of widely grown subsistence crops. There are many reasons for this, among them the high cost of seeds relative to cereal

grain prices, the limited number of appropriate varieties that meet the needs of farmers, inconsistent seed quality, and the dispersed location of seed production. Farmers are generally considered as consumers, rather than as seed producers and key participants in seed assessment and dissemination (Chakanda, 2000, Maredia et al., 1999).

Participatory plant breeding is becoming a widely recognized approach to improve client-orientation of research and develop more adoptable in varieties. ICRISAT is pursing this strategy in Mali, using Farmer Participatory Variety Selection (FPVS) (Weltzien et al., 2006, Vernooy 2003). This methods can include farmers at every step of the breeding process (Friis-Hansen and Sthapit, 2000; Vernooy 2003). Farmer participation in technology generation can enhance the effectiveness of selection and has been show to improve adoption (Ashby 1990; Sperling et al., 1993; N'tare et al., 2008). Farmer involvement in variety evaluation provides means for identifying a wide range of locally valued varietal traits (N'tare et al., 2008; Baidu-Forson, 1997, Almekinders et al., 1999).

PVS is a useful research communication tool that facilitates researcher and farmer interaction. It enhances the ability of plant breeders to quantify the performance of new genotypes across the wide variability of growing conditions in a target area and helps to assess the response of varieties to farmer management (Rasabandit et al., 2006).

Seed system analyses conducted in Mali have shown that farmers are interested in trying new types of varieties that combine preferred variety traits (Weltzien et al., 2005). An opportunity is presented by the shift over the last decade in plant breeding priorities in Mali to incorporate farmer selection criteria. This provides a new environment, with the development of farmer-selected sorghum varieties.

Research Objectives

This is a participatory research project, conducted in collaboration with farmers. It aims to quantify farmers' evaluation of variety traits in recently developed improved sorghum varieties, and provide information on farmer preferences to be incorporated into the plant breeding priorities of the ICRISAT and IER sorghum breeding programs in Mali.

Hypotheses

We tested the following hypotheses:

- Farmers in both study zones have the same preferred variety traits for sorghum.
- There is no gender specificity in terms of variety trait preference.
- We hypothesize that under irregular and low rainfall farming conditions, yield, early maturity and drought resistance are the three most popular varietal traits in the study area.

MATERIALS AND METHODS

A Participatory Variety Selection (PVS) method was used to assess farmers' preferences for modern sorghum varieties in trials conducted in the Dioila and Mande zones. The trials were planned jointly by farmers and researchers and managed by farmers (Weltzien et al. 2007). Evaluation of the trials was done jointly, by farmers and researchers, each evaluating specific traits. In addition, a survey was conducted to document farmer assessment of all varieties they have experience with, including the varieties they have seen in the on-farm trials and the varieties they are currently growing.

Participatory variety selection trials

The location of the trials and the dates of farming activities were chosen by farmers, whereas inputs in the form of seed, fertilizer and technical support such as the trial design were provided by plant breeders from ICRISAT and IER (Weltzien et al., 2006).

The trials were conducted to evaluate 32 varieties (16 tall and 16 short varieties) at on-farm sites located in 9 villages (five in Dioila and four in Mande). In each village, two trials were established, each with four replications, i.e. twp replications per farmer.. One compared the short varieties and the other the tall varieties. Thus, 14 modern varieties were compared, plus one local and one common control variety in each of these trials. The local variety was one of the main varieties used in the village and was chosen by four farmer participants (Weltzien et al., 2007). The common control variety for all the trials was TIEBLE (CSM 335). The experiments were conducted in farmers' main sorghum production fields. The plots had 6 rows of 5 meter length each arranged in 4 ranges of eight plots and randomized as alpha lattice designs with four plots per block

(Weltzien et al., 2007). The trials were managed by farmers, with support from a farmer organization secretary, whose position was called an "*Animateur*" and by visits by ICRISAT and IER technicians. This supervision was an important means of supporting farmers to be involved in evaluation, as not all farmers were literate.

Many farmers were involved in the variety evaluation conducted at harvest time (end of November and beginning of December 2007), just before harvest when the grains were mature and easy to observe.

Table 3-1: Name of the 32 varieties that farmers evaluated to assess farmers variety trait preference in December 2007 in the Dioila and Mande zones

	Variety names	
Entry #	Tall type	Short type
1	Sekounioni	Kakou
2	Nionifing	Boulen
3	Yebagasago	Djelefi
4	Bibagalawili	Oki
5	Bamouka	Tamia
6	Kassoroka	Koule
7	Bandokablen	Lebo
8	Dougouba	Tiguila
9	Sobani	Gagna
10	Yoka	Kouladji
11	Palo	Drasa
12	Yalama	Tiandougou Coura
13	Koroba	Marakanio
14	Niakafa	Grinkan
15	Yamasa	Tieble
16	Tieble	Local

Farmer evaluation

There were two types of farmer evaluations carried out. First, a simple scoring method, where farmers chose varieties in the experiment, was used to document farmers' expressions' of preference for the top three preferred varieties. This approach is called 'voting for varieties' (Christinck et 2005, Weltzien et al. 2007). Second, a survey was

carried out to document farmers' assessments of the varieties they grow. For the voting exercise, farmers first conducted a visual evaluation of plants standing in the field, based on the overall plant appearances (strength of the stem, appearance of the panicles, grains, leaves). Farmers first scored all 16 varieties for ICRISAT/IER FPVS. Ballots of three different colored papers (white, yellow, and red) were used for voting.

In addition, farmers were asked to select the three best varieties using pieces of cloth with different numbers of lines on each. Each farmer had to tie the piece with one line at the beginning of the field plot that was his/her first or best, then the piece with two lines on the second best, and the third on the third best. After this evaluation, the technicians conducted a short survey about the reasons for the farmers' choices.

These evaluations were conducted in 9 villages by me, working in close collaboration with the plant breeder evaluation team from ICRISAT/IER. As done by Rasabandit et al. (2006) for rice PVS, the evaluation was done directly in the field by farmers.

Farmer appointment and field preparation

The fields (replication) where the evaluation was to take place were chosen jointly by the research technicians and me, and the farmers conducting these trials were informed ahead of time about the chosen locations. The *animateurs* of the villages were informed about the dates of the evaluations, and they had to inform all the farmers (men and women).

Early in the morning of the day of the evaluation, the research technicians and the owner of the trial headed into the field to prepare it for voting. A paper bag was hung tied to the stems of the first plants in a plot for receiving ballots from farmers during voting.

A shade tree was identified for gathering farmers for the quick survey on the reasons of their choices.

Farmers' evaluation

Farmers were asked to express their preferences for individual varieties by scoring them using colored papers. A white paper indicated that the farmer was interested in growing this variety, yellow indicated the varieties that might require more testing and red indicated varieties that the farmer rejected. Each farmer was given an envelope containing about 30 pieces of paper of each color and the three pieces of cloth material (Christinck et 2005, Weltzien et al. 2007).

Before making a decision, farmers were asked to carefully observe and consider the performance of variety in each plot. The procedure was carefully explained to farmers, beforehand and again in the field just before starting the evaluation. Thus, the evaluation involved an initial field tour where all farmers walked around the field to look at the different varieties. During the second round farmer sscored the varieties . During the third round, the farrmers identified the three best varieties.

Samples

The goal was to involve equally women and men farmers; thus, I used a purposive selection process. Upon arrival in the village, the first 30 or 40 people were selected. However, when there were only men in the first 30 or 40, we postponed the selection until about 50% or so of the farmers participating were women. In a village where the number of farmers showing up was less than 30, everybody was selected. In total, 230 farmers (124 men and 106 women) participated in this part on the research. For the Dioila zone, there were 141 farmers from Wobougou (trial hybrid), Kafla, Seribila,

Kegne, and Wakoro. For the Mande zone, there were 89 farmers from Teneya, Keniero, Kalague, and Gonsolo.

Table 3-2: Number of farmers by gender who participated in the on-farm farmers' sorghum evaluation exercise aimed to assess farmers' variety preferences in the Dioila and Mande zones in December, 2007

	Men	Women	Total/zone
Dioila	71	70	141
Mande	53	36	89
Total/gender	124	106	230

General farmers' survey

This survey is described in chapter 1. The survey provided an opportunity to document farmers' preference for variety traits. For detailed information about the survey process please refer to chapter 1. The survey was conducted from the end of November to mid December 2007, in the Dioila and Mande zones of Mali and involved interviewing 157 farmers in 8 villages. Each farmer were asked about his/her preferred dominant sorghum variety (name, source, village, and time of acquisition). I then documented the traits that the farmer described as being the reasons this variety was preferred. The variety traits in the survey included: yield, resistance to insects, early maturity, grain cooking traits, drought tolerance, secondary uses (like animal feed), and other.

Data documentation and analyses

The data for this chapter were collected by me and through close supervision of eight experienced assistants. These included four enumerators, two technicians from IER and two from ICRISAT, all of whom had been trained in conducting farmer variety evaluation surveys. It was important to conduct the evaluation in a timely fashion in order to meet farmer time constraints, thus, a large group of enumerators was required.

To synthesize the data, I grouped the variety traits described by farmers from the on-farm evaluation into six groups: yield, early maturity, resistance to drought and striga, grain appearance, adaptation to the farming areas and others. The details regarding farmer trait descriptions and how these were grouped into 6 categories are presented in Appendix 9.

The data were first recorded on notebooks and questionnaires in the field. They were then entered on a laptop computer in Microsoft Office Excel, which was used to generate standard descriptive statistics and frequency analyses.

RESULTS

On-farm field trial evaluation by farmers

The results of farmers' voting of varieties is presented in table 3-3. The trials for tall and short varieties were conducted separately at different farmers' sites to avoid that the short varieties get shaded by the tall varieties. Thus, genotypes were evaluated by farmers within each height category. As shown in table 3-3, there were notable differences between the Dioila and Mande sites in terms of farmer preferences. Gender, on the other hand, did not have a marked effect, at least in terms of farmer of the field performance: Women and men from Dioila tended to favor entries 1, 2, 13 and 14 among the tall varieties and 1, 14 and 15 among the short types (although women did not rank any variety except #1 above 70% among short types). In Mande, several of the same tall varieties were liked (1, 2, 14 and 16); however, short variety preference was quite different than that observed in Dioila (Table 3-3).

Table 3-3: Farmers' preferences expressed in percentage for the 32 varieties in the on-farm trials by gender, variety type (short versus tall types) and by zone (Dioila and Mande) from the ICRISAT/ IER in December 2007

	Dioila (%)				Mande (%)			
Entry	Tall type		Short types		Tall type		Short type	
#	men	women	men	women	men	women	men	women
1	81	80	72	72	83	78	53	50
2	87	81	38	45	86	81	34	57
3	45	46	28	35	79	69	53	53
4	46	49	29	39	80	73	38	52
5	66	73	28	33	71	71	46	51
6	60	58	23	46	60	63	40	52
7	56	68	23	35	58	60	41	47
8	51	52	58	51	51	60	51	59
9	47	52	35	40	49	57	22	35
10	18	32	30	30	27	36	32	47
11	22	39	64	58	23	35	61	60
12	34	46	65	66	54	60	56	58
13	76	71	28	30	63	71	35	36
14	76	73	70	68	68	68	53	57
15	67	61	82	65	51	56	92	84
16	68	52	63	63	76	75	86	74

Source: Results of ICRISAT/IER on-farm field trial evaluation, 2007.

Farmers were asked to next select their top three varieties and describe the traits that led to that selection. The table 3-4 presents the results from this second step in the farmers' evaluation of sorghum varieties grown in on-farm field trials.

Table 3-4: The results of reasons why farmers from Dioila and Mande zones (n=230) rated the sorghum varieties as their three top choices from the on-farm field trials in December 2007

Preferred varietal traits	1st choice*		2nd choice		3rd choice	
	n	%	n	%	n	%
Yield	178	77	137	60	131	57
Early maturing	45	19	22	9	18	8
Drought and *Striga* tolerance	27	12	23	10	15	6
Grain appearance	129	56	99	43	95	41
Adaptation to the cultivation area	47	20	26	11	25	11
Others	11	5	8	3	6	3

The percentages summed are greater than 100% because farmers were allowed to cite as many variety traits as many as they thought were important.

As shown in table 3-4, yield traits were noted as keys factor by 77% of farmers for their top pick 77%, 60% of farmers for their second pick and 57% of farmers for their third pick. Grain appearance was also important, with 56% of farmers noting this for their fist pick, 43% for their second pick, and 41% for their third pick. The third most preferred variety trait was adaptation to the field environment, which was noted by 20% of farmers for their first choice, and by 11% for the second and third choices.

A more in-depth understanding of farmer preferred varietal traits was arrived at by evaluating responses for the two locations, Dioila and Mande. As shown in table 3-5, the variety traits assessed in on-farm trials at both locations prioritized yield and grain appearance, but in addition early maturing varieties were valued by farmers particularly in Dioila (18%), and resistance to drought and striga was noted by 8% of farmers at both sites (table 3-5)

Table 3-5: Results of farmers' variety traits evaluation done on December 2007 by zone of the on-farm trials, expressed as the number of farmers and percentage of the sample citing different reasons for their variety preferences, per zone in southern Mali

	Dioila n=141		Mande n=89	
Varietal traits	n	%	n	%
Yield	93	66	55	62
Early maturity	25	18	4	4
Resistance to drought & Striga	12	8	7	8
Grain appearance	61	43	46	52
Adaptation to the area	28	20	9	10
Others	6	4	3	3

The percentages summed are greater than 100% because farmers were allowed to cite as many variety traits as they thought were important.

The results in table 3-5 show that yield, listed by 66% of farmers in Dioila and 62% in Mande, was the most popular varietal trait that farmers in both zones were looking for in new sorghum varieties. Yield is followed by grain appearance in second

place with 43% in the Dioila zone versus 52% in Mande. Then adaptation to the cultivation area is the third most popular varietal for farmers in both zones.

Gender considerations in varietal trait evaluation

Table 3-6: Results of farmers' variety traits evaluation done in December 2007, by gender

	Men n=124		Women n=106	
Varietal traits	n	%	n	%
Yield	80	64	68	64
Early maturity	16	13	11	10
Resistance to drought & Striga	12	10	6	6
Grain appearance	55	44	51	48
Adaptation to the area	23	18	13	12
Others	6	5	2	2

The percentages summed are greater than 100% because farmers were allowed to cite as many variety traits as they thought were important.

The results in table 3-6 show that varietal trait preference for new sorghum varieties are the same for both men and women in the study areas. Yield was still the most important varietal trait for both men and women (64%). This result agrees with our research hypothesis.

Table 3-7: Results of farmers' variety traits evaluation done in December 2007, by gender and by zone

	Dioila n= 141		Mande n= 89	
Varietal traits	Men n=71	Women n=70	Men n=53	Women n= 36
	%	%	%	%
Yield	64	68	61	67
Early maturing	17	13	5	6
Resistance to drought & striga	7	9	10	6
Grain appearance	46	41	57	45
Adaptation to the area	20	20	15	4
Others	5	2	4	3

The percentages summed are greater than 100% because farmers were allowed to cite as many variety traits as they thought were important.

The results by zone and by gender about farmers' preferred varietal traits are the same as for the entire sample, with the only exception being that women in Mande preferred early maturity and resistance to drought and Striga rather than adaptation to the cultivation area.

Farmer survey

Table 3-8: The name of dominant preferred sorghum varieties (varieties grown in large space by farmers encountered in Dioila and Mande. The table also shows the frequency (%) (the number of time a variety was cited as dominant by farmers). The data to make this was from farmers' general survey conducted in December 2007.

Order	Dioila			Mande		
	Variety name	Variety type	Frequency (%)	Variety name	Variety type	Frequency (%)
1	Nionbleni	LCV	16.4	Tiemarifing	LCV	22.7
2	Bandoka	FV 07/08	15.2	Seguetana	LCV	13.3
3	Seguetana	LCV	7.6	Keleyabomusola	FV 07/08	8
4	Tieble	MV	5	Doronkonikalan	LCV	5.3
5	Yubleni	LCV	5	Tieble	MV	4
6	Gnegnebleni	LCV	5	Niagafing	FV	4
7	Kassaroka	FV 07/08	5	Kalosabani	LCV	4
8	Fambe	MV	2.5	Touroukani	LCV	2.7
9	Sumba	MV	2.5	Kenike	LCV	2.7
10	Tiemarifing	LCV	2.5	Sumalemba	MV	2.7

The frequencies in this table don't add to 100 because there were more than 10 varieties (28 in Dioila and 29 in Mande) listed by farmers as dominant preferred varieties. The percentages were taking from the total sample of sorghum growers interviewed (79 in Dioila and 75 in Mande)
LCV refers to local varieties used as control varieties in trials, FV 07/08 refers to farmers varieties included in trial for 2007/2008 and MV stands for modern varieties

The results in table 3-8 indicate that in both zones, varieties such as Seguetana, Tieble were cited by farmers as their preferred dominant varieties i.e. the varieties they plant in larger area because they like them.

Table 3-9 presents the results regarding farmers' preferred varietal trait evaluation from the farmer survey conducted in both zones. Results from women were not reported

in this evaluation because it was conducted with sorghum growers in the survey sample, of which women represented only 5%.

Table 3-9: Results of farmers' variety traits preference evaluation of their preferred dominant varieties expressed in percentage, from the farmers' general survey (the initial survey) conducted in December 2007 in the Dioila and Mande zones in southern Mali

Varietal traits	Percentage of farmers who listed the trait
Yield	95
Resistance to insect	58
Early maturity	43
Grain cooking traits	75
Drought tolerance	72
Secondary uses (like animal feed)	17
Other	15

The percentages summed are greater than 100% because farmers were allowed to cite as many variety traits as they thought were important.

Table 3-9 shows that yield, cited by 95% of the farmers, is the most preferred varietal trait by farmers in both zones. Cooking characteristics, listed by 75% of farmers interviewed, occupies the second place. Finally, drought tolerance, cited by 72% of the farmers, is the third most important varietal trait in the areas.

Results from farmers' survey per zone

Table 3-10: Results of farmers' variety traits preference evaluation of their preferred dominant varieties, expressed in percentage per zone from the farmers' general survey (the initial survey) conducted in December 2007 in Dioila and Mande zones.

Varietal traits	Dioila n=79	Mande n=75
Yield	97	92
Resistance to insect	67	49
Early maturing	58	28
Grain cooking traits	91	57
Drought tolerance	76	68
Secondary uses	25	8
Others	10	20

The percentages summed are greater than 100% because farmers were allowed to cite a variety traits as many time as they think important.

From table 3-10, the three most popular varietal traits preferred by farmers in both zones are the same. Yield is the number one in both zones, with 97% in Dioila and 91% in Mande. There is slight switch in position for cooking characteristics and drought tolerance. While cooking characteristics (91%) occupied the second place and drought tolerance, with 76%, the third place in Dioila, in Mande their position switched.

DISCUSSION

Farmers have always been plant breeders, although they are often not formerly recognized as such at the institutional level (Chakanda, 2000; Almekinders,1999; ICRISAT, 2000). Farmers' choice of varieties is based on their farming objectives, the environment and farming conditions where they live (Diakite, 2003; Kudadjie et al., 2004). Under irregular and low rainfall farming conditions, early maturity or drought tolerance, in addition to yield, are expected to be preferred variety traits; however, the evaluation by farmers in this study did not provide much evidence for interest in early sorghum varieties.

Overall, farmers participating in PVS field trial evaluation and in the survey were interested in similar varieties, and specifically in traits such as high yield potential, adaptation to the field environment and grain appearance (Tables 3-5 and 3-6). These results indicate that sorghum breeders can breed for varieties that address farmers' preferences across this region, without having to tailor a specific variety for each zone. The farmer interest in grain appearance documented here is in accord with the PVS literature that shows farmers have strong preferences for specific grain color and size aspects (Diakité 2003). This is somewhat surprising in that early maturity and drought tolerance would appear to be of increasing importance, as climatic variability in Mali over the last decade has included drought, and short and irregular rainfall (Simpson 1999). An earlier study conducted in the region of my study by Siart, (2008) found evidence that early flowering was related to early maturity and high yield, which were the variety characteristics with the highest frequency in farmers' ranking. These traits were followed by culinary qualities, which is a similar characteristic to the cooking traits

described by farmers in our study (Table 3-8). In contrast to that the research reported here, visual traits such as grain appearance were mentioned by only a few farmers (<7%) in Siart's research.

The largest difference between the results we observed from farmer evaluation in PVS trials and the survey results were that grain appearance was important in the PVS variety evaluation (table 3-4), while size and color traits were not mentioned by farmers who we surveyed. This might be related to the setting of the evaluation. When evaluating 16 varieties in a field trial, clear differences can be observed in terms of grain color and size in addition to yield. Since the fields were all at maturity, the grain appearance was an obvious factor. This result is consistent with Baidu-Forson's (1997) study on "on-station farmer participatory varietal evaluation" of millet in Niger. The setting could help explain the result by gender as well, because the presence of men could influence women's evaluation and criteria, and could have focused attention on yield rather than post-harvest characteristics. Women's preference criteria were supposed to be different from men's including processing and cooking traits, but this was not observed here (Table 3-6).

The results of the farmers' survey showed that yield, cooking characteristics, and drought tolerance were reasons that farmers preferred specific sorghum varieties. These results accorded with our research hypothesis, which stated that the three most dominant varietal traits would be yield, early maturity and drought tolerance. It is also close to Siart's (2008) finding on farmers' varieties choice in the two zones. These results agree with the results of Chakanda (2000) and the results of Nkongolo et al.. (2008) on PVS and characterization of sorghum in Malawi, indicating that farmers prefer varieties adapted to their climatic conditions, production goals and specific utilization and post-

harvest characteristics (Siart, 2008). Yapi et al. (2000) showed that farmers' choice for new sorghum varieties was determined by their socio-economic, environmental and climatic conditions; where farmers' preferences in all their study regions (Segou, Mopti and Koulikoro regions) for sorghum and millet were for early maturity, yield and food quality.

Since sorghum is mainly produced in Mali as a staple food crop, it is not surprising that the survey elicited farmer criteria that included processing and food quality as a determinant factor in acceptability by farmers, as indicated in Diakite (2004) in his study on improved sorghum diffusion in Dioila and Mande zone. Kudadjie (2004), in his diagnostic study on assessing production constraints, management and use of sorghum diversity in north-east Ghana, also found similar result that farmers' preferences for different sorghum varieties depends on agronomic and gastronomic variety traits. A PVS with improved pearl millet study done by Omanya et al. (2006) in West Africa (Mali, Niger, and Burkina-Faso) showed that early maturity was the second important variety trait for millet farmers followed by adaptation and acceptable taste. Their results indicated that farmers' preferences for crop varieties to plant are influenced by their farming goals and environmental conditions, especially the quantity of rainfall.

A deeper look of the data showed that farmers in Dioila rated cooking characteristics higher than drought tolerance, while Mande farmers switched the ranking by placing drought tolerance before cooking traits. We conducted a follow-up workshop in each village, where initial results were discussed with farmers, and documented through this discussion that although a variety called "SUMBA" is high yielding and early maturing, some farmers in Dioila said they did not prefer it because of its poor

cooking quality (author's follow-up workshop in Dioila zone, 2008). A farmer from Wakoro said: "*SUMBA is a very high-yielding variety, and it matures earlier than all our sorghum varieties, but I will never plant it again in my field because my wives complain about its processing and the quality of the food. I sold all my production to a grain seller I knew. The following year, he told me to not bring again this type of grain because he almost all his clients complained about it*" (September 12th 2008 workshop in Dioila). Some farmers in the same zones, however, said that they like SUMBA because its stems and grains are very good animal feed. A farmer from Magnambougou said " *My wives don't have problems processing and cooking SUMBA because there are some dishes like "Yeyekiny and Bashy" (cous-cous) that can be made well out of it*" (September 13th 2008 workshop in Dioila).

CONCLUSIONS

A finding from both the on-farm field trial evaluation and the survey was that yield and adaptation to the local environment were very important variety evaluation criteria, but there were additional traits of interest to farmers from Dioila and Mande. These included cooking traits (easy processing, good taste and easy storage of dishes made of a variety) and drought tolerance. However, the farmers in Dioila were more interested in cooking quality than in drought tolerance. In some cases, they even put cooking quality before yield. For example, the variety SUMBA was not preferred by some farmers, despite it high yield and early maturing, as it had poor cooking quality traits for the locally preferred 'to'.

A two-component evaluation of farmers' decision criteria and preferred varietal characteristics provided additional insights. The PVS trials provided opportunities for farmers to examine and comment on specific varieties in a group setting, whereas the individual surveys provided more opportunity for comments on post-harvest traits, and reduced the influence of farmers on each other's criteria. The results of these evaluations will help researchers to develop varieties that meet the majority of farmers' needs in a given area.

CHAPTER 4

IMPROVING FARMERS SEED PROVISION FOR SORGHUM

INTRODUCTION

Seed is a central part of a farmer's life (Leonardo, 2002). Seed management is a central issue for farmers and a key element in addressing the challenges of responding to farmers' different requirements and preferences, increasing agricultural production, and achieving food security in Sub-Saharan Africa (SSA) (Almekinders et al. 1994).

Understanding seed demand and supply among small-scale farmers is particularly crucial for crops that are not high value, such as subsistence pulses or cereals, which are also are self-pollinating crops (e.g. the common bean, groundnuts, sorghum...) (David, 2003). In order to improve farmers' access to good quality seeds, it is imperative to understand the existing seed system to be able to identify the weaknesses and strengths as a basis for developing more well functioning seed systems (Siart, 2008).

There are several factors that influence farmers' seed provision—for example the need to replace the seed of an existing variety that is no longer meeting their farming goal, or to obtain a new variety with higher yield or more pest and/or diseases resistance (Heisey, 1991;Tripp, 1997). Seed provision can then be divided into two categories. Seeds from the formal sector, commercial or certified seeds, are supplied by commercial input distributors and produced under strict conditions to meet the certification requirement. Seeds from the informal sector include farmer-saved seeds, farmer-to-farmer exchange seed, and purchase of market grain for use as seed (Pejuan, 2005). In

most developing countries such as Mali, smallholder farmers rely primarily on their own production (saved-seed) as the source of seed for subsistence crops such as sorghum (Siart 2008). Many farmers in Mali have few resources, with limited access to agricultural inputs, services, and markets (Setimela et al., 2004).

In 2006/07, farmers in both research zones of this study (Dioila and Mande) obtained sorghum seeds from three sources: their own stock, saved from the previous season, local markets and other farmers (author's survey data). This pattern is common for most subsistence crops including millet, groundnut in the research areas.

Worldwide, local seed systems are poorly understood, and few empirical studies on this topic exist (Cromwell, 1990, Almekinders et al., 1994, David, 2003, Siart, 2008, Christinck, 2002). Local seeds are important in relation to on-farm crop diversity and for meeting the local seed requirements of farmers (Leonardo, 2002).

Literature on seed systems and technology adoption in developing countries offers various explanations for non-adoption of improved crop varieties by farmers (Tripp, 1997, David, 2003). Two of the more common explanations that are relevant to improved varieties adoption include (a) lack of information about improved varieties and/or lack of access to improved seed and (b) inappropriate or unprofitable technology (i.e., experimental results are not representative of farmer agronomic and/or economic conditions) (Pejuan, 2005). Other explanations for weak technology adoption for sorghum in Mali are the cost attached to the adoption of the new varieties, the subsistence nature of sorghum production and the availability of sorghum seed in informal sector (Yapi et al, 2000; Siart 2008; Almekinder and Lourwaars 1999). The high cost of seed

associated with formal seed systems is in part due to regulations and a complicated variety release process in many SSA countries (Maredia et al., 1999).

Seed system analysis in Mali has shown that farmers frequently change varieties they sow and are interested in trying new types of varieties that include their preferred variety traits (ICRISAT, 2005; Siart 2008). Today in Mali, there are regulations on the books that could complicate release of new varieties and consequently access to seeds for farmers, but in practice they are not enforced.

Insights into seed system functioning may be obtained by assessing farmers' willingness to pay for seeds that meet their needs. Understanding seed systems, and the role of seed fairs, could contribute significantly to the development of good quality seed production and marketing systems in Mali.

Sorghum seed marketing in Mali

ICRISAT has supported farmer organizations to form farmer committees at community level. In the Dioila zone, the farmer committees were from OPC[12]s of ULPC, and in the Mande zone, they were formed with help of ACOD and AOPP into a cooperative called COPROSEM (Weltzien et al., 2007). In both zones, some members of these farmer committees hosted on-farm field trials with ICRISAT and IER, and then started producing seeds locally after training by the research technicians (Weltzien et al., 2006). Local seed producers through the farmer committees organize seed sales in their community, as well as working through seed fairs in the Mande zone and OPCs stores in Dioila.

[12] OPC: Organization of cereal producers

Previous research has indicated that farmers' demand for seed of modern varieties of sorghum (MV) depends on the performance of varieties in farmer' fields compared to their traditional varieties (Pejuan, 2005), including their adaptation to local soil and climatic conditions. In addition, demand for purchasing seeds will depend on the availability and affordability of seed.

Sorghum seed sales were a relatively new concept to farmers in this region of Mali. In the Mande zone, seed fairs were initiated in 2005 and in Dioila with the OPCs in 2003-2004 (Siart, 2008). This can be an explanation for the limited sourcing of seed from markets in both zones. There are socio-cultural reasons as well, as farmers do not consider it appropriate to sell or buy sorghum seed (Siart, 2008). Seed distribution activities must take into account that seed selling from farmer to farmer is not socially acceptable. Broek (2007), in her survey of women in these two zones, also found weak market demand for sorghum seed, which she attributed as being due to poverty, lack of information on the new varieties on the markets and the existence of seeds through informal systems such as trading seed through kin and neighbor networks.

As most farmers have limited access to transportation (Setimela et al., 2004), these constraints limit access to purchased seeds (David, 2003).

Seed fairs

Seed fairs were defined by Almekinders et al., 1999 as meetings where farmers trade seeds, exchange information about their varieties and crop species, and share their knowledge about agro-biodiversity management. In Zimbabwe, community seed fairs were used as an approach to facilitate access to and use of diverse and locally produced seeds to promote local seed security (CTDT, 2006). The main achievement of the seed

fairs was increased crop genetic diversity at the community level and greater capacity among farmers to judge and select plants and thus to make informed decisions in breeding (CTDT, 2006).

Seed fairs were first introduced in the study area with farmer seed producer cooperatives around 2005 as an application of one of the recommendations from the seed system security assessment done in northern Mali by Sperling et al. (2006). The first test of seed fairs in Mande zone was held in May 2005 and was judged as successful by the organizers based on the participants' appreciation of the seed quality, price, the setting (place and day) of seed fairs (Siart, 2008).

Willingness to pay

Myrick (1993, Pejuan, 2005) defines willingness to pay as the maximum amount of money an individual is willing to pay instead of doing without increase in the quantity of some good. Willingness to pay is most frequently associated with nonmarket valuation techniques like contingent valuation (Hanley et al., 1998), it can also be used with observed data of marketed good. Farmers' willingness to pay an agricultural input such as seed of modern sorghum varieties depends on its price, their economic situation, and the availability of credit and/or government intervention such as subsidies, but also on the additional gain or advantages expected from using the seed.

Objectives

The main objective of this chapter is to investigate ways to improve farmers' access to good quality seeds on time and at affordable prices of their preferred varieties.

Specific objectives:

- Assess farmers' willingness to pay for seed of preferred sorghum varieties

- Assess the suitability of seed fairs as a way to improve seed distribution and to promote the dissemination of improved sorghum varieties

Hypotheses

H1: Farmers are willing to pay for seeds of preferred sorghum varieties

H2: The price farmers are willing to pay depends on variety traits

H3: The price farmers are willing to pay is high enough to attract seed companies or COOPROSEM or other individual seed producers to invest in the sorghum seed business.

H4: Seed fairs are useful tools to promote sorghum seed of improved varieties

MATERIAL AND METHODS

To assess the usefulness of seed marketing as way to improve farmers' access to good quality seed, I used the willingness to pay approach and an evaluation of seed fairs done in the Mande zone. Both the willingness to pay and the seed fair evaluation were done through surveys.

Seed fair survey

In May of 2007 we conducted surveys with sellers, buyers, and visitors at two seed fairs organized by COOPROSEM (local union of farmer seed producers) in the Mande zone, in Bancoumana on 5/14/08 and in Siby on 5/12/08. The goal of our survey was to see how well seed fairs function in terms of improving farmers' access to modern varieties in rural areas of Mali. In the first part of the survey, seed sellers were asked about the species and varieties (local or modern) of seeds they brought to the seed fairs to sell. For each crop (or variety), we asked about the source of seed and whether it was self-produced or from others (friends or relatives who could not attend the fair). We were interested also in determining the sellers' experience in seed selling as well as their participation at previous seed fairs. This was to understand their motivations and concerns regarding participating in seed fairs. We were interested in determining if seed fairs were effective means of selling seed, from the perspectives of seed sellers.

The second part of the survey we interviewed seed buyers to investigate how effectively the information about seed fairs was promoted in rural areas. In addition to this information, we wanted to know why these farmers decided to buy seeds at seed fairs. We also asked the buyers their impressions regarding the seed quality, prices, presentation (size of bag/label), and varietal diversity available at seed fairs. Finally since

seed sellers (COOPROSEM, members) are trained by ACOD and AOPP agents in marketing seeds, I wanted to know whether the information that they (seed sellers and NGOs workers) provided was helpful in terms of buyers' choice of varieties. If the information was not helpful or was insufficient, we asked what further information buyers would like to have, and what would they be interested in seeing improved about the seed fair to meet their needs.

The survey conducted of fair visitors[13]' was to ascertain the following: a) Why did he/she decide to visit the seed fair? b) How had they heard about it? c) Did they ever buy seeds in any seed fairs? If yes, what (species), what varieties, how many times and where they did they buy?. Then why he/she did or did not buy anything at the fair today? An open-ended question was asked of visitors regarding their overall impression about seed fairs in terms of place (location), time (day in the year), and a general rating.

Willingness to pay survey

This part of the data collection was done as part of the evaluation of farmers' preferred sorghum varieties (reported on in chapter 3). The survey is described in detail earlier. In brief, it was conducted in 9 villages (five in Dioila and four in Mande) and focused on farmers' rationales for their choice of the three best varieties. At the end of the survey, they were asked about how much they were willing to pay for the seeds of their top three preferred varieties if the market was the only seed source for this seed.. A baseline price was given to the farmers which they could not go below; this was the price of grain for consumption. The grain price, used as the base price in my study, was 150

[13] Visitors are people who came to the fair just to look around and didn't buy anything.

FCFA[14]/kg. For example, for the number one choice variety, a farmer could be willing to pay 200 FCFA/kg, second best = 155 FCFA/kg and 150 FCFA/kg for the third.

This survey was conducted in collaboration with three ICRISAT technicians (Arouna Sangare, Moussa Kanoute, and Sidy Dembele) and two IER technicians (Bocar Diallo and Karim Cisse). These technicians were experienced at evaluation and conducting surveys on farmer preferences, as they constituted ICRISAT/IER on-farm farmers' field trial evaluation team, where they provided technical assistance in participatory plant breeding trials hosted by farmers in this region.

General farmers' survey

This survey is part of the general farmers' survey on seed quality assessment described in chapter 1. It provided an opportunity to document farmers' seed provision (source, mode of acquisition, time of acquisition and reasons of choice of the source). For all information about the process, the sample size, the time and places (villages) the survey was conducted, please refer to chapter 1. Also, the survey materiel is provided in the appendix of the document.

Data documentation and analyses

The data for this chapter were collected by me and three people, including two local NGOs workers and one extension worker of a governmental agricultural service (Mamadou Coulibaly from the "Association des Organisations Paysannes des Producteurs" (AOPP), Adoulaye Sangare from the"Association Conseil pour le Développement" (ACOD) and Brehima Camara from the "Office de la Haute Vallée du Niger" (OHVN)).

[14] FCFA is the currency used in Mali, at the survey time 1US dollars was 450 FCFA

The data were first recorded in notebooks and questionnaires in the field. They were then entered in a laptop computer in Microsoft Office Excel. The data were analyzed using Microsoft Office Excel as well for standard descriptive statistics (means, maximum , minimum prices, and standard deviation of the sample) and frequency analyses calculation.

RESULTS

Results from the general survey

Seed sourcing

Table 4-1: The main sources of sorghum seed, villages where seeds were obtained, and the time of its acquisition by zone (Dioila and Mande), from the farmer general survey done on December 2007

	Dioila n=121	Mande n=120
Seed sources in percentage in the sample per zone		
Own production	71	85
Market	10	7
Relatives	16	8
Research	2	0
Others	1	0
From Where (%) (the village where the seeds were obtained)		
Same village	85	84
Another village	15	16
Time of acquisition (% in the samples per zone)		
Since harvest	49	87
Planting time	42	9
Others	9	4

Farmer's own production - saved from a previous harvest - was the main source of sorghum seed in both zones, 71% in Dioila and 85% in Mande (table 4-1). The market was the third source in both zones, 10% in Dioila and 7% in Mali.

Looking at the villages where farmers got their seeds, the results from these data showed that in both zones, most seeds came from the same village where the farmer lived (85% for Dioila and 84% for Mande).

Most seeds in both zones were obtained since harvest. In other words, during harvest or just after harvest, farmers set apart the quantity of sorghum that they intended to use as seed for the next planting season. However, more farmers in Mande (87%)

chose their seeds at harvest time than Dioila (49%). In the Dioila zone, 42% of the sorghum producers interviewed got their seeds at planting time.

Market sourced sorghum seeds from the general survey

Table 4-2: Information on sorghum purchased seeds in Dioila and Mande, from farmer general survey conducted on December 2007 to document market sourced seed in both zones.

	Dioila n=14	Mande n=8
Place of purchase		
Market	0	100
COOPROSEM/ULPC	100	0
Choice of seller		
Familial relationship	0	50
Information from other growers	100	50
Average Distance to seller in km	10	20
Type of seller used		
Seed producer association	100	0
Grain sellers	0	100
Mode of payment		
Cash	100	100
Reason of choice for a purchased source		
Lack of seed	50	50
Past experience with the varieties	50	50
Satisfaction with this source		
Yes	100	100
No		

The results from table 4.2 show that farmers' seed producer association stores were the place where all purchased seeds (100%) in Dioila were from, while in Mande, the market place (terminal market) was the place where 100% of purchased seeds were obtained.

In Dioila, the choice of seller (from whom to buy) was 100% based on information obtained from other sorghum growers. In Mande, on the other hand, the choice of seller was 50% based on familial relationships and 50% on information obtained from other sorghum growers in the zone. The type of sellers used by seeds

buyers in Dioila was 100% seed producer association and 100% grain sellers in Mande. Buyers in Dioila traveled in average 10 km to get their seeds, while buyers in Mande had to travel 20 km on average to get their seeds. Cash payment was the mode of payment used in both zones.

Lack of seeds and the farmer's past experience with the varieties were the two main reasons for choosing market seed source in both zones. All the buyers reported that they were satisfied with the seeds they purchased.

Result from farmers willingness to pay survey

Farmers willingness to pay for sorghum seeds in Dioila and Mande zone

Table 4-3: Prices (in F CFA) that farmers are willingness to pay for seeds of their three most preferred varieties, for the entire sample (n=230).

Prices in FCFA/kg	1rst choice	2cd choice	3rd choice	Average
MEAN	245	193	169	202
MAX	2000	1000	500	1167
MIN*	75	50	30	52
STDV	175	87	60	107

* The minimum price reported in this table is below the 150 FCFA reported in the method section because no matter how hard we insisted to not propose price below that some people would give less than 150

As presented in table 4-3, farmers are willing to pay on average 202 FCFA/kg for seed of their top three choices sorghum varieties. However, with an average maximum price of 1167FCFA/kg, an average minimum of 52 FCFA /kg and standard deviation around the mean of 107 FCFA/kg, the average price was subject to a high variability. The location of the farmers influenced their willingness to pay, and thus was a contributor to this variation in price. As shown in Table 4-4, farmers from Mande were on average willing to pay 38% more than were farmers from Dioila.

Table 4-4: Farmers' willingness to pay for their preferred varieties survey per zone

Prices in FCFA/kg	Dioila n=141	Mande n= 89
Average price	176	244
Max	300	1167
Min*	52	83
STDEV	40	155

* The minimum price reported in this table is below the 150 FCFA reported in the method section because no matter how hard we insisted to not propose price below that some people would give less than 150

Further, the standard deviation in Mande was very high compared to that in Dioila. This result suggested that the average price of Dioila provides a better inference about the preferences of all the sorghum growers in Dioila than does the average price of Mande.

One hundred twenty four men and 106 women participated in the variety evaluation exercise. There was no influence of gender on willingness to pay; this is shown in figure 4-1 where the variability was high and there was no significant difference by gender.

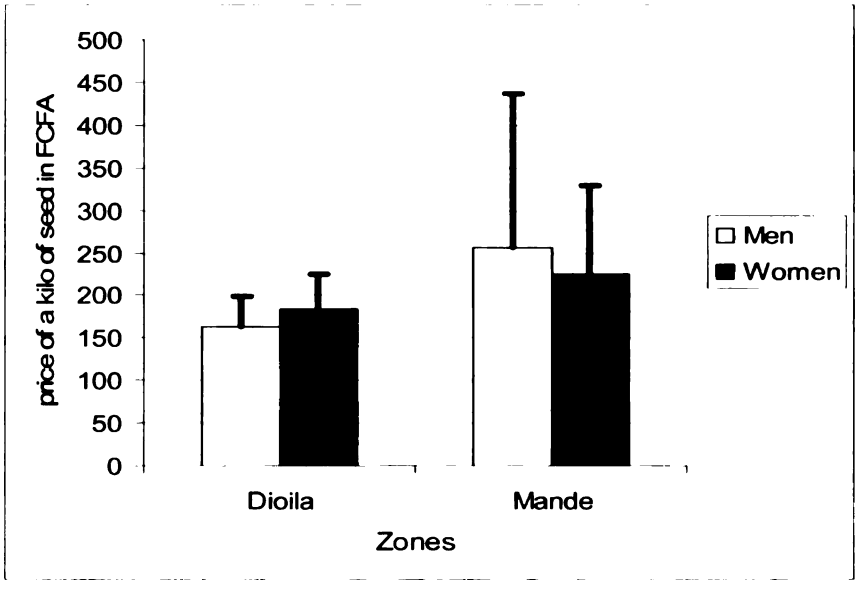

Figure4-1: Farmers willingness to pay evaluated by gender in Dioila and Mande zones through the survey done along with on-farm variety evaluation in the two zones in December 2007

Farmers' willingness to pay for variety traits

Table 4-5: Results of farmers' mean willingness to pay for their preferred sorghum varieties in relationship to the most popular variety traits studied in chapter 3. Mean price in CFA for a kg of seed in relationship to varietal traits (the standard deviations are in parentheses)

	1rst choice	2cd choice	3rd choice	Average
Yield	241 (109)	193 (74)	169 (57)	201 (80)
Early maturing	220 (63)	181 (37)	185 (58)	195 (53)
Drought and *Striga* tolerance	239 (105)	186 (40)	161 (32)	195 (59)
Grain appearance	244 (125)	193 (72)	168 (46)	202 (81)
Adaptation to the farming areas	225 (52)	176 (28)	161 (41)	187 (40)
Others	207 (70)	176 (34)	160 (74)	181 (59)

The results in the table 4-5 show that farmers are generally willing to pay more for their top (number one) preferred variety, but this varies in relation to variety traits, and the prices for the top variety are subject higher variability than the two other preferred varieties. For the first preferred variety, the ranking of the willingness to pay puts grain appearance in first place, with an average price of 244 FCFA/kg; followed by yield, with a mean price of 241 FCFA/kg; and resistance to drought and Striga in the third position, with a mean price of 239 FCFA/kg. For the second preferred variety, grain appearance and yield tie for first rank, with an average price of 193FCFA/kg; followed by resistance to drought and Striga, with 186FCFA/kg. For the third choice, earliness got the highest price (185FCFA/kg) ,followed by yield (169FCFA/kg) and grain appearance (168 FCFA/kg).

For the overall evaluation, grain appearance and yield got the highest willingness to pay, but the proposed prices have higher variability than the other traits.

Evaluation of the seed fairs

Table 4-6: The numbers of participants interviewed at the fairs held in Bancoumana and Siby in May 2007 in Mande zone to test the appropriateness of seed fairs as tool to improve farmers' access to good quality seed of their preferred varieties.

	Sellers	Buyers	Visitors	total
Siby	10	23	31	64
Bancoumana	12	34	31	77
Total	12*	57	62	141

* The total of sellers being 12 instead of 22 is because it was the same sellers from Siby plus two grain vendors who were in Bancoumana

Among the interviewed participants, about 47% of them were visitors and 43% were buyers. The 34 buyers in Bancoumana could be due to the fact that the fair of Siby happened first, and provided background information that helped farmers choose to buy their seeds at Bancoumana.

Table 4-7: Numbers of crops species presented at the seed fairs held in May 2007 in Bancoumana and Siby in the Mande zone.

	Sorghum*	Groundnut	Rice	maize	Cowpea	Millets
Siby	6	2	6	0	1	0
Bancoumana	8	0	0	2	0	0

* The modern sorghum varieties at the fairs were ICRISAT or IER varieties in production at the farmers' level. They are produced by members of the cooperative of farmers producing seeds in that Mande zone that get technical assistance from ICRISAT, ACOD and AOPP (COOPROSEM) to sell to the other farmers.

Table 4-8: Information on crop types (number of varieties, variety names, variety types and reasons of selling it) presented on the seed fairs held in Bancounama and Siby in May 2007

Crop types	Number varieties	Variety name	Variety types	Reason for selling this variety
Sorghum	9	Sakoykaba	Modern	High yield
		Soumalemba	Modern	High yield and farmers like it
		Toroba	Modern	First time of being sold
		Weli	Modern	Not being sold yet
		Girinkan	Modern	Not being sold yet
		Niangaye	Modern	Not being sold yet
		Tieblen	Modern	High yield and good taste
		Toronkanikela	local	Not being sold yet
Rice	6	Kalaban	Modern	High yield and farmers like it
		Nerica1	Modern	High yield
		Nerica2	Modern	High yield
		Nerica 4	Modern	New variety in diffusion
		Sikassoka	Modern	New varieties in diffusion
		Kumbabani	Modern	New varieties in diffusion
		Jigifa	Modern	New varieties in diffusion
Cowpea	1	Cowpea	local	High yield and good source of cash
		Birindima	Modern	High yield and early maturing
Groundnut	2	Tigaba	local	High yield and adapted to the area
Maize	1	Sotubaka	Modern	High yield and adapted to the area

Sorghum and rice were the dominant crops with seed offered for sale at the fairs. Among the nine varieties of sorghum, 8 were modern varieties. These varieties are ICRISAT or IER varieties developed through PPB, and their seeds are produced by the members of COOPROSEM, who with help of ICRISAT, ACOD and AOPP organized the fairs. These sorghum varieties were chosen for seed production, because farmers had shown interest in them during the on-farm variety evaluations.

Table 4-9: Information collected from seed fair vendors about their experience as seed sellers and membership in farmers' organizations

Information	number in the sample	percentage
Member of COPROSEM	11	92
Grain vendors	1	8
Participation in previous fairs		
Yes	11	92
No	1	8
Participation in previous fairs as vendors		
Yes	10	92
No	1	8
Motivation for participating in the seed fairs (%)		
Diffusion of new varieties		17
Discover new seed production techniques		25
Become member of COOPROSEM		8
Get financial and technical assistance from research and extension services		8
Bring more seeds in the fairs		25
Others		17
Satisfaction about the seed fair (organization and functioning)		
Yes	11	92
No	1	8

As shown in table 4-9, the sellers at the Mande seed fairs were predominantly (92%) members of COPROSEM. Among the COPROSEM seed sellers, all had participated in previous (2005 and 2006) seed fairs held in the Mande zone, and all but one were seed sellers previously. Some of the sellers (25%) were motivated to participate in the fairs to discover new seed production techniques and to bring more seeds to the fairs. Others were motivated to participate in the fairs to help diffuse new sorghum varieties (17%), or to become member of COPROSEM (8%) and to obtain financial and/or technical assistance from research and extension services (8%). Almost all the sellers (92%) indicated that they were satisfied with their participation in the fairs.

Table 4-10: Information collected from seed fairs seed buyers about their experience in buying seed and the reason why they chose to buy seed at the fairs

	Percentage
Gender	
Men	77
Women	23
Types of farmers	
Normal farmers	88
Tester of new sorghum varieties	0
No response	12
Information about the fairs	
Market	35
Radio	31
Other farmers	23
Others	11
Reason for buying seeds	
Interested in new varieties	19
Variety characteristics	66
Test	4
Seed quality	4
No response	7

The results presented in table 4-10 show that 77% of the seed buyers were men and 23% women. The majority of farmers (88%) were not involved in plant breeding research, e.g., did not host on-farm field trial programs. About one-third (35%) of the buyers had heard about the fairs from the market[15], 31% learned about the seed fair from a local radio program, and 21% were informed by other farmers. Among the buyers, 66% cited variety characteristics as their reason for buying seeds in the fairs; some 19% bought because they were interested in testing new varieties.

[15] When they came in the market, they heard the sound of the drum and went to see what was happening.

Table 4-11: Information collected from seed fairs visitors about their experience in visiting the fairs held in Siby and Bancoumana on May 2007 in Mande Zone

	Percentage
Connection with COOPROSEM or ICRISAT	
Normal farmer	89
Tester	11
Motivation for visiting the fairs	
Just look	13
Get information on new varieties	77
Others	8
Source of information about the fairs	
Market	18
Radio	29
Project workers	6
Other farmers &radio	8
Radio & project workers	5
Radio-project workers-other farmers	6
Others	28
Have you ever bought seeds in a fair?	
Yes	8
No	92
Why you didn't buy anything to day?	
No money	43
Already have seeds	6
Will buy another day	37
Others	14

From table 4-11, 89% of the visitors were farmers who did not participate in research trials, and 77% of the visitors stopped at the fairs to get information on new varieties that they had seen with the seed producers. Most of these visitors heard about the fairs from local radio programs (29%), other sources (28%) and from the market (18%). The other 25% heard from project (ACOD and AOPP) workers, or other farmers, or radio and project workers, and/or radio-project worker. Ninety-two percent of the visitors had never bought seeds at a seed fair, but they took the time to stop at the fair. Among the visitors, 43% did not buy seed because they did not have money that day, and

37% said they would buy seeds another day. (They needed time to go look for money or make a decision about what varieties to plant.)

Table 4-12: Quantity of sorghum seed purchased at the seed fairs held in Bancoumana and Siby in May 2007 during the time the surveys were conducted

Variety names	Quantity in kg
Bobodje	4
Kalaban	2
Sakoykaba	4
Sumalemba	16.5
Tieblen	3
Total	27.5

The numbers presented in this table do not reflect the total amount of seeds purchased during the fairs because we did not stay until the end of the fairs.

Table 4-12 shows that Sumalemba was the most purchased variety during the fairs. Alone, it accounted for 60% of the total quantity of seeds purchased during the period of the survey. The quantity purchased per buyer ranged from 0.5 to 2 kg.

Participants impression on seeds at the fairs

Table 4-13: Buyers' impressions on seed quality, prices and seed presentation in the seed fairs

	Percentage
Seed quality	
Very good	12
Good	77
Poor	0
Don't know	11
Seed prices	
Very high	4
High	35
Acceptable	42
Low	4
Don't know	15
Seed presentation i.e. packaging	
Good	73
Bad	7
No answer	20
Obtaining the preferred varieties	
Yes	88
No	12

The results presented here show that seed quality was judged good for 77% of the buyers and very good by 12%. Forty-two percent of the buyers also found that seed prices were acceptable, while 35% found that they were high. Fifteen percent of the buyers didn't want to answer this part of the questionnaire. In terms of seed presentation, i.e., packaging, 73% of the buyers said it was good, and 20% didn't want to comment on that part. In terms of ability to obtain their preferred varieties, 88% said they were able to do so.

Participants' suggestions for future improvement of the seed fairs

Table 4-14: Suggestions made by the interviewed seed fair participant in Bancoumana and Siby for future improvement of seed fairs in the Mande zone.

Seed sellers	Buyers	Visitors
• Get fixed places where farmers can get seeds after the fairs • Have more crops and varietal diversity so that everybody can get what they want • Help the COOPROSEM to widely inform farmers on the variety traits of the new varieties and the seed quality • Decentralize the places of the fairs, i.e., hold the fair in more places	• Bring more crops and varieties • Reduce the price of seeds • Spread the information about the fairs frequently and on time • Provide more information on the varieties • Have the fair every year at the beginning of rainy season • Make some mobilization campaign on seed quality	• Have seed fairs more than once a year • Add more crop types and varieties • Reduce the price of seeds • Associate all the local farmers organizations • Give more information about the fairs, the crops and varieties • Make more advertisements on local radios • Diversify the place of the fairs • Choose a place easily accessible like the current places

All seed fair participants interviewed shared similar concerns in terms of interest in having access to more crop types and varieties at the fair. Another common point was to have more information about the fair, and more frequent fairs held at more locations. For promotion of the fair, they suggested that it be announced in local radio programs and broadly disseminated using different channels. There was also interested in information being made available about varietal characteristics associated with the varieties the sellers bring to the fair.

DISCUSSION

Major elements were highlighted by this study regarding sorghum seed systems function in Mali. These included a high level of farmer-produced seed (80%), local sourcing of seed, and limited adoption of improved varieties (Tables 4-1).As found by an earlier survey conducted in the same zones (Diakite, 2004), more than 80% of the seeds were from the village in which the grower lives.

New sorghum varieties have been released with higher yield potential and good cooking habits especially Tieble , Ngologing, Fambe, Soumalemba, Soumba and Sakoykaba. In both of the study zones, these new varieties were favored because of their yield, relative earliness, excellent grain qualities and adaptation to 800-1000 mm rainfall zone (Siart, 2008). Despite farmer preference for these traits associated with some of the modern sorghum varieties, there still was almost no market for sorghum seeds by which farmers could access these varieties in the study zones. Own seed production is still the dominant seed source (>70% of the total seeds used) for sorghum in both zones (Table 4-1), which is similar to earlier findings from surveys conducted in Dioila and Mande by Diakite, 2004, Siart et al., 2005, and Siart et al., 2006.

Forty-two percent of sorghum seeds in Dioila zone were obtained at sowing time. This result can be related to farmers' seeds management practices in Dioila. Siart, 2008 showed that 71% of sorghum in Mande was stored in sheaves[16] selected during harvest in the field; this percentage was only 30% in Dioila. This means that many farmers in Dioila don't separate seeds from grain. It is only at sowing time that they start looking for seeds

[16] A sheave is a group of panicles selected and attached together by farmers at harvest time to be used as seeds for next planting seasons.

from their grain, and in case all their production was consumed, they will then use other sources (market, friends and relatives). Our result also showed that more farmers in Dioila purchased seed, and these farmers in general prefer to buy just at sowing time, which confirms earlier findings from this area (Siart, 2008). Diakite (2004) found that there are part-time farmers (e.g., school teachers or NGO staff) in Dioila zone who do not keep their own seed regularly and are keen to buy good quality seed on a regular basis.

Our results for market sourced seeds show that in Dioila seeds were purchased from the OPCs, while in Mande, seeds were purchased at markets. There were two seed fairs held in Mande, so that it is surprising that the survey found no purchased seeds. However, Diakité 2004 showed that most farmers in the study areas obtained new varieties from friends. Thus in Mande, most of the farmers who want the new varieties of COOPROSEM might have gotten seeds from friends or relatives who are members of COOPROSEM (Diakite and Diarra, 2000).

Willingness to pay assessment

The willingness to pay study showed that farmers were prepared to pay up to about 200 FCFA for a kilo of sorghum seeds (Table 4-3), about 30% higher than the price for sorghum grain. This is a surprisingly high price of seed given the low income level (CIMMYT, 2007), the limited cultural concepts of paying for seed of a crop for which the markets are weakly developed, and a setting in which seed is exchanged generally as a gift or through non monetary exchange (Siart, 2008, Diakite, 2004 and Diakite and Diarra, 2000). The questions still remain regarding: a) Are these prices high enough to create an incentive for seed companies or other traders and agricultural input dealers to invest in producing sorghum seed? b) Is the quantity of sorghum seed demand sufficient

to encourage seed production of new sorghum varieties? The latter question was asked in the survey, but clear answers were not forthcoming (author's unpublished data), as farmers indicated that the quantity of seed they are willing to purchase will vary greatly from year to year. It is site and time specific, as it will depend on other avenues of seed access, and the area that the farmer is interested in planting in a specific year.

Information on the cost of production of improved sorghum seeds will help us address the first question. Diakite and Diarra (2000) in their study on seed sector development in Sahelian countries, estimated the cost of sorghum seed production as follows for Mali:

Table 4-15 Estimate cost of production of 1 kg of improved sorghum seeds

Designations		Cost in FCFA/kg	Percentage in total cost
Inputs		44	39
Labor		28	24
Amortization	Motorized equipment	11	8
	Animal traction	16	13
	Small equipment	4	0
Quality control fees		6	3
Storage fees		16	13
Total cost in 2000		125	100
Actualized cost in 2007		145	
Marketing cost (transportation and other fees)		20	
Total production and marketing cost		165	

The cost used here was adjusted from 2000 estimation by using the Consumer Price Index (CPI) for Mali from http://data.un.org/CountryProfile.aspx?crName=Mali, and an estimated marketing cost from "Office du Marche Agricole" (OMA). Thus the costs in 2007 would be roughly 125*1.16 + 20 = 145+20 = 165 F per kg minimum. .

Source: adapted from Lamissa Diakite and Alpha Macki Diarra, 2000

From table 4-15, the total average cost of production of one kg of sorghum seeds was estimated to be 165 FCFA. Note these costs do not include research fees. If we consider research as public good, i.e. no direct cost for plant breeders charged through

market in Mali, this total cost compared to the average price of 200 FCFA/kg farmers were willing pay. If research has a cost this total will need to be re-estimated and from there new comparison will be made between cost and willingness pay price.

Considering the first case scenario where research is a public good:

Table4-16: Estimated revenue for sorghum seed production and distribution per zone when research costs are not paid for through market receipts

Unit : FCFA/Kg	Dioila n= 141	Mande n= 89
Average price (P)	176	244
Total production cost (TC)	165	165
Difference P- TC	51 ≈50	119 ≈120

The cost used here was adjusted from 2000 estimation by using the Consumer Price Index (CPI) for Mali from http://data.un.org/CountryProfile.aspx?crName=Mali, and an estimated marketing cost from "Office du Marche Agricole" (OMA). Thus the costs in 2007 would be roughly 125*1.16 + 20 = 145+20 = 165 F per kg minimum. .

To summarize, if farmers were not obligated to pay for the cost of the underlying research directly through the market, then the price that farmers are willing to pay would exceed the private costs of producing these varieties with preferred variety traits. These results confirmed the statement of Weltzien et al., (2006) that Malian sorghum growers are interested in trying new sorghum varieties that combine their preferred variety traits. However, price alone is not enough to start promoting seed sale. One needs to know the quantity of seed demanded for these new sorghum varieties and the market for sorghum grain (the output) in Mali.

In a previous study conducted in this region, Siart, (2008) found that improved variety seed production and dissemination from 2003 to 2006 increased from 400 to 4,300 kg of seed. This survey indicates that larger quantities of improved variety seed is produced and sold in Dioila than in Mande, which may be due to the larger area associated with the Dioila zone. It is of concern that quantities sold in Dioila were

decreasing over time. In 2004, ICRISAT found that this may be due to recycling of seed, so after initial purchases of new varieties farmers would not necessarily buy seed (ICRISAT, 2004). Farmers also give seeds of new varieties to relatives and friends (Diakite, 2004), which reduces market demand for such seed. This makes investment in seeds of self-pollinated crops that can be recycled, such as sorghum, risky for production by seed companies (Tripp, 2000).

Seed fair evaluation

Seed fairs have been used in Peru, Zimbabwe and Kenya to increase awareness of diversity in crops and varieties, and enhance farmer access to a diversity of species (Almekinders and Louwaars, 1999). The Mali seed fairs reported on in this study were appreciated by participants (table 4-13): more than 80% of the 131 participants interviewed were happy with the fairs and requested they be continued in the future. The sellers at the fairs presented 19 varieties of sorghum, rice, groundnut, cowpea and maize (Table 4-8). This is less biodiversity than seed fairs held in 2005, when 42 varieties were available for purchase, and other crops were available as well such peas, millet, and *fonio* (Siart, 2008) However, the number of buyers and the villages where the participants came from were higher in 2007 compared to 2005.

The main objective of the fairs was to improve the diffusion of new sorghum varieties through sales and to spread information about the varieties (Siart, 2008; Diakite, 2004, and CTDT, 2006). This appears to have been achieved, as our survey showed that 50% of the seed sellers were motivated to participate in the fairs as a means to bring more varieties to farmers and to learn more about new varieties and seed production. These are key elements in improving access to new varieties and the overall seed supply channel

(Sperling et al., 2003). More than 70% of the buyers said seeds in the fairs were good quality (compared to the other seed sellers' seeds). Some 35% of participants found the price of seed to be above their purchasing power, against 42% who thought the price was acceptable. The proportion of buyers who complained about the price in 2007 was higher than that of 2005. In summary, the goals for the seed fairs (COOPROSEM, ACOD, AOPP and ICRISAT) were being met, based on our survey of seed sellers, buyers and visitors. As Diakite (2004) pointed out, diffusion of improved varieties depends on information being made available about varietal characteristics, and almost all the participants surveyed pointed out the need for more information on research activities in their areas in general and particularly regarding traits of associated with new varieties. Promoting information about variety traits and seeds available at the fairs will help ensure successful seed fairs in the future, and increase awareness about new varieties adapted to farmer preferences, and local agro-socio-economic conditions.

CONCLUSION

One of the important findings from this study was that farmers in both zones were ready to pay 200 FCFA/kg for seed for their preferred varieties. This is a surprisingly high investment given the low income level and the limited cultural concepts of paying for subsistence crop seed. Generally, sorghum seed is exchanged as a gift or by non-monetary exchange, as documented in this case. However, there was evidence that farmers are willing to purchase seed at a price that would support moderate-priced privately produced seed, assuming that the research costs were supported by donors or general tax revenues. This suggests that there may be modest incentives for seed companies or other seed sellers (OPCs in Dioila and COOPROSEM in Mande) to invest in sorghum seed production, particularly in Mande, where farmers' willingness to pay was higher. However, it was not possible to document the quantity of seed farmers were willing to pay for, as farmers considered this to be too site specific and to vary from year to year. Seed recycling, exchange and gift of seeds among farmers indicates that demand for large quantities of seed will be rare or non- existent. This uncertainty would reduce the incentives to enter into private seed production in Mali.

Seed fairs were shown to be an effective means to promote local crops and farmer access to diverse varieties. Farmers were happy with their participation in the seed fairs and were enthusiastic about future fairs. Constructive suggestions were documented to improve future seed fairs such as:

- Promote a wide diversity of crops as well as varieties and widely provide information on the fairs and the products to be presented in them using all available means.

- Have the fairs in many villages to make their access easy to many people and have some fixed and known sale places of seeds after the fair.

However the overall quantity of seed sold was extremely low, and does not really warrant investment of time and funds in seed fairs. The quantity sold is in no proportion to the value of the seed, or the commercial gains the seed sellers can achieve.

APPENDIX

APPENDIX 1

Table 1-26 shows Number of seed samples collected per village and per crop type for the seed quality analyses in the laboratory on 2007 in Dioila and Mande zones

Places		Groundnut	Millet	Sorghum	Total
Dioila	Seribila	23	17	25	64
	Mangnambougou	6	12	21	38
	Wakoro	20	4	40	64
	Wobougou	25	11	18	54
	Total Dioila	74	44	104	222
Mandé	Gonsolo	35	0	23	59
	Kenioro	8	0	29	37
	Siranikoro	20	2	21	44
	Siby	26	15	24	65
	Total Mandé	89	17	97	203
All sample	Dioila + Mande	163	61	201	425

APPENDIX 2

Table 1-27 shows the sample size of head of household interviewed during the survey for seed quality assessment on 2007 study per zone

		Magnabougou	Seribila	Wakoro	Wobougou
Dioila	Men	20	20	19	19
n=80	Women	0	1	1	0
		Gonsolo	Keniero	Siby	Siranikoro
Mande	Women	17*	18**	20	19**
n=74	Men	0	0	0	0

**In Keniero the number is 18 instead of 20 because one head of family passed away and one move to another place between the seed collection on the survey. In Siranikoro, the twentieth head of household just refused to participate in the survey part.
*In Gonsolo, we could not find the three other head of household for the survey.

APPENDIX 3: Questionnaire for seed fairs survey

Name of the enumerator.....# of questionnaire.....Date

For seed sellers/ member of the cooperative

Name of Respondent: ..... Have you ever participate in ICRISAT trial.....

Gender of Respondent: ..... Village of provenance.....

Q1: What species and varieties of seeds are you selling? Specify if it is local or improved varieties

	sorghum	Millet	Groundnut	Maize	others
Varieties					

For each crop notify if the seed is self-produced =S, or from others (friend or relatives who could not attend the fair) = F

Q3: Why did you decide to sell these varieties?

Q4: Have you ever participated in a seed fair before? Yes ..... No.....

If Yes: as seller..... or buyer.....

Q5: What are your motivations in joining this seed fair?

Q6: Are you satisfied with the seed fair?

Yes..... No

Q7: If No, What are the constraints to overcomes

If yes: what are perspectives (strenghs) to enforce?

Q8: Which other possibilities of effective seed selling can you think of?

For seed Buyers

Name of Respondent: ..... Gender of Respondent: .....

Village: .....

Have you ever grown an experiment trial for ICRISAT?

Q1: How did you hear about the seed faire?

Other farmers	Radio	Farmers association	Market	Extension workers/workshop	Invitation By friend	Others sources

Q2: Why have you decided to buy your seeds in the seed fair?

Lack of seeds	Interest for new varieties	Seed quality	Varietal characteristics	others

Q3: What varieties did you buy and how many kilos? What do you think about the seeds: quality, price?

Varieties	Qty	quality				Prices			
	Kg	VG	G	B	VB	VL	L	H	VH

Note: Qty = quantity, Kg= kilogram, VG: Very good, G= Good, B= Bad, VB= Very bad, VL= Very low, L= low, H= High, VH= very high For each specie, specify the name, PM= pearl Millet, M= maize, S= sorghum, G= groundnut

Q4: Did you get all the all the varieties you were looking for here?

Yes No If no what are the missing varieties of which species?

How much of them did you need? .....(# of kg)

Q5: What do you think about seed presentation (size of bag/label) ?

Q6: Was the information you received helpful in making your choice for varieties?

Yes No If No, What further information would you like to have?

Q6: What would you like to be improved about the seed fair to meet correctly your needs?

For visitors

Name of Respondent: ..... Participant in ICRISAT trails Yes.... No...

Gender of Respondent: ..... Village: .....

Q1: Why have you decided to come in the seed fair?

To meet others farmers.....To relax.....To learn about news varieties.....Just to look at.....Others to specify.....

Q2: How did you hear about the seed fair?

Other farmers	Radio	Farmers association/OP	Market	Extension workers/workshop	Invitation By friend	Others sources

Q2: Did you ever buy seeds in any seed fairs? If yes, What (species) did you buy.....

What varieties .....Number of time.....Where.....

Q3: Why didn't you buy anything today? Prices too high..... Quality not attracting.....Don't know the varieties

Don't have money.....Will buy later..... (where?) .....Already have seeds .....Others reason to specify

Q4: By looking around what do think about the fair?

	In general	Place	Day in year	Week day
Very good				
Good				
Bad				
Very bad				

Q5: What are the possible improvement areas for you?

APPENDEX 4: Seed samples collection surveys questionnaire

Number of questionnaire.....

1- Identification of seed source

Zone.....County.....Village:..... date.....

Name of the head of family: .....Name of the person interviewed: .....

Crop Type..... Variety Name .....

1- Information on the seed lot

Year	Seed source	Seed production methods				
		Variety planted in isolation (individually) or not	Off type elimination before flowering	Selection of panicles	storage	Preparation of seed for planting

APPENDIX 5 : Questionnaire for variety evaluation 2007 in Dioila and Mande zone

Name of the enumerator: .... date
Name of the head of the household..... Gender .....
Village ..... County.....
1- Have you ever done an ICRISAT trial.....Yes=1, No=2, others (to specify) =3
If yes how many times..... Which trial .....

2- After done with your evaluation we want you to give us your impressions on your three best choices of varieties.....

Name of the variety	Reason of your choice and ranking
1-	
2-	
3-	

3- If the seed of these three varieties were available for sale on the market, how much will you be willing to pay for the kilo if the consumption grains cost more than 150 Fcfa ? The top best .....Fcfa , Second best.....Fcfa, 3rd .....Fcfa

4- Have ever planted one of the above listed varieties? .....Yes= 1, No= 2, If yes which one .....

APPENDIX 6: Head of the household interview questionnaire

Zone.....Commune..... Household number..... ...
Village:.....
Name of Respondent: ..... Gender.....Age group..... Young= 1, Middle age= 2, Senior (old) = 3 Are you responsible for farm work (chef des travaux)? ..... Yes= 1, No =2 , If yes continue the interview with him/her alone, if no ask for the person in charge of farm work to come and associate him to the interview

1- How many people are in your UPA? ..... (Number of people eating in your UPA); How many work in family field full time.....

2- Is any of them involve in other group/collective farming activities such as varieties trials, farmers association, etc..?

3- What is your family fields' size? (# Hectares).....

4- What do you grow in your family field.....? 1= sorghum, 2= millet, 3=millet and Sorghum, 4= sorghum and groundnut, 5= millet and groundnut, 6= all three.

5- How many women and men in your family have their individual field?

6- Do you know what crop they plant on their field? ....Yes= 1, No= 2
If yes how many of them are growing: Groundnut..... Sorghum..... Millet.....

7- Do you know how/where they get their seeds? .....

8- Level of equipment ..... (Well[17] =1, Average[18] = 2, Not[19] =3)

[17] Well in equipment means the farmer has all common rural farming equipments used in Mali : plow (mold-board, gang, disk, lister, cattle (ox), cart (donkey cart)

[18] Average: the farmer has only one plow and one pair of ox

[19] Not= no Equipment

APPENDIX 7 : Questionnaire individuel pour l'arachide (Groundnut individual growers survey)

Zone…… Commune…… Village:…… UPA numéro ……
Nom du Répondant: …… Genre……
Nom du chef de famille du répondant…… Genre…… Pour le genre 1= masculin, 2= féminin
Groupe d'âge…….. Jeune= < 35, âge moyen= 35 to 50, Vieux = >50
1- Sur quel champ avez-vous planté votre arachide cette année? ……Champ de famille= 1, Champ individuel= 2, champ de groupe = 3, autre (à préciser)= 4
Si dans le champ familial, demandez le chef des travaux champêtres si c'est différent du chef de famille et si dans un champ de groupe (champ de coopérative ou d'association) demandez le chef du groupe ou le chef des travaux champêtres pour ce groupe.
2-Qui prend la décision pour l'approvisionnement en semence de ce champ ? .....
Chef de famille= 1, Chef des travaux champêtres= 2, moi même= 3, autres (à préciser) = 4
3- Listez les variétés d'arachide que vous avez cultivé cette 2007:

Nom de la variété	Source de la semence	Quantité	Temps d'acquisition	Mode d'acquisition	De qui	Lieu de provenance

Pour le temps d'acquisition: depuis la récolte=1, au moment des semis= 2, autres (à spécifier)= 3
Source de la semence: propre production, marché, proches (parents, amis, etc.), institution de recherche, etc……
Pour la quantité, indiquez le nombre de kg obtenu de chaque source……
Pour le mode d'acquisition des semences: cadeau, échange, achat, autres,
De qui vous avez obtenu votre semence ? : Membre de la famille (époux), voisin, amis, autre parents, vendeurs, autres (à spécifier).
Et pour le lieu de provenance de la semence: même village=1, autre village= 2, autres (à spécifier)= 3
Si 2 à quelle distance se trouve ce village du votre? …… (# de kilomètres)
4- Si les semences viennent d'un vendeur c'est-à-dire d'une source d'achat:
Où est ce que vous avez eu votre semence?

Marché	Coopérative des producteurs de semence	ULPC (OPC)	Producteurs de semences formés	Producteurs de semences auto-établis	Autres (à spécifier)

4.a.1 Comment vous avez choisi votre vendeur de semence……..
A quelle distance vous vous trouvez de votre vendeur? ……..
4.a.2 listez les types de vendeurs de semence que vous avez utilisé:
Association des producteurs d'arachide= 1, les vendeurs de graines d'arachide au marché (petits vendeurs généralement les femmes)= 2, les détaillant de grains= 3 , les grossistes= 4, autres (à décrire) = 5
4.a.3- Comment vous avez acheté?..... Au comptant= 1, crédit payable en argent = 2, crédit en nature=3, les deux (une partie au comptant et une partie en crédit) =4, autres (à spécifier) = 5
4.b – Pourquoi avez-vous utilisez une source d'achat, (prenez toutes les réponses applicables):

Perte de semence à cause de problèmes de stockage	Qualité des semences	Situation de la saison pluvieuse	cout	Location du vendeur	Connaissance de la variété	La diversité varietal	Autres (à spécifier)

Est-ce que vous pouvez nous donner plus d'explication sur les raisons du choix de la source d'achat?
Êtes-vous satisfait avec les semences que vous avez achetées ?.....oui=1, Non=2
Sinon, qu'est ce que vous pensez qui peut être fait pour promouvoir/ améliorer les semences du marché?
5- Si la semence provient de votre propre production:
5.a. production de semence

Description du champ	**practices agronomiques**	**sélection de semences**	**Récolte**
Choix du champ (rotation)	Semis	Quand	Récolte
Isolation	sarclage		séchage
Préparation du champ	élimination des plants hors type :	comment	Egoussage
	application d'engrais		Décorticage :

5.a.1- Laquelle des pratiques de production ci-dessus listées affecte plus la qualité de la semence d'arachide pour vous?

Pour l'egoussage : 1= juste à la récolte au champ 2= quelques jours après récolte,
Si 2, combine de jour après la récolte?.....
Pour le décorticage de la semence .....juste après récolte=1, après le séchage=2, juste avant le semis= 3
5.a.2-Quelle quantité de semence que avez-vous produite? ..... Avez- vous donné à d'autre producteurs/trice.....
Si oui combien ?..... Et où.....

5.b Stockage des semences:

5.b-1 – Comment gardez-vous votre semence d'arachide? .....1= en gousses, 2= en graines décortiquées
Si 1, comment conservez vous vos gousses d'arachide?

En vrac dans le grenier	En sacs stockés dans le grenier	En sacs stockés dans la chambre	Autres (à spécifier)

5.b.2 – Si les gousses d'arachide étaient gardées dans des sacs, quels sortes de sacs étaient? .....
Les grands sacs en plastic= 1, petit sacs en plastic= 2, sacs en fibre de dah ou coton= 3, autre (à spécifier)= 4

5.b-3 – Comment vous gardez ces sacs? .....
Séparément d'autres culture = 1, séparément des autres variétés d'arachide= 2, En isolement de l'arachide de consommation= 3, autres (à spécifier) = 4

5.b-4 Avez-vous fait un traitement durant le stockage de votre semence? .....oui=1, Non=2
Si oui, quel type de traitement avez-vous fait?..... Application insecticide liquide dans la place de conservation= 1, utilisation des granule d'insecticide dans les sacs= 2, poudre pesticide= 3, traitement traditionnel= 4, autres (à spécifier)=5
Quand..... ..... Combien de fois.....

5.b-5- Durant le stockage des semences quels sont les facteurs, auxquels vous faites plus attention en terme de préservation de la qualité de vos semences? (marquez toutes les réponses qui s'appliquent)

Température	humidité	insectes	Dommages physiques	Autres (à spécifier)

5.b-6- Quelles sortes de précaution prenez vous pour protéger vos semences contre les facteurs que vous avez mentionné en ci-dessus i.e. Comment vous les prévenez?

6- Si vous avez eu des semences d'une institution de recherche, ces semences étaient pour quoi?

Multiplication de semence	Essais variétaux	Diffusion de nouvelles variétés	Autres (à specifier)

7- Appréciation de la qualité des semences: cette partie concerne toutes les sources

7.a- Comment appréciez vous la qualité des semences avant la période du semis?

Apparence	Réputation du vendeur	Information sur la variété des autres producteurs	Information des ONG/ vulgarisateurs	L'expérience passée avec les variétés	Autres (à spécifier)

7.a.1 Si la réputation du vendeur est important pour vous, pouvez vous m'expliquer comment vous utilisez ce facteur pour apprécier la qualité de la semence?

7.a.2. Si l'apparence est important pour comment vous apprecier la semence a partir de ce facteur?

Intégralité de la membrane couvant la semence	impureté	La forme des graines	couleur	taille	Attaques d'insectes	Autres (à spécifier)

7.a.3. Si la pureté variétale important pour vous, comment vous appréciez ce facteur?

couleur	forme	taille	Présence des graines d'autres cultures	Autres (à spécifier)

7.b- Comment vous appréciez la qualité des semences après semis?

Taux de germination	Vigueur à la levée	Nombre de plant en bonne santé	Autres (à spécifier)

8- Préférence de la variété:

8.a Quelle est la variété dominante que vous avez cultivé cette année?

Quel est son nom? …….. …….

Quant est ce que vous avez eu cette variété pour la première fois (estimez l'année si nécessaire)?……..

8.b- S'il vous plait descrivez les caracterisques varietaux de cette variete ici:

a) Morphologie de la plante (taille, forme des branches, etc……..)
b) Cycle végétatif ……..(nombre de mois); Rendement……..(#kg/ha), Couleur des graines……
c) Adaptation ……..
d) Autres (à spécifier):

8.c- Pourquoi cette variété est votre variété dominante, donnez plus détails:

8.d- Quant est ce que vous avez changé votre variété dominante pour la dernière fois? ……

Pour quoi avez-vous changé……..

8.e- Quels les caractéristiques variétaux qui vous attirent plus pour le choix de cette variété, (marquez toutes réponses):

Rendement en graines	Resistance aux insectes	précocité	Habitude culinaire	Tolérance de la sécheresse	Utilisation secondaire	Autres (à spécifier)

9- Comment vous obtenu votre semence de l'annee passee (2006)?

Nom de la variété	**Source de la semence**	**Quantité**	**Temps d'acquisition**	**Mode d'acquisition**	**De qui**	**Lieu de provenance**

Informations générales

Taille du champ…… (Nombre d'hectares)

Combien de personnes travaillent dans ce champ en plus de vous même? ……. (Nombres de personnes)

Êtes-vous allés à l'école? …… oui=1, Non = 2

Si oui quel niveau avez-vous atteint? ……premier cycle=1, second cycle=2, lycée/école secondaire=3, université= 4, "alphabétisation" en langue nationale =5 autres (spécifier) = 6

APPENDIX 8 : Questionnaire individuel pour le sorgho et petit mil (sorghum and pearl millet individual growers survey questionnaire)

Zone…… Commune…… Village:…… UPA numéro ……
Nom du Répondant: …… Genre……
Nom du chef de famille du répondant…… …… Genre…… Pour le genre 1= masculin, 2= féminin
Groupe d'âge…….. Jeune= < 35, âge moyen= 35 to 50, Vieux = >50
1- Sur quel champ avez-vous plante votre sorgho cette année? ……Champ de famille= 1, Champ individuel= 2, champ de groupe = 3, autre (à préciser)= 4
Si dans le champ familial, demandez le chef des travaux champêtres si c'est différent du chef de famille et si dans un champ de groupe (champ de coopérative ou d'association) demandez le chef du groupe ou le chef des travaux champêtres pour ce groupe.
2-Qui prend la décision pour l'approvisionnement en semence de ce champ ? .....
Chef de famille= 1, Chef des travaux champêtres= 2, moi même= 3, autres (à préciser) = 4
3- Listez les variétés de sorgho que vous avez cultivé cette 2007:

Nom de la variété	Source de la semence	Quantité	Temps d'acquisition	Mode d'acquisition	De qui	Lieu de provenance

Pour le temps d'acquisition: depuis la récolte=1, au moment des semis= 2, autres (à spécifier)= 3
Source de la semence: propre production, marché, proches (parents, amis, etc.), institution de recherche, etc……
Pour la quantité, indiquez le nombre de kg obtenu de chaque source……
Pour le mode d'acquisition des semences: cadeau, échange, achat, autres,
De qui vous avez obtenu votre semence ? : Membre de la famille (époux), voisin, amis, autre parents, vendeurs, autres (à spécifier).
Et pour le lieu de provenance de la semence: même village=1, autre village= 2, autres (à spécifier)= 3
Si 2 à quelle distance se trouve ce village du votre? …… (# de kilomètres)
4- Si les semences viennent d'un vendeur c'est-à-dire d'une source d'achat:
Ou est ce que vous avez eu votre semence?

Marché	Coopérative des producteurs de semence	ULPC (OPC)	Producteurs de semences formés	Producteurs de semences auto-établis	Autres (à spécifier)

4.a.1 Comment vous avez connu votre source? ..... Comment vous avez choisi votre vendeur de semence..... A quelle distance vous vous trouvez de votre vendeur? .....

4.a.2 S'il vous listez les types de vendeurs de semence que vous avez utilisé:
Association des producteurs d'arachide= 1, les vendeurs de graines d'arachide au marché (petits vendeurs généralement les femmes)= 2, les détaillant de grains= 3 , les grossistes= 4, autres (à décrire) = 5

4.a.3- Comment vous avez acheté?..... Cash= 1, crédit payable en argent = 2, crédit en nature=3, les deux (une partie au comptant et une partie en crédit) =3, autres (à spécifier) = 4

4.b – Pourquoi avez-vous utilisez une source d'achat, (prenez toutes les réponses applicables):

Perte de semence à cause de problèmes de stockage	Qualité des semences	Situation de la saison pluvieuse	cout	Location du vendeur	Connaissance de la variété	La diversité varietal	Autres (à spécifier)

Est-ce que vous pouvez nous donner plus d'explication sur les raisons du choix de la source d'achat?
Êtes-vous satisfait avec les semences que vous avez acheté ?
Sinon, qu'est ce que vous pensez qui peut être fait pour promouvoir/ améliorer les semences du marché?

5- Si la semence provient de votre propre production c'est-à-dire propre production de semence:
5.a. production de semence

Description du champ	**practices agronomiques**	**sélection de semences**	**récolte**
Choix du champ (rotation)	Semis	Quand	récolte
	sarclage		séchage
Isolation	élimination des plants de physiologie différente :	comment	
Préparation du champ	application d'engrais		Battage

5.a.1- Si oui pour l'élimination des plants de physiologie différente combien de fois vous faites cela au champ? …… A quel stage du cycle végétatif? ……..

5.a.2.- Quant est ce que vous faites le battage? ……..
1= juste a la récolte au champ 2= quelques jours après récolte,
Si 2, combine de jour après la récolte?.....
5.a. 3- Quant est ce que vous faites le battage de la semence de la semence? …… après le séchage=1, juste avant le semis= 2
5.a.4- Laquelle des pratiques de production ci-dessus listées affecte plus la qualité de la semence de sorgho pour vous?

5.a.5-Quelle quantité de semence avez-vous produite? …… Avez- vous donné à d'autre producteurs/trice……..
Si oui combien ?..... Et où……

5.b Stockage des semences:

5.b-1 – Comment gardez-vous votre semence de sorgho? ……1= en panicules, 2= en graines vannées, 3= autre (à preciser)
Si 1, comment conservez vous vos panicules de sorgo?

En vrac dans le grenier	En sacs stockés dans le grenier	En gerbe suspendue sur un arbre	En gerbe de panicules stockées dans le grenier	En gerbe de panicule stockee ailleurs que le grenier

5.b.2 – Si les panicules étaient gardées dans des sacs, quels sortes de sacs étaient? ……
Les grands sacs en plastic= 1, petit sacs en plastic= 2, sacs en fibre de dah ou coton= 3, autre (à spécifier)= 4
5.b-3 – Comment vous gardez ces sacs? …….. Dans le grenier = 1, dans la chambre= 2, autres (à spécifier) = 3
5.b-4 Avez-vous fait un traitement durant le stockage de votre semence? ……..oui=1, Non=2
Si oui, quel type de traitement avez-vous fait?..... Application insecticide liquide dans la place de conservation= 1, utilisation des granule d'insecticide dans les sacs= 2, poudre pesticide= 3, traitement traditionnel= 4, autres (à spécifier)=5
Quand…… …… Combien de fois…….
5.b-5- Durant le stockage des semences quels sont les facteurs, auxquels vous faites plus attention en terme de préservation de la qualité de vos semences? (marquez toutes les réponses qui s'appliquent)

Température	humidité	insectes	Dommages physiques	Autres (à spécifier)

5.b-6- Quelles sortes de précaution prenez vous pour protéger vos contre les facteurs que vous avez mentionné en ci-dessus i.e. Comment vous les prévenez?

6- Si vous avez eu des semences d'une institution de recherche, ces semences étaient pour quoi?

Multiplication de semence	Essais varietaux	Diffusion de nouvelles variétés	Autres (à specifier)

7- Appréciation de la qualité des semence: cette partie concerne toutes les sources

7.a- Comment appréciez vous la qualité des semences avant semis?

Apparence	Réputation du vendeur	Information sur la variété des autres producteurs	Information des ONG/ vulgarisateurs	L'expérience passée avec les variétés	Autres (à spécifier)

7.a.1 Si la réputation du vendeur est important pour vous, pouvez vous m'expliquer comment vous utilisez ce facteur pour apprécier la qualité de la semence?

7.a.2. Si l'apparence est important pour comment vous apprécier la semence a partir de ce facteur?

Intégralité de la membrane couvant la semence	impureté	La forme des graines	couleur	taille	Attaques d'insectes	Autres (à spécifier)

7.a.3. Si la pureté variétale important pour vous, comment vous appréciez ce facteur?

couleur	forme	taille	Présence des graines d'autres cultures	Autres (à spécifier)

7.b- Comment vous appréciez la qualité des semences après semis?

Taux de germination	Vigueur à la levée	Nombre de plant en bonne santé	Autres (à spécifier)

8- Préférence de la variété:

8.a Quelle est la variété dominante que vous avez cultivé cette année?

Quel est son nom? ....

Quant est ce que vous avez eu cette variété pour la première fois (estimez l'année si nécessaire)?.....

8.b- S'il vous plait décrivez les caractéristiques variétaux de cette variété ici:

e) Morphologie de la plante (taille, forme des branches, etc.....)

f) Cycle végétatif .....(nombre de mois); Rendement.....(#kg/ha), Couleur des graines.....

g) Adaptation .....

h) Autres (à spécifier):

8.c- Pourquoi cette variété est votre variété dominante, donnez plus détails:

8.d- Quant est ce que vous avez changé votre variété dominante pour la dernière fois? .....

Pour quoi avez-vous changé.....

8.e- Quels les caractéristiques variétaux qui vous attirent plus pour le choix de cette variété, (marquez toutes réponses):

Rendement en graines	Resistance aux insectes	précocité	Habitude culinaire	Tolérance de la sécheresse	Utilisation secondaire	Autres (à spécifier)

9- Comment vous obtenu votre semence de l'année passée (2006)?

Nom de la variété	**Source de la semence**	**Quantité**	**Temps d'acquisition**	**Mode d'acquisition**	**De qui**	**Lieu de provenance**

Informations générales

Taille du champ..... (Nombre d'hectares)

Combien de personnes travaillent dans ce champ en plus de vous même? ..... (Nombres de personnes)
Êtes-vous allés à l'école? ..... oui=1, Non = 2
Si oui quel niveau avez-vous atteint? .....premier cycle=1, second cycle=2, lycée/école secondaire=3, université= 4, "alphabétisation" en langue nationale =5 autres (spécifier) = 6

APPENDIX 9 : Grouping of the farmers preferred variety traits recorded during the on-farm variety evaluation.

Original list of variety trait	Grouping
Long panicle with a lot grain, long big and heavy panicles, high yield,	Yield
Early maturity, this variety is more mature than the other planted at the same time	Early maturity
Plant with green leaves, strong plant on striga infested places	Drought and Striga tolerance
Color, size, beautiful	Grain appearance
No matter when you plant this variety here you will get something, adapted to our conditions, strong stem,	Adaptation to the cultivation area
Anything else than what are listed above	other

APPEDIX 10 : Liste des codes

Genre: 1= masculine, 2= féminin
Group d'âge : 1 = Jeune (moins de 35 ans),
2 = âge moyen (35 to 50),
3= Vieux (plus de 50 ans)
Type de champ: 1= Champ de famille, 2= Champ individuel, 3= Champ de groupe, 4= autres
Décision pour l'approvisionnement en semence du champ :
1 = Chef de famille
2 = Chef des travaux champêtres, 3 = moi même, 4 = autres (à préciser)
Nom de la variété : Pas de code
Source de la semence : 1 = propre production,
2 = marché,
3 = proches (parents, amis, etc.),
4 = institution de recherche,
5 = autres (à spécifier)
Quantité : le nombre de kg obtenu de chaque source
Temps d'acquisition : 1 = depuis la récolte,
2 = au moment des semis,
3 = autres (à spécifier)
Mode d'acquisition : 1= propre production, 2 = cadeau, 3 =échange, 4 = achat, 5 = autres (à spécifier)
De qui : 1= Moi-même, 2 = Membre de la famille (époux), 3 = voisin,
4 = amis, 5 = autre parents (oncle, tante, belle famille, etc..),
6 = vendeurs, 7 = autres (à spécifier)
Lieu de provenance : 1 = même village, 2 = autre village, 3 = autres (à spécifier)
Semence de source d'achat
Place d'achat : 1 = Marche
2 = Coopérative des producteurs de semence
3 = ULPC (OPC)
4 = Producteurs de semences formés
5 = Producteurs de semences auto-établis
6 = Autres (à spécifier)
Manière de choix du vendeur : 1= proximité
2 = Lien de parenté
3 = Information à radio
4 = Information aux marché
5 = Information des autres producteurs
6 = service de vulgarisation/ONGs
7 = autres (à spécifier)
Distance au vendeur : Nombre de kilomètres à faire pour arriver au vendeur
Type de vendeur : 1 = Association des producteurs d'arachide,
2 = les vendeurs de graines d'arachide au marché (petits vendeurs généralement les femmes),
3 = les détaillant de grains,

4 = les grossistes,
5 = autres (à décrire)

Mode de payement : 1 = Au comptant,
2 = crédit payable en argent,
3 = crédit en nature,
4 = les deux (une partie au comptant et une partie en crédit),
5 = autres (à spécifier)

Raison du choix de la source d'achat : 1 = Perte de semence à cause de problèmes de stockage
2 = Qualité des semences
3 = Situation de la saison pluvieuse
4 = Location du vendeur
5 = Connaissance de la variété
6 = La diversité variétale
7 = cout
8 = Autres (à spécifier)

Satisfaction avec la source : 1 = Oui, 2 = Non

Semence de propre production

Description du champ : Choix du champ (rotation) : 1 = Oui, 2 = Non
Isolation : 1 = Oui, 2 = Non
Préparation du champ : 1 = nettoyage, cassé les mottes, et labour
2 = nettoyage et cassé les mottes
3 = nettoyage et labour
4 = nettoyage simple
5 = autres

Practices agronomiques : semis : 1= semis sur terrain labouré
2 = semis sur terrain non labouré
3 = semis sur terrain sec
4 = aures
Sarclage : Nombre
Mode : 1= main
2= multiculteur (charrue)
3 = les deux à la fois

Elimination des hors types : 1= oui
2 = Non
Application d'engrains : 1= oui
2 = Non

Sélection de semences : 1= oui
2 = non
Quand : 1= au moment de la récolte
2 = au moment du battage
3 = autres
Comment : 1 = Sélection panicule
2 = Triage de graine

3 = autres

Récolte : Récolte : 1 = sur pieds, 2 = tiges cassées,3 = tiges coupées,
Séchage : 1= au champ, 2 = à la maison
Battage : 1 = à la main, 2 = Charrette, 3 = Machine
L'egoussage : 1= juste à la récolte au champ
2= quelques jours après récolte

Moment l'egoussage de la semence d'arachide: 1= juste après récolte,
2 = après le séchage,
3 = juste avant le semis

Moment du battage de la semence de sorgho : 1= juste a la récolte au champ
2= quelques jours après récolte

Quantité de semence produite en Kilo : nombre de kilo

Autre producteur/trice ayant reçu la semence : 1 = oui, 2 = non

Combien : nombre de producteurs

Stockage des semences : 1= en panicules,
2= en graines vannées,
3= autre (à préciser)

Manière de stockage des panicules : 1 = En vrac dans le grenier,
2 = En sacs stockes dans le grenier,
3= En gerbe suspendue sur un arbre,
4 = En gerbe de panicules stockés dans le grenier
5 = En gerbe de panicule stocké ailleurs que le grenier

Type de sacs pour garder la semence : 1 = Les grands sacs en plastic,
2 = petit sacs en plastic,
3 = sacs en fibre de dah ou coton,
4 = autre (à spécifier)

Manière de garder les sacs : 1 = Dans le grenier,
2 = dans la chambre,
3 = autres (à spécifier)

Traitement des semences : 1 = Oui, 2 = non

Types de traitements : 1= Application insecticide liquide dans la place de conservation,
2= Utilisation des granule d'insecticide dans les sacs,
3 = poudre pesticide
4 = traitement traditionnel,
5 = autres (à spécifier)

Reste des codes

5.b-4 Quand : 1= au début du stockage
2 = au milieu du stockage
3= autre (à spécifier)

5.b.5 facteur plus préoccupante durant le stockage :
1= insectes attaques
2= humidité
3= Température
4= dommage physiques
5= autres (à spécifier)

5.b-6 : dispositions pour prévenir ce facteur :

1= garde la semence en gerbe ou gousse (pour l'arachide)
2= Traitements
3= Surveillance de la semence durant le stockage
4= Autre (à spécifier)

6- si la semence provient d'une institution de recherche quelle était la raison :

1= Multiplication de semence
2= Essais variétaux
3= Diffusion de nouvelles variétés
4= autres (à spécifier)

7- Appréciation de la qualité des semences :

7.1- Appréciation avant semis : 1= apparence
2= Réputation du vendeur
3= Information de autres producteurs
4= Information des ONG/vulgarisateurs
5= propre expérience avec la variété
6= Autre (à spécifier)

7.a.1 – Reputation important : 1= oui, 2= Non

Si oui quels les facteurs qui vous orientent :

1= Serieux, 2= Qualite du produit, 3= prix de la semence, 4= echos des autres producteurs

7.a.2- L'apparence important : 1= oui, 2= Non

Si oui comment vous apprécier l'apparence :

1= Intégralité de la membrane couvant la semence
2= présence d'impureté
3= uniformité des graines
4= uniformité de la couleur des graines
5= la dimension des graines
6= Trace d'attaques d'insectes
7= autres (à spécifier)

7.a.3- La pureté variétale important : 1= oui, 2= Non

Si oui comment vous appréciez ce facteur :

1= uniformité de la couleur
2= forme des graines
3= dimension des graines
4= présence des graines d'autres cultures
5= autres (à spécifier)

7.b- Appréciation de la qualité après semis :

1= Taux de germination
2= vigueur à la levée
3= Nombre de plant en bonne sante
4= Autres (à spécifier)

8- Préférence variétale

8.a – Nom de la variété dominante : écrire le nom

Temps d'acquisition : Nombre d'années

8.b- Description variétale :

Morphologie :

Taille : 1= taille haute, 2= taille moyenne, 3= taille courte

Couleur des feuilles : écrire comme sur le fiche d'enquête

Forme de branches : même chose que pour la couleur des feuilles

Cycle végétatif : Nombre de mois

Rendement : nombre de kg/ha si mentionne autrement prend l'information figurant sur la fiche

Couleur des graines : se conforme à la fiche

Adaptation a la zone : 1= Bonne, 2= Moyenne, 3= Mauvais

Autres (à spécifier)

8.d – Avez-vous change votre variete dominante : 1= oui, 2= Nom

Si oui pourquoi : 1= chute de rendement
2= irregularite des pluies
3= probleme culinaire
4= pauvrete des sols
5= autres (à spécifier)

8.e- le caractéristique varietal qui vous attire plus pour cette variété

1= Rendement en graines
2= Resistance aux insectes
3= précocité
4= aptitude culinaire
5= tolérance de la sécheresse
6= utilisation secondaire
7= Autres (à spécifier)

9- Même codes que pour la question 3

Information générale :

Taille du champ = nombre d'hectare

Personnes travaillant dans ce champ plus de vous-même= Nombre de personnes

Allé à l'école : 1= oui 2= Non

Si oui, niveau atteint :

1= premier cycle
2= Second cycle
3= lycee/ecole secondaire
4= University
5= Alphabetisation en langue nationale
6= Autres (à spécifier)

APPENDIX 11: Survey consent statement

Informed consent form for Michigan State University/ICRISAT study of seed quality assessment for Sorghum Groundnut and Millet in two different agro ecological Zone: Mande and Dioila in Mali Republic

This survey is part of a team effort of Michigan State University and ICRISAT national of Mali in collaboration with: Association Conseil pour le Developpement (ACOD), Association des Organization professionnelles Paysanne (AOPP) and the Office de la Haute Vallee du Niger (OHVN) in Mande, and Union Local des producteurs de Cereales (ULPC) in Dioila. It aims at assessing seed quality and farmers preference for varietal traits through

- Documenting seed quality through assessing samples from different sources.
- Assessing farmers' preference for varietal traits
- Developing recommendations to improve farmers' access to quality traits

The interview will take about one hour to complete and will be repeated. The first run will focus on seed sources and collection of seed samples and the second will be on the farmers' choice for varieties based on varietal traits

If you choose to participate, you may refuse to answer any questions, or you may stop participating at any time.

Your responses will be kept confidential to the maximum extent allowable by law. Your responses will be summed together with those of 270 other households in Mande and Dioila and only results from analysis will be reported.

You indicate your voluntary consent by participating in this interview: May we begin?

If you have any questions or concerns for ICRISAT and Michigan State University regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact - anonymously, if you wish, Rattunate Eva Weltzen, Mrs Goita Marthe Diallo ICRISAT at (tél. 222 33 75), Abdoulaye Sangare for ACOD, Mamadou Coulibaly for AOPP et Ibrahima Camara for OHVN in Mande and Mamoutou Diarra for ULPC in Dioila and Peter Vasilenko, Ph.D., Director of the Human Research Protection Programs (HRPP) at Michigan State University: (517) 355-2180, fax: (517) 432-4503, email: irb@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824 USA

REFERENCES

ABT 2002. Mali Agricultural Sector Assessment. Volume 1: Summary of Finding and Recommendations, Agricultural Policy Development Project. Abt Associates Inc., BetheSEa.

Almekinders C.J.M., N.P. Louwaars and G.H. Bruijn. 1994. Local seed systems and their importance for an improved seed supply in developing countries. Euphytica, vol 78 #3, pp 207- 216, June 1994 in International Journal of Plant Breeding.

Almekinders C.J.M. and N.P. Louwaars. 1999 : Farmers' seed production: New approaches and practices Intermediate Technology Publication, London

Almekinders C.J.M. and W. de Boef. 1999 . The challenge of collaboration in the management of crop genetic diversity. ILEIA Newsletter December 1999, pp. 5-7

Almekinders C.J.M. 2001. Management of Crop Genetic Diversity at Community level. Deutshe Gesellschaft fur Technische Zusammenarbeit (GTZ) project of Managing Agro-biodiversity in Rural Areas, Department of Rural Development Eschborn, Germany.

Almekinders C.J.M. & Jaap Hardon (eds). 2007 : `Bringing Farmers Back Into Breeding : Experiences with Participatory Plant Breeding and Challenges for Institutionalization. International Development Research Center (IDRC) Ottawa

Baidu-Forson, J. 1997. On-station farmer participatory varietal evaluation: a strategy for client-oriented breeding. *Experimental Agriculture* 33: 43-50

Basra . A.S., 1995 : Seed Quality: Basic Mechanisms and Agricultural Implications. Haworth Press.

Bazile, D. (2006). State-farmer partnerships for seed diversity in Mali. London: Gatekeeper series 127.

Bellon, M.R. 1996. The dynamics of crop infraspecific diversity: A conceptual framework at the farmer level. Economic Botany 50:26-39.

Benech-Arnold, Roberto L.; R. A. Sanchez. 2004 : Handbook of Seed Physiology Application to Agriculture. Food Products Press Imprints of The Haworth Reference Press, Inc New York. London. Oxford

Becker, L.C. (2000). Garden money buys grain: Food procurement patterns in a Malian village. Human Ecology: 28(2): 219-250.

Brick, M.A. 2004. "Improve Yield with High Quality Seed." Colorado State University Cooperative Extension professor, soil and crop sciences. (publication details)

Broek. E. van den. 2007. Sorghum production by Malian women – its role/importance. Results of a field research for MSc thesis in International Development Studies; specialization Rural Development Sociology Wageningen University

Boughton. D., B. H. De Frahan. 1994. Agricultural Research Impact Assessment the case of Maize Technology Adoption in Southern Mali. MSU International Development Working Paper No. 41. Department of Agricultural Economics and the Department of Economics, Michigan State University, East Lansing.

Byth D.E. (ed.) , 1993. "Sorghum and Millets Commodity and Research Environments." Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid (ICRISAT).

Community Technology Development Trust (CTDT) 2006. Community Seed Fairs in Zimbabwe, presented in Community Based Development Center (CBDC) (40-43)

Chakanda. R, 2000. Farmers' seed systems for sorghum in Mali: An evaluation of farmers' variety characterization criteria. MS Thesis, Wageningen University and Research Centre, research conducted at ICRISAT Regional Centre at Bamako, Mali.

Chavas . J.P, P.M. Kristjanson and P. Matlon, 1991. "On the role of information in decision making: the case of sorghum yield in Burkina Faso". Journal of Development Economics, Vol. 35, pp 261-280., Elsevier Science Pubishers B.V. (North-Holland)

Christinck. A, E. Weltzien, and V. Hoffmann (eds). 2005. "Setting Breeding Objectives and Developing Seed Systems with Farmers". A Handbook for Pratrical Use in Participatory Plant Breeding Projects. Margraf Publishers, Weikershein, Germany and CTA, Wageningen, The Netherlands

Cooper.H.D. 1 and L. Sperling 2. 2003. Understanding seed systems and strengthening seed security. 1 Seed and Genetic Resource Service Food and Agriculture Organization (FAO), 2 International Center for Tropical Agriculture (CIAT). Effective and Sustainable Seed Relief: A Stakeholders' Workshop, Rome, 26-28 May 2003

Coulibaly . S. 2004. Characteristics of the seed sector in the Republic of Mali. West Africa Seed and Planting Material, the Newsletter of west Africa seed Network (WASNET) # 12 ISSN 1595-2312, PO Box 9698, KIA Accra, Ghana.

Copeland. L. O, M. B. McDonald. 2001: Principles of Seed Science and Technology. Springer,

Daniel. I. O, J.A. Adetumbi. 2006. Maize Seed Supply Systems and Implications for Seed Sector Development in Southwestern Nigeria. Journal of Sustainable Agriculture, Vol.28 (2)
Defoer, T., A. Kamara and H. De Groote. 1997. Gender and variety selection: Farmers' assessment of local maize varieties in Southern Mali. African Crop Science Journal 5:65-76

Diakité, S. 2004. Etude sur la diffusion des variétés améliorées de sorgho à partir de la vente de semences dans la zone de Dioila. ICRISAT, Mali.

Diakité, S. 2003. Le système semencier local: Description, Evaluation, Valorisation. Cas de 7 villages au Mali. Working papers on Local Knowledge #2. Point Sud, Bamako, Mali.

Diakité . L and A. M. Diarra . 2000. Etude du développement de la filière des semences dans les pays du Sahel (cas du Mali). CILSS/INSAH/IER. Bamako, Mali

Doss.C.R. 2001. Designing Agricultural Technology for African Women Farmers: Lessons from 25 Years of Experience. Yale University, New Haven, CT, USA and CIMMYT (International Center for the Improvement of Wheat and Maize) Mexico city, Mexico.

Downess, R. W. 1970. Effect of light intensity and leaf temperature on photosynthesis and transpiration in wheat and sorghum. Aust. J. Biol. Sci., 24:843

Folkertsma. R.T., H. F. W. Rattunde, S. Chandra, G. Soma Raju and C. Tom Hash. 2005. The pattern of genetic diversity of Guinea-race Sorghum bicolor (L.) Moench landraces as revealed with SSR markers. Theor Appl Genet (2005)

Elang. J, 2004. Commercial Channels of seed and Planting Materials in sub-Saharan Africa: Seed markets and regulations in sub-Saharan Africa. West Africa Seed and Planting Material, the Newsletter of west Africa seed Network (WASNET) # 12 ISSN 1595-2312, PO Box 9698,KIA Accra, Ghana

Food and Agriculture Organization of the United Nations (F.A.O.) .1997. " Production des semences de qualité déclarée au Rwanda. " Kigali, Rwanda.

Food and Agriculture Organization of the United Nations (F.A.O.) (2004) : Seed fairs revive a battery of a tradition.
http://www.fao.org/newsroom/en/focus/2004/49923/article_49930en.html.

FAOSAT production/ProdStat/Crops,
http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

Fehr, W.R. 1987. Principles of cultivar development: Volume 1, Theory and technique. Macmillan Publishing Company. New York.

Friis-Hansen .E, and Turner .M, 1992. The seed sector in developing countries: A framework for performance analysis. Overseas Development Institute (ODI). working paper #65, Regent's college Inner Circle, Regent's Park London NW1 4NS

Harlan JR. Agricultural origins: centers and noncenters. Science (1971) 174:468–474

Heisey, P.W. and J.P. Brennan (1991) An Analytical Model of Farmers' Demand for Replacement Seed, American Journal of Agricultural Economics. 73(4): 1044-52

Huvio.T and A. Sidibe. 2003 Strengthening farmers' capacities for plant genetic resources conservation in Mali. Plant Genetic Resources 1(1); 31-41

ICRISAT, October 2005. Creating opportunities for poor farmers: Intensification of Sorghum and Millet Systems using local biodiversity and market opportunities in Semi-Arid West Africa. A research proposal for Sahelian and Sudanian zones of Mali, Niger, Burkina Faso and Nigeria, Bamako Mali.

ICRISAT 2002. Project Proposal, ICRISAT, Mali

Jaffee, S.and J. Srivastava 1992. Seed Development: The appropriate Role of the private and pubic sectors. World Bank Discussion paper. # 167. Washington, D.C., World Bank.

Jarvis, D. I., A. H. D. Brown, P. Hung Cuong, L. Collado-Panduro, L. Latournerie-Moreno, S. Gyawali, T. Tanto et al.. 2008. A global perspective of the richness and evenness of traditional crop-variety diversity maintained by farming communities. Proceedings of the National Academy of Sciences, USA 105: 5326–5331

Jarvis D.I, and Campilan DM *(2006)* Crop Genetic Diversity to Reduce Pests and Diseases On-Farm: Participatory Diagnosis Guidelines *(*Bioversity International, Rome*)* Ver 1.

Jayne .T.S. Isaac J. and Gem Argwings-Kodhek, 2002. Perspectives on Agricultural Transformation: A view from Africa. Nova Science Publishers, Inc New York.

Kelly, V.; Carpenter, J.; Diall, O.; Easterling, T.; Koné, M.; McCormick, P.; McGahuey, M.; 2005: Options for Economic Growth in Mali through the Application of Science and Technology to Agriculture. USAID.

Kudadjie. C.Y; P.C. Struik; P. Richards and S.K. Offei. 2004. Assessing Production Constraints, Management and use of Sorghum diversity in North-east Ghana: A diagnostic study. NJAS # 52-3/4 P.O. Box 68 Legon, Ghana.

Leonardo. W. J. 2002. Organizing seed fairs in emergency situations: Improving the efficiency of seed distribution. International Crops Research Institute for the Semi-Arid

Tropics (ICRISAT) and Instituto Nacional de Investigâçao Agronomica (INIA) Maputo Mozambique.

Longley .C. 2004. Relief or Agricultural Development? Emergency seed projects, farmers seed systems and the dissemination of modern varieties in Mali and Niger. Working Paper. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru 502 324, Andhra Pradesh, India.

Maredia . M, Howard .J, and Boughton .D, with Naseem .A, Wanzala .M, and Kajisa .K .1999. "Increasing Seed System Efficiency in Africa: Concepts, Strategies, and Issues". MSU International Development Working Paper #77. Department of Agricultural Economics, Michigan State University, East Lansing, MI

Manderscheid, L. 1965. Significance Levels--0.05, 0.01, Journal of Farm Economics 47:1381-1385.

Mburu . C. 1986. Importance of Genetic Resources and Breeding of Small Millets in Kenya, In Proceedings of the First International Small Millets Workshop, Bangalere, India, October 29 to November 2 1986. small millets in global Agriculture, pp. 149-154.

Mekbib. F. 2006. Farmer and formal breeding of sorghum *(sorghum bicolor (L) Moench)* and the implications for integrated plant breeding. Euphyca (2006) 152:163-176

Minot . N, M. Smale, C. Eicher, T. Jayne, and J. Kling,. 2006. Seed development programs in sub-saharian Africa: A review of experiences. Submitted to Peter Malton Rockefeller Foundation Nairobi, Kenya 11 November 2006.

Mulatu. E. and K. Belete. 2000. Participatory Varietal selection in Lowland Sorghum in Easthern Ethiopia: Impact on Adoption and Genetic Diversity. Alemaya University of Agriculture (AUA), Department of Plant Sciencs P.O. Box 138, Dire Dawa, Ethiopia. Expl Agric (2001), Vol 37, pp. 211-229 printed in Great Britain.

Nigam S. N., Giri D.Y. and Reddy A.G.S. 2004. Groundnut Seed production Manual. Patancheru 502 324, Andhra Pradesh, India: ICRISAT. 32 pp.

Nkongolo. K.K., K. K. , L Chinthu, M. Malusi, and Z. Vokhiwa. 2008. Participatory Variety Selection and Characterization of Sorghum *(sorghum bicolor (L) Moench)* elite accessions from Malawian genepool using farmer and breeder knowledge. African Journal of Agricultural Research Vol. 3(4), pp. 273-283 ISSN 1991-637X 2008 Academic Journal

N'tare, B.R.; A.T. Diallo.; J. Ndjeunga and F. Waliyar. 2008 . Groundnut Seed Production Manual. Patancheru 502 324, Andhra Pradesh, India: International Crop Research Institute for Semi-Arid Tropics (ICRISAT)

N'tare, B.R.; A.T. Diallo.; J. Ndjeunga; F. Waliyar; O. Kodia; CA Echekwu; I. Kapran; A.D. Sylva; A.T. Diallo; A. Amadou; H. Y Bissala and K. Sako . 2008 : Farmer Participatory Evaluation and Dissemination of Improved Groundnut Varieties in West Africa. International Crop Research Institute for Semi-Arid Tropics (ICRISAT) publication Andhra Pradesh, India. 30pp

Omanya. G.O., E. Weltzien-Rattunde., D. Sogodogo., M. Sanogo, N. Hassens, Y. Guero and R. Zangre. 2006. Participatory Varietal Selection with Improved Pearl Millet in West Africa. Experimental Agriculture (2007), volume 43, pp. 5-19 2006 Cambridge University Press

Puchner. L. 2003. Women and literacy in rural Mali: a study of socio-economic impact of participating in literacy programs in four villages. International Journal of Education Development 23 (2003) 439- 458. Elsevier Science Ltd

Rao, S.A., K.E. PrasadaRao, M.H. Mengesha&V.Gospal Reddy, 1996. Morphological diversity in sorghum germplasm from India. Genetic resources and Crop Evaluation 43:559-567.

Rasabandit. S., P. Jaisil, G. Altin, C. Vera Cruz, B. Jongdee, and P. Banterng. 2006. Participatory Varietal Selection (PVS) to Assess Farmer Preferences of Traditional Glutinous Rice Varieties in the Lao PDR. KHON KAEN AGRIC. 34 (3): 128-141 (2006)

Rice, E. M. Smale and J. L. Blanco. Farmers use of improved seed selection practices in Mexican maize: evidence and issues from the Sierra de Santa Marta. World Development 26:1625-1640

Saito. K. A and C. Jean Weidemann. 1990 Agricultural Extention for Women Farmers in Africa. Population and Human Resources Department, The World Bank Working papers # 0398 Women in Development.

Saito. K. A., H. Mekonnen, D. Spurling, 1994. Raising the Productivity of Women Farmers in Sub-Saharan Africa

Shargie .N.G and W.Wenzel. 2008 . Identifying Farmers' preferences for improved sorghum varieties in Limpopo, South Africa. ARC-Grain Crop Institute, Potchefstroom, NW, 2520, South Africa.
http://www.sik.se/traditionalgrains/review/Poster%20Presentations%20PDF%20files/Shargie.pdf

SAS GLIMMIX PROCEDURE documentation. June 2006. online resource
http://support.sas.com/rnd/app/papers/glimmix.pdf

SAS GLM CONTRAST PROCEDURE. 1999 SAS OnlineDoc®, Version 8, Cary, NC: SAS Institute Inc. North Carolina 27513

http://www.sfu.ca/saSEoc/sashtml/stat/chap30/sect12.htm

Setimela. P. S., Emmanuel Monyo. 2004: Successful Community-based Seed Production Strategies. International Maize and Wheat Improvement Center, Marianne Bänziger Contributor International Maize and Wheat Improvement Center . CIMMYT.

Shiferaw. B.A, T.A.Kebede, L. You. 2008. Technology adoption under seed access constraints and the economic impacts of improved pigeonpea varieties in Tanzania. Agricultural Economics 39 (2008) 1-15.

Siart, Sonja. 2008 : Strengthening Local Seed Systems: Options for Enhancing Diffusion of Varietal Diversity of Sorghum in Southern Mali. Margraf Publishers, Scientific books. KanalstraBe 21; D-97990 Weikersheim .

Siart, S., E. Weltzien, M. Kanoute, and V. Hoffmann. 2006. Farmers' Sorghum Seed Sources after a Drought in Southern Mali. Conference Proceedings Tropentag Conference on International Agricultural Research for Development, University of Bonn, Germany.

Scott. J, P. Kambewa, R. Chirwa, and V. Aggarwal revised by Soniia David. 2003 : Local seed systems for beans in Malawi CIAT Africa Occasional Publication series # 40 Kampala, Uganda.

Sperling .L, E. Weltzien, M.B. Sangare, J.S. Shines, S.S. Bore, A. Bamba, C.Traore, D. Coulibaly, S. Traore, C.O. Keita, M.A. Hamada, M. Ballo, F. Sangare, M. Kanoute, B. Sanogo, H. Guindo, B. Konte, S. Sanogo, A. Traore, M. Leoffen and A. Dembele . 2006. Seed system security assessment (SSSA) in DOUENTZA, Northern Mali. Catholic Relief Services/Mali and Partners, Bamako Mali. Internal Report

Tefft, J. 2004: Mali's white revolution: Smallholder cotton from 1960 to 2003. Focus 12, Brief 5 of 10, Building on Successes in African Agriculture 2020 Vision for Food , Agriculture and Environment, IFPRI, Washington.

Tripp .R, and Rohrbach .D. 2001.Policies for African seed enterprise development. Overseas Development Institute (ODI), 111 Westminster Bridge Road, London SE1 7JD, UK. International Crop Research Institute for Semi-Arid Tropics (ICRISAT), P.O.776, Bulawayo, Zimbabwe. Food Policy 26 (2001) 147-161.

Tripp. R. 2000. The organization of farmer seed systems. Relevance for participatory plant breeding. Overseas Development Institute (ODI), paper prepared for the symposium, "Scientific Basis for Participatory Improvement and Conservation of Crop Genetic Resources", Oaxtepec, Mexico, 8-14 October 2000.

Tripp, R. (1997) The Institutional Conditions for Seed Enterprise Development. Overseas Development Institute (ODI), Working paper 105, London

Venkatesan .V, 1994. Seed Systems in Sub-Saharan Africa: Issues and Options. World Bank Discussion papers Africa Technical Department series # 266, Washington, D.C. World Bank.

Vernooy.R. 2003. Seed that give: Participatory Plant Breeding. International Development Research Center (IDRC) PO Box 8500, Ottawa, ON, Canada K1G 3H9 ISBN 1-55250-014-4

Weltzien, E.; Christink, A.; Touré, A.; Rattunde, H.F.W.; Diarra,M.; Sangare, A.; Coulibaly, M. 2006. : Enhancing farmers' access to sorghum varieties through scaling-up participatory plant breeding in Mali, West Africa. In Almekinders, C.; Hardon, J. (Eds) 2006: Bringing Farmers Back into Breeding. Experiences with participatory Plant Breeding and Challenges for Institutionalization. Agromisa Special 5, Agromisa, Wageningen.

E. Weltzien, K. Von Brocke. 2001. Seed systems and their potential innovation: Conceptual framework for analysis. In Sperling. L. 2001. Targeted Seed Aid and seed system interventions: Strenghtening small farmer seed systems in East and Central Africa. Proceedings of Workshop held in Kampala, Uganda, 21-24 June 2000.

Witcombe. J.R., A. Jashi, K.D. Jashi and B.R. Sthapit. (1996). Farmer Participatory Crop Improvement I. Variety Selection and Breeding methods and their impact on biodiversity. Experimental Agriculture 32: 445-460.

Wolfgang Pejuán. 2005. Constraints to and opportunities for developing a bean seed production and marketing system in Honduras. Thesis submitted to Michigan State University in partial fulfillment of the requirements for the degree of Master of Science in the Department of Agricultural Economics.

Wolfinger, R. and O'Connell, M. (1993), "Generalized Linear Mixed Models: A Pseudo-Likelihood Approach", Journal of Statistical Computation and Simulation, 4, 233–243.

Yapi,A.M.; Kergna,A.O.; Debrah,S.K.; Sidibe,A.; Sanogo,O. 2000. Analysis of the economic impact of sorghum and millet research in Mali. Impact-Series-International-Crops-Research-Institute-for-the-Semi- Arid-Tropics (India).no. 8, 57 p. ICRISAT-WASIP, BP 320, Bamako, Mali.

Web link:

http://www.cia.gov/cia/publications/factbook/geos/ml.html

http://data.un.org/CountryProfile.aspx?crName=Mali

http://en.wikipedia.org/wiki/Pollination

http://www.icrisat.org/sorghum/sorghum.htm