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Plan B paper

Analysis of the Constraints to the Development of a Domestic Improved Seed Potato Industry in Mali

By

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DEDICATION

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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ABSTRACT

This paper outlines proposed research, using concepts of New Institutional Economics, to identify the factors constraining the emergence of a market for domestically produced improved seed potatoes in Mali**.** It uses the Principal –Agent model to outline how to investigate the feasibility of developing a domestic seed potato industry in Mali by applying the concepts of efficient contract designs and other institutional arrangements. This research will contribute to the literature on: (a) contract and institutional design in the context of asymmetric information and uncertainty typical of agricultural markets in low-income countries and (b) design of improved seed production systems, particularly for clonal crops, in developing countrie*s*.

The Malian potato sub-sector has expanded rapidly over the past 20 years due to increasing domestic and regional demand. Despite the expansion, the production is constrained by the high cost of seed due to Mali's total reliance on imported improved potato seeds. Recently, Dr. Bretaudeau and his research team at the school of agriculture at the University of Bamako have used tissue culture techniques to develop locally produced improved virus-free potato mini and micro tubers (potato seed) from the laboratory. In collaboration with researchers, farmers, input traders, and other actors involved in potatoes sub-sector, this research will help me investigate two hypotheses to respond the following question: what are the conditions necessary to go from this lab-based production to a local private-sector potato seed industry that would be competitive with the imported seed potatoes?

LIST OF ABBREVIATIONS

AMATEVI: Association Malienne d'Assistance Technique Villageoise

APCAM : Assemblée Permanente des Chambre d'Agricultures Maliennes

AOPP: Association des Organisations Paysannes des Producteurs

APROFA: Agence de Promotion de Filières Agricoles.

APPS: Association des producteurs de Pomme de terre a Sikasso

AV: Association villageoise

BNDA : Banque Nationale pour le Développement Agricole

CAE : Centre Agro Entreprise

CIRAD: Centre International de Recherche Agronomique et de Développement

CIP: Centro International de la PAPA

CMDT: Compagnie Malienne pour le Developpement Textile (Cotton Compagny in Mali)

DNSI: Direction Nationale de la Statistique et d'Information (Mali's National Direction of Statistics and in Information)

ECOFIL : Economie des filières Agricoles

EDS: Enquête Démographique et de Santé

FAO: Food and Agriculture Organization of the United Nations

FAOSAT: Food and Agriculture Organization of the United Nations Statistics

Fcfa : Franc Communauté Financière d'Afrique

GDP: Gross Domestic Product

IER: Institut D'Economie Rural

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

Kg: Kilogram

SOC : Science Outils Culture

SOMAFERT: Société Malienne de fertiliseurs

OMA: Office des Marches Agricoles

URDOC: Unité de Recherche/Développement Observatoire du Changement (a French funded research unit based in Niono

PRODEPAM : PROGRAMME DE DEVELOPPEMENT DE LA PRODUCTION AGRICOLE AU MALI

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Introduction

Potato (*Solanum Tuberosum*), a clonal[1] crop, originated in South America and was introduced in Mali by the colonial administrators in the early 1900's (ECOFIL, 1998). Potato is an important food and cash crop that contributes significantly to the process of diversification of agricultural production and the economic growth of Mali. Potato production attracts farmers because it is a high-yielding and easily marketable crop compared to millet, cotton and sorghum and its production does not interfere with the other crops because it is produced mostly during the dry season (IER/CIRAD, 1996).

As in many developing countries, since the 1990's, potato production entered a new, rapidly expanding phase in Mali due to increasing domestic and external demand. The increased demand is caused by the diversification of people's eating habits, new perceptions about the nutritional attributes of potatoes, population growth, and the effects of the devaluation of the CFA franc [2] (FCFA, the currency in Mali) in 1994. Despite the increasing demand for potatoes and the crop's economic and agronomic advantages, potato production is constrained by the high cost of improved seeds (certified, disease-free, and high-yielding), which have been imported from France and the Netherlands ever since the introduction of potato in Mali. Recently, Malian researchers[3] have developed the technology to produce virus-free micro-tubers locally at IPR/IFRA (Institut Polytechnique de Formation et de Recherche Appliquee). IPR can perform only the first step of seed potato production, called "pre-base" micro-tuber seed potato. The next step, which is the "multiplication" of the micro-tubers to mini-tubers (the seed potato ready to

[1] A clonal crop is a crop that propagates by tissue or organ transplant (not with pollen crossing)
[2] Devaluation of FCFA opened new export markets for Malian potatoes in neighboring countries such as Cote d'Ivoire, Togo, Ghana, Burkina-Faso and Benin.
[3] Alhouseni Breteaudau and co-workers, Department of Agriculture, University of Mali at IPR/IFRA of Katibougou.

be planted by farmers), has to be done at the farm level by farmers who can carefully follow specific practices to produce seeds of good quality. However, to date, nobody has investigated how to organize the steps following the pre-base production necessary for the emergence of a market for an improved seed potato produced domestically in Mali.

This paper outlines proposed research, using concepts of New Institutional Economics, to identify the factors constraining the emergence of a market for domestically produced improved seed potatoes in Mali**.** It will use the Principal –Agent model to outline how to investigate the feasibility of a domestic seed potato industry in Mali by applying the concepts of efficient contract designs and other institutional arrangements. These contracts or institutional arrangements will deal with potential information economics problems such as adverse selection and moral hazard inherent in the process of seed potato multiplication.

The proposed research considers four major participants involved in seed potato production and distribution: the laboratory that produces the micro-tubers by tissue culture; multipliers who propagate micro-tubers to mini-tubers; distributors who act as intermediaries between multipliers and farmers or between multipliers and the laboratory; and the farmers who buy seed potatoes for use on their farms. Potentially, asymmetric information[4] occurs between any two participants involved in the production process. In this research, I will focus only on the case of asymmetric information between the multipliers and the distributors. The paper is composed of four parts: 1) the problem statement, objectives and a description of the study area; 2) an overview of the potato

[4] Asymmetric information is the fact that one party (e.g., multipliers) involved in the production activity has more information about what he or she is doing at that specific level than the other party (e.g., laboratory or intermediary).

sub-sector in Mali; 3) the theoretical framework stating the principal-agent problem, the source of asymmetric information, and contract designs, and 4) the research design.

Definition of some keys concepts

Contract: is a document or oral agreement that specifies the obligations of the participants in transactions and the transfers that must be made between them under different contingencies. Both contingencies and terms of a contract must be verifiable in order for the contract to be enforceable.

Principal- Agent model: is a bilateral relationship established through contracts between two groups of participants (individuals, institutions or firms). The individual or group controlling or "owning" (having rights to the residual claims from) a resource is called the principal, and is responsible for designing and proposing the contract. The individual or group with which the principal wishes to contract for the use or management of the resource (for a purpose designated by the principal) is referred to as the agent. A key characteristic of the principal-agent model is that there is typically a conflict of interest between the principal and the agent. For example, the principal wants the agent to expend effort in order to maximize the principal's returns to the asset. Yet expending effort is not the primary goal of the agent; she is interested in maximizing her utility, and often increasing effort creates disutility. The model deals with a how the principal tries to design a contract that induces the agent to act in conformity with the principal's goals.

Moral hazard: is a principal-agent situation, under asymmetric information, in which the agent, after agreeing to a contract, engages in behavior which is either not observable by the principal or if it is observable, is not verifiable. For example the principals' inability to costlessly monitor the agent's level of effort can be source of moral hazard, as the agent has an incentive then to shirk, not delivering the effort agreed to in the contract.

Adverse selection: is a principal –agent situation in which, prior to agreeing to the contract, the agent has more information than the principal on the agents' personal characteristics that affect the agent's ability to meet the terms of the contract. For example, a driver has more information about his driving abilities and practices (e.g., whether he drinks and drives) than does the insurance company.

Chapter 1. Problem Statement, Objectives, and Study Area

1-1 Problem Statement

Why do markets fail to emerge when there are seemingly clear profit opportunities for trade? The failure of socially beneficial trade to emerge because of lack of appropriate institutions is a major cause of underdevelopment (Ray, North, 2005). This proposed research uses concepts from New Institutional Economics, in particular, concepts that deal with the problem of information asymmetry, to investigate the factors constraining the emergence of an important new agricultural market in Mali: the market for domestically produced improved seed potatoes**.**

The Malian potato sub-sector has expanded rapidly over the past 20 years due to increasing domestic and regional demand (CAE/CHEMONICS, 2001). Despite the expansion, production is constrained by the high cost of production, the most important element of which is the need for large volumes of certified disease-free and high-yielding seed tubers (improved seed potato). Up to now, all improved seed potatoes used in Mali are imported at high cost from Europe (France and the Netherlands) and sold by three companies, all located in one place, Sikasso. This is due to the complexity of the production technology, which has prevented local production of high-yielding, virus-free seed in Mali. The imported seeds ensure an excellent phytosanitary status, but they make the expenses in seed very high for the potato growers. Seed alone constitutes 46% of the total production cost and 72% of the expenses on non-labor purchased inputs (ECOFIL, 1998). Recently, Malian researchers have used tissue culture techniques to develop a way of locally producing improved virus-free potato micro-tubers, known as “pre-base”. A key question is what are the conditions necessary to go from this lab-based production micro-tuber to mini-tubers (seed potato) produced by the local private sector that would be competitive with the imported seeds?

This paper lays out a research proposal to test two hypotheses, with the second conditional on the first:

1. **The development of a domestic industry to produce of improved seed potatoes that are competitive with imports is NOT constrained by agronomic and physical factors (soils, weather, diseases, and cultivation practices) under conditions of perfect information.**
2. **The development of a domestic industry is constrained primarily by the lack of appropriate contracting and institutional arrangements necessary to deal with potential asymmetric information, i.e. moral hazard (hidden action) and adverse selection (hidden information) inherent in the production process of improved seeds.**

1-2 Objectives

This proposed research aims to explore more deeply the potato sub-sector in Mali, focusing on the seed problem of clonal crops such as potatoes. In doing so, this research will illuminate the broader and widespread question of how to develop sustainable seed systems for clonal crops in low-income tropical countries.

The Specific Objectives of the proposed research are to:

- Examine the structure of seed potato production in Mali: the physical steps involved, current institutional arrangements, and how moral hazard and adverse selection can pose problems in the process of developing a domestic seed potato industry in Mali.

- Model the hidden-action and hidden-information problems inherent in production of improved seed potatoes.
- Design possible institutional arrangements (contracting schemes) to deal with these problems, including ways of enforcing these arrangements, in order to get a reliable domestic industry producing improved seed.
- Elicit Malian potato sub-sector participants' views regarding constraints to the emergence of a domestic improved seed potato industry (physical, institutional, and contracting constraints, financing requirements, and certification procedures).

1-3 Study Area (Mali)

Mali is a landlocked country located in West Africa. It is surrendered by 7 countries and composed of eight administrative regions (figure 1). 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. The climate is subtropical to arid; hot and dry from March to April; rainy, humid, and mild from May to October; and cool and dry from November to February.

Mali is among the poorest countries in the world. Its economic activity is largely dominated by the agricultural sector, which contributes about 45% of 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 rice) and cash crops (such as cotton and peanuts), as well as ruminants. Since the 1980s, agricultural growth has been impressive, with horticulture (including potatoes) emerging as a strong growth node.

Figure 1: Map of Mali Republic and Surrounding Countries
Source : http://www.cia.gov/cia/publications/factbook/geos/ml.html

Chapter2. Overview of the Potato Subsector in Mali

Potato (*Solanum tuberosum*), is originally from South America, where it has been consumed for more than 8,000 years (CIP, 2006). Since the 19th century its production has expanded rapidly throughout the world because it provides cheap and abundant food for people. SOC (2002) found that the potato is nutritionally superior compared to cassava and yam (more protein and less fat). The same source indicates that it is high-yielding and has a short vegetative cycle compared to other tuber crops (see table1 below).

Table 1. Comparisons between Potato and the Others Tuber Crops

	Potato	**Cassava**	**Yam**	**Sweet potato**
Vegetative cycle in months	3 to 4	10 to 12	7 to 12	6 to 8
Yield (tons/ha)	25T/ha	20T/ha	20T/ha	6 T/ha

Source: Les principales cultures tropicales, Vandenput, 1981 adopted from SOC International (2002)

Today, because of its nutritional and agronomic qualities, potato is the one of the most important food crops in the world. Its annual production is estimated at 300 million tons, of which one-third comes from developing countries (FAOSTAT, 2005). Potato production in developing countries is expanding rapidly since the 1990s; the production, which was less than 30 million tons in 1960s, surpassed 100 million tons by the mid 1990s, with an annual increase rate estimate at about 5% (FAOSTAT, 1998). Annual potato production in West Africa is estimated at an average 766,000 tons (FAOSTAT, 2007). It is produced mostly in Nigeria, Senegal, and Mali.

Potatoes are consumed mainly in unprocessed form in West Africa, with the most important consumption in urban areas. The demand for potatoes in the different countries in sub-region was estimated as follows: Ivory Coast (only in cities)--18,000 tons, Senegal --24,900 tons, Mali -- 23,000 tons Mauritania -- 7,800 tons, and Guinea -- 3,800 tons (CAE/CHENOMICS, 2001)[5].

To satisfy those demands, many of these countries rely on importation from Europe to complement the domestic production. According to the same source, Mali is the only country that exports potatoes in the sub-region. The devaluation of FCFA made the importation from Europe more expensive, which is why most these countries in the sub-region turned their demand for potatoes toward Mali. This new market opportunity for potatoes is attracting many people's attention (researchers, traders, processors, and farmers) to the potato sub-sector in Mali.

2-1 General Background on Potato Farming in Mali

2-1-1 History of Potato Production in Mali

Introduced in Mali by the colonial administrators in 1938, potatoes were first grown in Sikasso and Kayes in the southern and eastern parts of Mali; in 1940 they reached Segou in central Mali; and between 1955 and 1960 significant quantities were produced in the northern Mali (Tombouctou and Gao) (Vanderhofstadt, 2002). Today, potatoes are cultivated in many parts in Mali as long as the agro-climatic conditions (temperatures, hydrographic conditions) are favorable and the soil moisture and texture are appropriate for its cultivation. The popular varieties planted are: Claustar, Pamina, Spunta, Lola, Aida, Atlas, Sahel, Cosmos, Diamant, Provento, Mondial, Liseta, Itoise,

[5] These data should be interpreted with caution because they are about 7 years old and many changes happened in these countries since then.

Charlotte, Yasmina and Cynthia. The choice of those varieties is a function of their storage capacity, resistance to diseases, and productivity (yield).

In addition to the increase in demand, farmers are attracted to potato production because it is a high-yielding crop, easily marketable and its production doesn't conflict with the other crops because potatoes are grown mostly during the dry season.

2-1-2 Potato Production in Mali

Potatoes are produced by small-scale farmers, mainly for sale rather than for home consumption. The biggest production occurs during the dry and cold season (October – April) because the process of formation of tubers requires low temperature at night. Only about 20% of the total production can be done during the rainy season (around the hills) because of the high temperature during that period. The national production is estimated at 67,000 tons/year, with an average yield of about 20 tons/ha a year (FAOSAT, 2008).

Today, potatoes are grown in many parts of Mali, but the main production area is still Sikasso in the southern part of the country. About 80% of the national production is from Sikasso region, where the yield can reach 30 ton/ha (DNSI, 2003).

Farmers usually get the inputs from private companies. Two types of seeds are used in Mali: the traditional seeds (smallest tubers from the harvest) and imported seeds from Europe (France and Netherlands). The second source represents 80% of total seeds used by farmers. Those imported seeds are supplied by three companies: "*la Sikassoise*", "*Inter agro"* and "*Cikela*", all located in Sikasso. The payment for seeds and fertilizers is in cash for individual farmers, and on credit for farmers' associations (AV).

Note that while devaluation of the FCFA opened new market opportunities for Malian potatoes, at the same time it almost doubled the cost of imported inputs for potato production (see table 2 below).

Table 2. Cost of Potato Production per Hectare in Sikasso before & after Devaluation

Inputs	**Before devaluation (1994)**		**After devaluation (1995)**	
		Value in FCFA		Value in FCFA
Labor	665d/ha[6] x 625 FCFA	415,625	665d/ha x 625 FCFA	415,625
Seeds	1000 Kg x 380 FCFA	380,000	1000 Kg x 760 FCFA	760,000
Chemical fertilizers	1000Kg x 120 FCFA	120,000	1000Kg x 210 FCFA	210,000
Organic fertilizers	13000Kg x 10 FCFA	130,000	13000Kg x 10 FCFA	130,000
Transportation	25000 Kg x 5 FCFA	125,000	25000 Kg x 5 FCFA	125,000
Total FCFA		**1,170,625**		**1,640,625**

Source: ECOFIL survey 1996 adopted from SOC international (2002)

2-1-3 Potato Marketing Channels

In contrast to cotton, the marketing channels for potatoes are not regulated by any governmental services in Mali. The transactions are based on informal agreements and ethical considerations such as sincerity and trust. There are three types of payment: cash, credit, and in-kind; more than 90% of the sales are done by cash payment (ECOFIL, 1998). The marketing channel is composed of farmers, assemblers, wholesalers, retailers, and consumers. In this channel, there is no specialization at different levels of the distribution process because some farmers can also engage as traders after the production period.

About 90% of the national production is sold domestically or exported. Among the quantities marketed (90%), about 30% are sold at farm gate by farmers, and about 60% are sold in the markets of big cities such as Bamako, Sikasso, and Segou. More than 60% of exports originate from the markets of Sikasso region (located near borders of Ivory Coast and Burkina Faso). The domestic destinations (consumption markets) for

[6] d/ha: day of work in one hectare of potato field i.e. from 8 AM to 4 PM

potatoes are mainly cities; Bamako (the capital city) comes at the top with 65% of domestic markeing (Diakite et al, 2003).

The prices paid to the producers varied between 125 FCFA/kg to 275 FCFA between 1998 and 2004, depending on the period in year. The prices on the retail markets also vary significantly within the year and according to the location (e.g., 156 – 533 FCFA in Bamako, compared with 250 -700 FCFA in Kayes). Figure 2 shows the evolution of prices to consumers in one important consumption area.

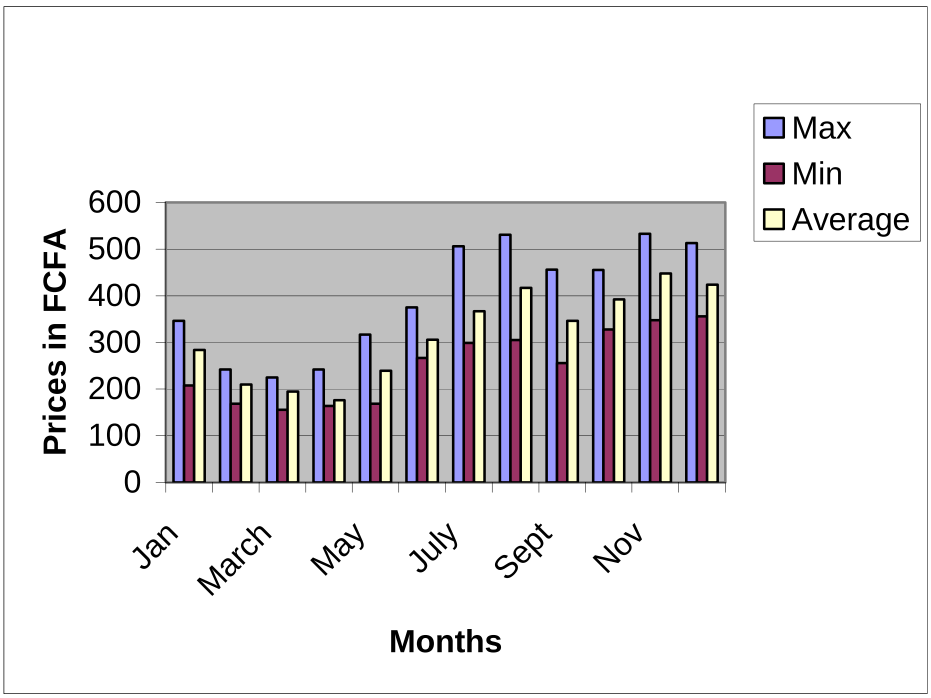


Figure2. Monthly Retail Potato Prices in Bamako-Dibida Market from 1998 to 2004
Source: OMA market price survey, 2005

Table3 shows the retail prices in various markets during year 2005.

Table 3. Retail Potato Prices in Various Markets in 2005				
Markets	**Average price**	**Min**	**Max**	**std.dev.**
Bamako Dibida	316	156	533	102
Bamako Medine	297	136	533	94
Kayes	464	250	700	128
Mopti	365	178	725	130
Segou	320	144	650	124
Sikasso	220	104	406	79
Source: OMA market price survey, 2005				

An important quantity is exported toward the neighboring countries: Ivory Coast (roughly 90% of total exports), Ghana, Burkina Faso, Togo, Benin, and Mauritania (CAE/CHEMONICS, 2001). Unfortunately, detailed statistics on these quantities do not exist.

2-2 Organization of the Potato Sub-sector in Mali

The potato sub-sector in Mali includes farmers, input suppliers, research structures, NGOs and development services, financing institutions, traders, transporters, and consumers.

The farmers are smallholders throughout the production areas. Central actors of the sub-sector, they are organized in some places into associations of potato producers to facilitate their access to credit from financing institutions or to get inputs (fertilizers and seeds) on credit. APPS (Potato Producers Association in Sikasso) is the most popular producer organization in the region of Sikasso. In the other places like the Office du Niger, the producers' organization is known as AV (*Association Villageoise*). At the national level, APPS and AVs are linked to the Permanent Assembly of the

Chambers of Agriculture of Mali (APCAM)—an umbrella organization of farmer organizations.

The suppliers of inputs are usually private companies. They generally supply fertilizers, pesticides and imported seeds. Therefore, they work directly with the foreign factories or industries producing these inputs. They are also linked via market directly to the farmers, extension and research services and indirectly to consumers. SOMAFERT (Societe Malienne de fertiliseurs) is one of the main companies importing fertilizers and pesticides.

Various NGOs, development services, research and extension institutions work on the technical aspects of potato production. They help farmers with training, other technical assistance to improve their productivity, and provide new varieties well adapted to the socio-economic and climatic conditions of the production areas. In the cotton production areas, it is the CMDT (Mali's sole cotton company) that provides extension support to potato farmers. And in the irrigated area of the Office du Niger (ON), the extension program of the ON, URDOC, and the IER research station are all involved in helping support potato production. Recently, some NGOs and donor-funded projects such as Trade Mali, APROFA and Mali Finance got involved in supporting marketing and processing, especially for exports.

The financial institutions are the banks such as BNDA (National Bank for Agricultural Development) and micro-finance institutions such as "*KAFO Jigene", "Niesigiso"* etc., that provide farmers, processors, and some traders with credit for potato production and marketing. These organizations usually extend credit to groups rather than individuals because there are no well established agricultural insurance or collateral systems in Mali, so peer pressure is relied upon make people repay their credit.

The following table summarizes the roles played by each actor in the subsector and the constraints they face in exercising their responsibilities.

Table 4. Roles and Responsibilities of the Potato Subsector Actors

Steps	Actors	Roles and responsibilities	Constraints
Upstream of the sub-sector	Input and agricultural equipment suppliers	Supply of fertilizers, seeds, insecticides and agricultural equipment	Market not well supplied. Inputs are frequently of poor quality or not productive enough to be profitable
	Agricultural research (AR)	Development of new technology to improve and/or address problems in potato production	Few resources for research, no specific research program
	Extension services	Dissemination of new technologies identified by AR by providing advice to farmers	Weak geographic coverage and insufficient support and advice to actors
Potato production	Potato growers (farmers)	Production and supplying markets with potatoes	Poorly trained and organized, with limited resources and facing high cost of inputs
Potato marketing	Assemblers, wholesalers, semi-wholesalers, retailers	Purchase of potatoes at farm gate, ensure the connection between farmers and consumers	Few organized, with limited resources, no credit lines for potato sub-sectors
	Women sellers of potatoes	Majority in potato selling at local markets, they are most of the times retailers	Not well organized and few resources to do their activity
	The import and export companies dealing with potatoes	In charge of assembly, conditioning, and distribution of potatoes	Not well trained or organized, with low levels of resources
Processing	Processors or structures providing potato processing services	In charge of potato processing	Not well developed yet; just at the experimental level
Transportation	Transportation companies, individual transporters	Ensure potato transportation from place to place	Few organized, and high bribes at import and export points
Consumption	Consumers	Terminal buyers and consumers	Irregular supply and high prices of potatoes

2-3 **Advantages of the subsector**

The potato subsector is expanding because of the following factors:

From an agronomic point of view: Potato production is well integrated in farmers' production systems in the production area because: a) potatoes are easy to grow (short vegetative cycle compared to other root crops), b) the production does not interfere with the other crops (potatoes are produced during the dry season), c) potato production is typically more profitable than that of other crops such as maize, and cotton, and d) potatoes are higher yielding than other tuber crops.

From a marketing point of view: The combined effects of the FCFA devaluation and changes in consumption habits has increased domestic as well as regional demand for Malian potatoes since the early 1990s. This increased demand makes potatoes more easily marketable; producers don't have to worry about where and to whom to sell their product. This high demand results in an increase of prices. Therefore, the producers as well as the traders generally make money even though post-harvest storage losses may reach more than 10% (CAE/CHEMONICS, 2001).

Despite all these advantages of potatoes compared to other crops, its production and production area still low because of climatic, soil and the cash-flow problem for potato growers to get the inputs on time.

2-4 Constraints Facing the Potato Subsector in Mali

Despite the growing demand for potatoes, the high profitability of the production, and some technical support to farmers, potato production is constrained by seasonality of soil moisture, limited cropland, weak storage facilities, disease issues and a high seeding rate, which implies a heavy demand for seeds.

Disease issues: Potatoes are very sensitive to diseases during the cropping and storage periods. Potato tuber seeds tend to accumulate viruses and others pathogens over time; this process is called degeneration (IPGRI, 2000). As seed moves long distances, the dissemination of the pathogen becomes widespread, and in this way the problem of diseases is aggravated. However, the identification and monitoring of the disease problem is still incomplete and needs to be investigated more by Malian researchers. The important diseases for potato are caused by:

- Bacteria (*Ralstonia solanacearum* and *Erwinia*)
- Viruses, which can infest potatoes during the seed production process. This is why the production of improved virus-free seeds is very delicate. Six viruses that can prevent disease-free certification by European authorities have been identified as endemic in Mali by Malian researchers: PVX, PVY, PLRV, PVS, PVM, and PVA.
- Some fungi attacks, caused by *Fusarium sp,* may occur during storage.

High costs of seed: Most of the seeds are imported and expensive; and most of the farmers don't have enough cash to get enough seeds at planting time. That is why this proposed research will focus on the high cost of production related to the problem of seeds. The quality, availability, and accessibility of seeds constitute a major constraint to the production of potatoes.

The cost of seeds (760,000 FCFA per ha) represents 46% of the total cost of production. The high cost of seeds is due to: a) the nature of potato production itself (high physical seed rate typical of clonal crops), b) the low productivity of locally produced seed (due to storage conditions, disease issues, etc.), and c) Mali's total reliance on imports for improved potato seeds (table 5).

Table 5. Quantity of Imported Seed Potatoes used in Mali from 1995 to 2005 (metric tons)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Quantity from France	701.7	809.4	582.1	714.1	834.7	1037.7	1222.1	929.9	1168.5	1112.6	1275.8
Quantity from Netherlands	26.3	39	65	52	57.5	99.2	124.8	229.3	221.5	122.1	550.7
Total quantity	728	848.4	647.1	766.1	892.2	1136.9	1346.9	1159.2	1390	1234.7	1826.5

Source: Eurostat

The quantities shown in table 5, evaluated at the market price of imported seed in Sikasso (760 FCFA), represent an average expense of 82.7 million FCFA [$1.65 million] a year in imported seeds.

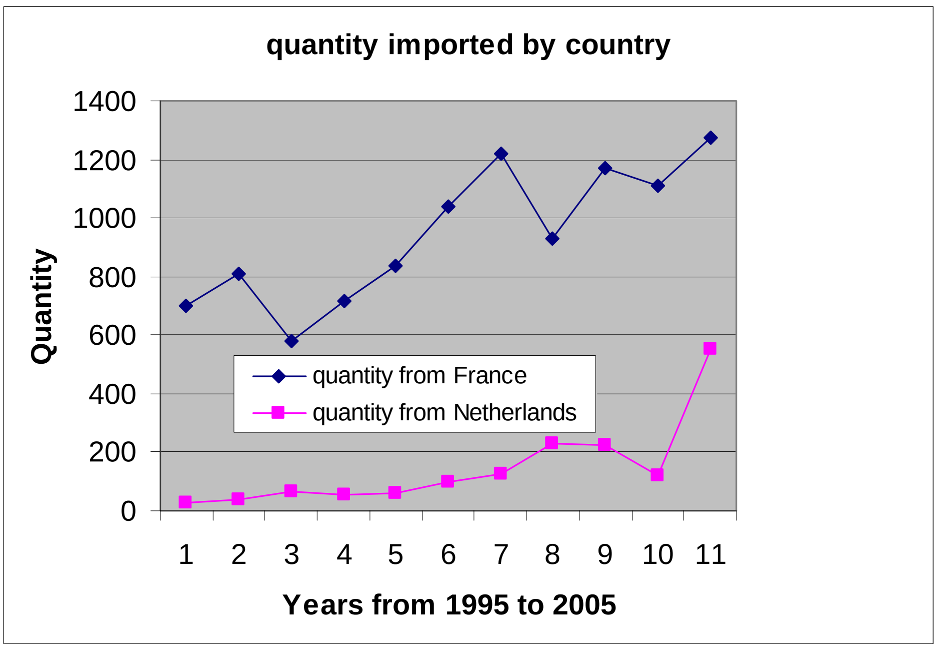


Figure 3. **Quantity Total of Improved Seeds Imported from France and Netherlands**

Source: European Community, Eurostat.

The location of all three importers in Sikasso makes seed access more difficult, in terms of time and cost, for producers in others localities in Mali. The firms also do not sell to individual farmers on credit, making it difficult for them to obtain improved seeds in a timely way.

Chapter 3: Theoretical Framework

The problems faced in developing a viable domestic seed potato industry are not unique to Mali. Many of the issues of certification, costs and benefits to producers of various degrees of "improvement" in the seeds that they use, and role of local producers vs. large commercial firms in improved seed production, are common to many low-income countries (Sperling et al., Mayona et al.). The issues are more pronounced in crops like potatoes, where seeding rates are particularly high. Thus, understanding the conditions necessary for the development of viable local improved seed potato industry in Mali will likely yield insights on how to improve seed systems in other similar low-income countries.

The theoretical framework used for this research is based on the information economic theories of Principal-Agent problems caused by asymmetric information among the different actors involved in improved seed potato production. The proposal focuses on the types of institutional arrangement that the different participants involved in the seed potato production (IPR, multipliers and wholesalers) can make to move the virus free micro-tubers from the laboratory to the farmers, taking into account the problems arising from asymmetric information. One set of institutions that might be particularly important and on which I will focus my analysis is that having to do with quality management. Quality is important because product differentiation, value-adding, and better control of characteristics of inputs that are key determinants of quality, seem to have emerged as important factors in restituting of agri-food systems (Hueth, 2000).

First I will briefly identify the sources of seed potato used by farmers and describe the process of improved seed potato production from previous research and literature.

From this description I will determine the sources of potential asymmetric information and model the principal-agent problem. Then I will investigate possible ways to deal with this problem by looking at possible contracting schemes.

3-1 Seed Potatoes Used and Their Production Process in Mali

Production of seed potatoes is long and complicated, and seeds are very susceptible to diseases. According to the purpose of production, potato producers' choices for new varieties are driven by the socio-economic conditions of their environment (market requirements, culinary qualities), the quality of seed potatoes, and genetic characteristics of varieties (Mayone et al 2000).

In Mali, as in many other potato-producing countries, two kinds of seed potatoes are used by farmers: the improved imported seeds and the local seeds (farmers' own seeds). The local seed potatoes involve saving parts of the harvest of the current year to serve as seed for next. These seeds are not as expensive as the imported seeds, and they are available. However, their quality (agronomic qualities, health status, etc.) is not attractive for the following reasons:

- There are typically no specific measures taken to preserve or to control the health conditions (purification and treatments) of seeds.
- The poor post-harvest storage conditions worsen the disease issues.

In addition to quality concerns, the quantity of local seeds is not big enough to supply all the farmers. As a result, most farmers use improved seeds despite their high unit cost because they are good quality (disease free and high-yielding) and they don't have to worry about storage of seed potatoes from harvest to the following planting season.

3-1-1 Process of Improved Seed Production

The production of improved seed potato is very delicate and long. In Europe, for example, it takes about 7 to 10 years to get certified seeds with a standard of 7% virus infestation.

The process starts with the production the micro-tubers, known as "pre-base," first in the laboratory from tissue culture, then in greenhouses under controlled conditions (temperature, humidity and protection against infections). The micro-tubers obtained are then multiplied by farmers through 3 to 4 generations in order to select the good quality and to get enough mini-tubers or seed potatoes ready to be planted by farmers to produce consumption potatoes. Under seed regulation, these seeds need to go through certification and quality- control processes to furnish certified seed potatoes or class A seed potatoes. Each multiplication of mini-tubers gives 4-12 similar tubers. Mini-tubers are planted in a very tight spacing (60,000/ha) so that when they multiply they stay small (Bretaudeau et al, 2003).

The first step of producing micro-tubers from plant tissue culture is also called micro-propagation. This is a practice used to propagate plants under sterile conditions, often to produce clones of a plant (see figure 4). The main advantage is the production of many plants that are clones of each other, i.e., the production of exact copies of selected plants. For potatoes, it is preferred because it allows the production of disease-free plants, which is the most important goal of improved seed potato production.

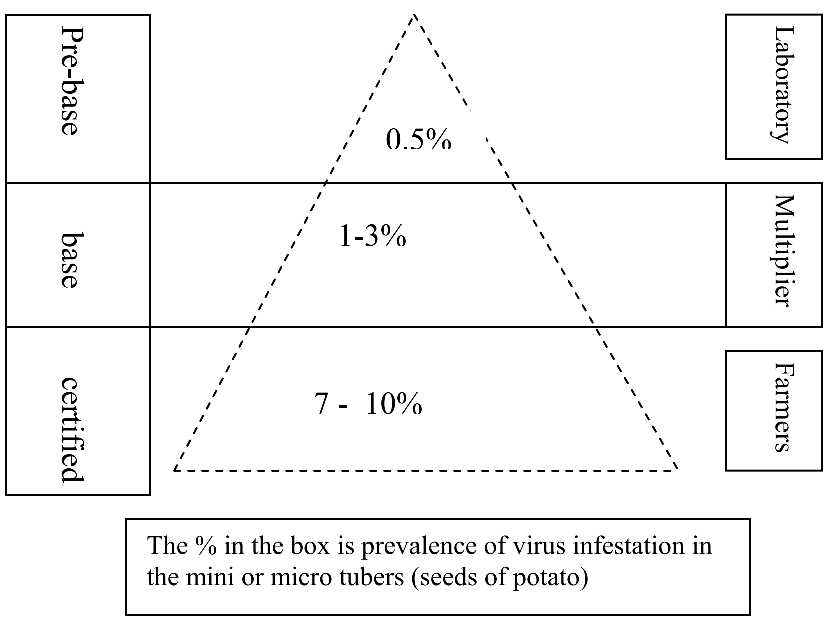
Figure 4. I**n-vitro tissue culture of potato plants**

Source: Google picture from Wikipedia free dictionary

The second step is the multiplication of the micro-tubers, also called G0 generation, obtained from tissue culture into mini-tubers (seeds ready to be planted). This is done through four subsequent generations (G1, G2, G3, and G4) from G0-- i.e., G0 produced in 2005 will lead to sale of G4 mini-tubers to farmers in late 2009. All these generations are needed in order to obtain more seeds because the multiplication rate of potatoes is low. An important factor that pleads in favor of this approach is the selection, throughout the different generations, of plants with desired agronomic traits and the elimination of infected plants to reduce the risk of unacceptable field infection a good investment in disease control (De Greef, 2004).

Improved seed production in Mali

In 1986, AMATEVI, a Malian NGO, tried multiplying micro-tubers in Mali. AMATEVI workers installed trials to identify adapted agronomic techniques for micro-tuber multiplication. In 1991 they put in place pilot teams of mini-tuber multiplication in Kati, Baguineda (the location of the Malian research station for fruits and vegetables), Sikasso and Bafoulabe (SOC International, 2002). These multiplication units were using the “pre-base” material or G0 generations of classic Western varieties (Desiree, Kennebec, Bintje, etc.) from France or the Netherlands. The production conditions make the G0 generations the most costly plant material in seed potato production process (Greef, 2004). This first trial did not work because in addition to cost of the G0 seeds, the health status of the mini-tubers produced was still questionable. Beginning in 1999, IPR/IFRA, the faculty of agriculture located in Katibougou, began to address the problem of high cost and quality of improved seed potatoes using tissue culture, using as its performance standard the European standard of virus infestation. This new method of seed potato production is done in the three steps, shown figure 5. It does not reduce the number of years of seed production, but does reduce the prevalence of diseases.



Source: SOC International, 2002

Figure 5. **Improved Potato Seed Production from the Laboratory to the Farm**

Requirements for good quality improved seeds

To ensure good-quality seeds, the multipliers are required to produce seeds under strict phytosanitary control. The presence of seed-borne diseases may require that fields be monitored regularly to keep the level of disease below the tolerances for that seed class. Although not always practical, or possible, growers should strive for complete freedom from disease in all classes of seed potatoes. Also, to reduce or prevent the spread of viral diseases in seed fields, sucking and chewing insects such as aphids a must be controlled with insecticides. Weeds must be controlled in seed potato fields to allow for proper inspection. Irrigation water can spread some diseases, such as blackleg and wilts. Precautions like disinfecting wheels should be taken when moving equipment from field to field or from plot to plot, to prevent the spread of these diseases. All diseased plants including the new tubers and seed-pieces should be removed from the field. After handling diseased plants, the grower needs to avoid handling healthy plants and disinfect hands and tools as soon as possible. For harvesting, some cautions are needed as well because the performance of disease-free seed potatoes is often directly related to the physical health of the tuber. Prior to harvesting and loading, all equipment must be cleaned and disinfected. (McAllister, 2001, revised in 2008). Storage facilities and all grading and handling equipment need to be thoroughly cleaned and disinfected after planting is completed and again prior to harvest. Seed potatoes should be stored at a temperature of 3-5^{o}C with a relative humidity of 90-95 per cent for long-term storage.

Because of these stringent requirements to produce disease-free seed potatoes, farming skill and technical assistance are some of the most important elements of the contracts we will discuss below.

Improved seed potato quality is a function of a certain number of variables such as size, health status, and the generation, which are all functions of how the steps are carried out. However, the only immediately observable indicator to buyers (multipliers and farmers) of improved seed quality is the size of the micro- and mini-tubers. The other indicators of quality are observed only after the seed is planted and usually later during the process of cultivation (a long time after planting). So the prices that farmers are willing to pay for the seed depend on the size that they can directly observe and their confidence in the sources of seed potatoes. Therefore, this research will use the size (diameter) as the principal indicator of improved seed quality for the initial adaption phase.

For micro-tubers, the desired diameters vary between 4.5 mm and10 mm, and the closer it is to 10 mm, the higher the probability of successful multiplication (mini-tuber of good size with qualities such as good germination, speedy growth, strength of the young plant, etc.). For mini-tubers, the diameters vary between 8 and 25 mm, and the recommended size varies between 10 and 15 mm (SOC international, 2002). Note that size is an imperfect signal of quality; it can be created at cost, especially right after harvest, by farmers who chose to "cheat", for example by applying high levels of fertilizer to their "unimproved" plants.

Seeds as well as the consumption potatoes are harvested at the same time of the year, and then seeds have to be stored for 5 to 7 months before the following year's production season. There is need of some specific storage facilities because it is very hot in Mali and the seeds are very sensitive to high temperatures. In addition, since all the newly harvested potatoes look nice, it is hard to judge the quality from just the size if the multipliers sell directly the seed to the wholesaler right after harvest.

3-1-2 Source of Asymmetric Information

According to Willy De Greef (Biotechnology Specialist, PRODEPAM project, 2004), the quality of seeds produced depends on interrelationship of the following:

1- Tissue culture laboratory producing the micro-tubers or G0 mini-tubers

2- Seed potato multipliers (growers) who work on generations G1 to G3 or G4

3- Storage and logistics structures (transportation, packaging, etc.)

4- Inspection and certification structures.

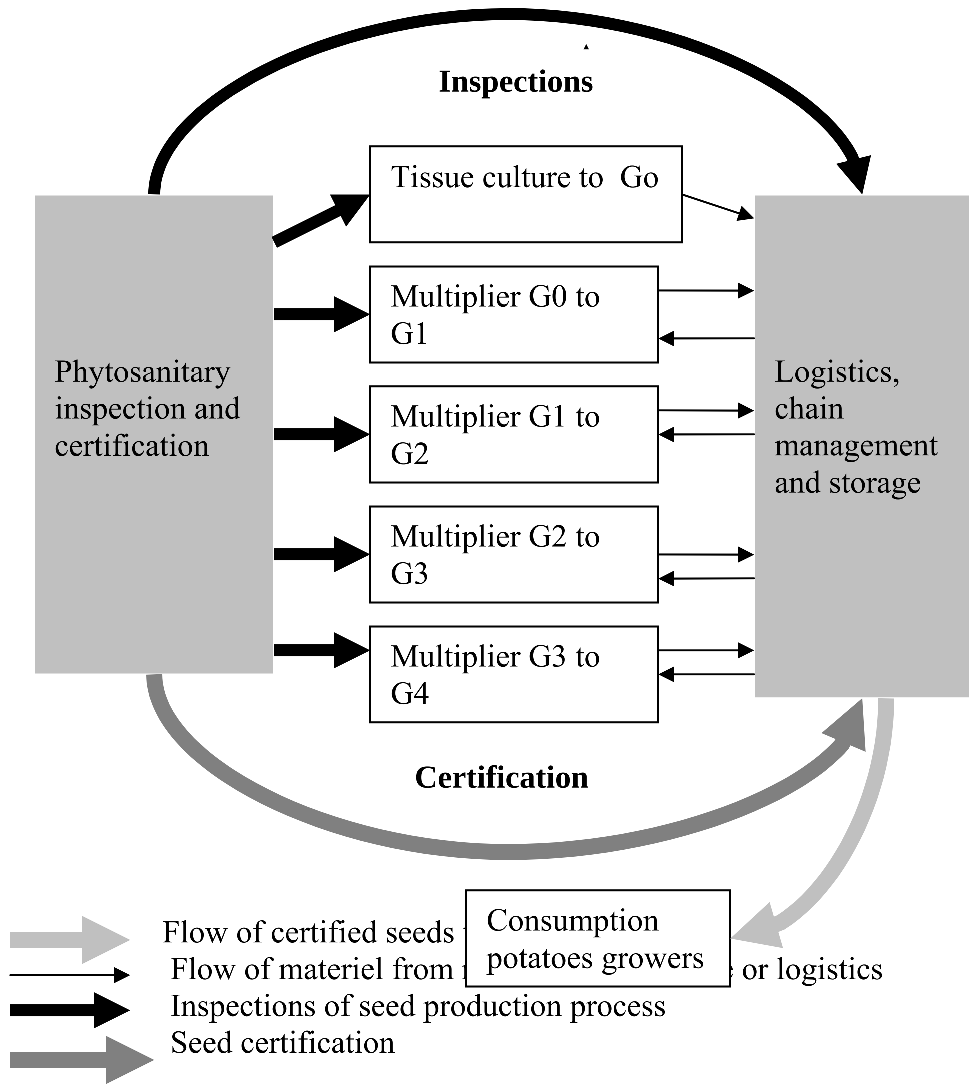
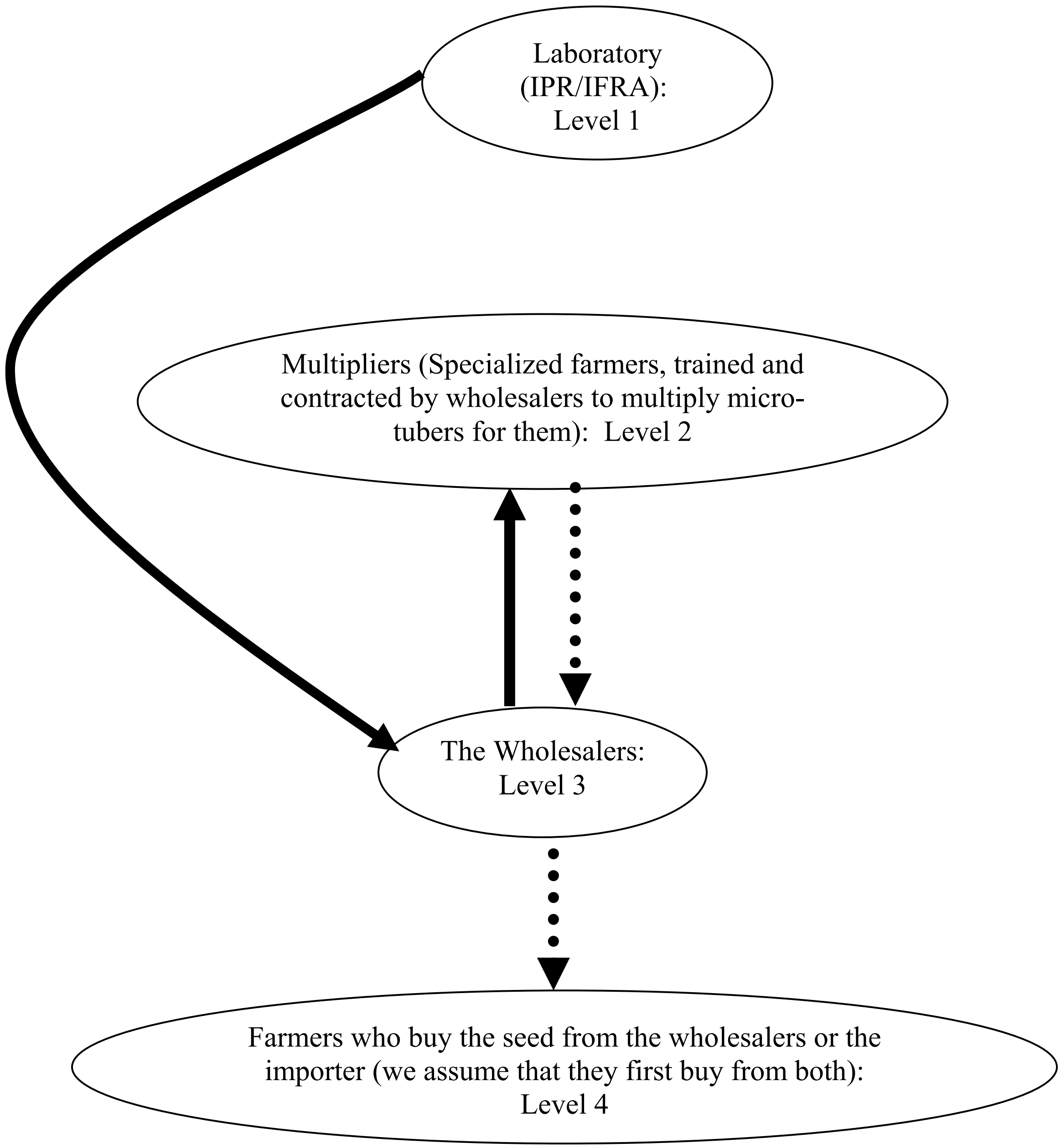


Figure 6. **Flow of Plant Material and Work Involved in Producing Certified Seed Potatoes**
Source: Willy De Greef Biotechnology Specialist, PRODEPAM project, 2004

The quality of work done at each level shown in figure 6 determines the success of the technology (seed quality). Each step has specific tasks to carry out, and the result of the grower's action at each step can affect significantly the next step. For example, at the multiplier level, the tasks include use of inputs on time in the right amount and carrying out the different cultivation techniques correctly. If the multiplier doesn't know his/her tasks well or if he/she cheats during the work by using too little or too much fertilizer, the quality of final product will be negatively affected. This behavior can go undetected at first because of the asymmetric information, which is due to the complexity of the tasks and their interrelationship as well as the costliness of monitoring lots of different multipliers. Since it is more costly to the multiplier to carry out all the steps correctly than to shirk, a potential principal-agent problem exists.

Note that in the existing improved seed production plan, there are no wholesalers or distributors for domestically produced improved seed potatoes because up to now nobody has investigated this part of the seed business. In this project, I want to introduce the wholesalers as an intermediary between the multipliers and the farmers. This is to include the marketing agents to the physical production process; since they create utility in the channel, they are also "producers." I am going to analyze the situation shown in figure 7.



Flow of inputs including micro-tubers from the lab to the wholesaler and from there to the multipliers

Flow of final product (mini-tubers)

Figure 7. **Plan of the Domestically Produced Improved Seed Industry in Mali**

The quality of the seed is critical for the emergence of a market for domestically produced improved seeds. One can define the quality of improved seed potato as a function of the following variables:

$\Psi = \theta_q f$ *(size, generation, soil, storage, health status [as proxy by phytosanitary inspection and certification level])*

Where, Ψ is quality and θ_q measures exogenous uncertainty.

As mentioned earlier, since the size is the only observable variable here, in modeling the initial adoption of domestically produced improved seeds, all institutional arrangements will be based around this observable variable. Let's call Y the size of the mini-tubers which is [10- 25 mm] of length, and Q the quantity of mini-tubers of size Y produced and where:

$Y = \theta_y g$ *(input use, cultivation techniques, farming skill),*

Where Y represents size of the mini-tubers and

$Q = \theta_{qt} h$ *(inputs use, cultivation techniques, farming skill)*

Where Q is the quantity of mini-tubers produced

Here also the stochastic factor of the production appears because the weather or other natural events that are beyond the multipliers' control can affect the seed size as well. Then the production function can be written as:

$Y = \theta_y\, g(e,x)$ *and* $Q = \theta_{qt}\, h(e,x)$

Where, e represents the total effort of the multiplier in producing the mini-tubers and x represents the others inputs used.

I assume that this production function is well behaved (twice continuously differentiable) and that the quality of improved seed is an increasing function effort level.

Thus, the multipliers need to provide a significant level of effort (cost) to get a seed of good quality.

Since both the quality and quantity of mini-tubers are function of the multiplier's effort, and effort is costly, there are possibilities conflict of interests between multipliers and wholesalers.

3-2 Principal-Agent Model

Since the laboratory is the innovator of domestically produced improved seed, I will assume that it correctly follows its own requirements to be able to move its finding from the lab-level production to farmers' fields. Given that assumption, to make the problem simpler, I will analyze only the case of a potential principal-agent problem between the wholesalers and the multipliers. I will model the principal-agent problem as follows: the wholesaler is the principal and the multipliers are the agents.

In the model, I consider the principal as risk neutral, in order to make the analysis easier. He buys the micro-tubers from IPR/IFRA and contracts with risk-averse multipliers to whom he gives the raw materiel (micro-tubers) and all the other non-land and non-labor inputs necessary to produce mini-tubers of good quality (i.e. the mini-tubers of size between 10 and 15 mm).[7] The multipliers will provide the land and effort. The principal will provide the other inputs as a way of gaining some additional control over quality.

The result to be obtained is mini-tubers of size Y Є [10-15mm]. This result, *Yg(e,x) and Qh(e,x)*, is a function of the agent's effort. The effort level also is a function

[7] Note that the decision to provide all the inputs is itself a contract design decision. It is based on the assumption that providing the inputs directly is a cheaper way of reducing variance in quality of output than specifying what inputs the multipliers use and then monitoring to see that they buy those inputs.

of the compensation proposed by the principal, called *p,* the price that the wholesaler offers to buy the mini-tubers of quality Yi from the multipliers (Macho-Stadler, 2001).

In this relationship, the principal aims to maximize his profits, which is function of the sale price **P,** which depends on the size of the mini-tubers in the single period game and his reputation in the repeated game setting. Farmers are buying from the both wholesaler of domestically produced improved seed and from the importer of improved seeds from Europe. This is to allow them to make a realistic evaluation of the quality of domestic seeds compared to imported seeds. If the seeds are not good in the first period of the game, they will prefer buying the imported seeds despite their high price. In this case the wholesalers will lose the market for his improved seeds and we are back to the starting point again. In order to prevent this kind of situation from happening, wholesalers will want to ensure that agents provide them with good seeds.

So the principal-agent problem is modeled as follows. A risk neutral principal wants to maximize his profit, subject to quality requirement.

Principal's maximization problem is:

$$Max\pi_w \equiv P_Y Q_Y(e,x) - c(Q_Y(e,x)) - w(e)$$

Subject to:

$Y = \theta f(e,x) \leq Y_{imp}$ [8]

And $P_Y Q_Y(e,x) \geq C(Q_Y(e,x)) + w(e)$

Where:

$P_Y Q_Y(e,x)$ is the principal's total revenue

[8] For simplicity, I assume that the size of the imported minitubers represents the standard that farmers use in evaluating whether the local seed is "improved." It is possible that some farmers might accept smaller local minitubers if the price were low enough, but at some point, if farmers are using size as their indicator of seed quality, they will be reluctant to buy local minitubers that are "too small."

$C(Q_Y(e,x))$= the agent's cost function, which depends on the quantity handled (a function of the agent's effort) and the principal's costs (x) of handling, conditioning, storing and marketing the seed

$W(e)$= the compensation payment to the agent, a function of the price and quantity of seed produced: $we = p_Y Q_Y(e,x)$,

and Y_{imp} is the quality of the improved imported seed.

The agent also aims to maximize his utility in multiplying the micro-tubers for the wholesaler:

$$Max \quad E(U(we,e,x)) = E(p_Y Q_Y(e,x) - V(e))$$

Where $U(we,e,x)$ is the agent's utility in multiplying the seed for the wholesaler. Since agent is risk averse, I assume that U'(we,e,x) ≥ 0 and U''(we,e,x) ≤ 0 (i.e,. concave utility function). $V(e)$ represents the cost of producing improved seed of size Yi and quantity Qi to multiplier, in other words, it is the disutility of effort for the agent, including the disutility of associated with his labor input, the costs incurred in conditioning the seed, the opportunity cost of land used, etc. Again I assume that V(e) is a convex function (i.e. V'(e) > 0 and V"(e) ≥0).

The principal's profit is increasing in *Y and Q,* which is an increasing function in effort. So the principal will want agent to put on a high level of effort, whereas the agent's utility is a decreasing function of effort. One can thus see that there is a conflict of interest between the wholesaler and the multiplier.

Now that we have discussed the existence of conflict of interest between the principal and agent, we need to analyze the different types of contracting schemes from theory that can be applied to this situation to resolve that conflict.

3.3 Contract Design

Debate rages in agricultural and development economics about how to design effective markets reforms in developing countries where uncertainty and asymmetric information are pervasive. Commentaries on the continuing “industrialization” of agriculture typically refer to the increasing use of “contracts” as to be opposed to “markets” for mediating exchange between producers and people or firms who buy their products (Hueth, 2000). Although the use of contracts in the agricultural sector is relatively new in developing countries, it has been used at lot in developed countries for commodities such fruits and vegetables. This is because contracts play three important roles in promoting the industrialization of agriculture. First, they help make the production systems more predictable and therefore motivate people to allocate their resources with greater confidence. Second, they help market participants to share risk. And third, they are used to motivate performance (Milgrom and Roberts, 1992).

Developing a viable set of relationships between the producers of improved germplasm (cellular tissue of potato) at IPR/IFRA, the farmers who would multiply the seed stock, and wholesalers who would sell improved seed to farmers will require a set of contracts and other arrangements to help in making the production more predictable, sharing risk among the participants in the system, motivating the firms or individual businessmen to invest in this business, and then motivating good performance.

For example, what combination of monitoring and contract incentives will induce farmers charged with multiplying the seed stock to respect the very precise production practices needed to assure seed quality? There is a large literature on these issues, particularly in high-income countries (e.g., Hueth et al.). This research will extend this analysis to a developing country context, where many people are still reluctant to contract in the agricultural sector because of risk and the high cost of monitoring the production process. First, let's assume that both parties (principal and agent) have the same information (e.g., the size of the mini-tuber is perfect indicator of agent effort and it can be verified).

3-3-1 Contract under Perfect Information

If all the participants in the contract have the same information about the terms of the contract, the problem will be easy to deal with. In the other words, if the quality of the seed produced (size) could reveal correctly that the multipliers followed correctly all the technical and physical steps required, the contract design would be easy.

This is a situation of first best contract between principal and agent to assess the simplified version of contract using the information from Macho-Stadler (2001), assuming that the principal is risk neutral and agent risk averse. In a world with complete information, a risk neutral principal ought to insure a risk adverse agent against all idiosyncratic risk, as it would be costless to do so (Hueth, 1999). That is, the wholesaler knows exactly what the multiplier is doing in his farm or the size of mini-tubers can indicate with certainty the seed quality; therefore he will pay him a wage that compensates his effort. The agent would have no incentive to shirk, as such behavior would be revealed by the undersized tubers and the principal would terminate the contract. Here, in the language of principal-agent models, the principal cares only about the participation constraint[9] Thus, the principal's optimization problem becomes:

Principal maximize:

---

[9] The participation constraint refers to the need of the principal to pay the agent a level of compensation that will induce him accept the contract. This compensation needs to be greater or equal to the expected utility of agent not participating in the contract (the agent's "reservation utility.")

$$Max\pi_w \equiv P_Y Q_Y(e,x) - c(Q_Y(e,x)) - w(e)$$

Subject to only:

The agent's participation constraint or (IR)

$$E(U(we,e,x)) = E(p_Y Q_Y(e,x) - V(e)) \geq EU_0$$

Where, *U(we, e ,x)*= the utility that agent gets in producing the mini-tuber of quality and U_0 = the reservation utility (the utility that farmer would get either foregoing multiplying the seed or by multiplying it but not selling it to the wholesaler).

The theory of information economics says that under perfect information the IR constraint for a risk-averse agent is binding, which means it holds with equality. So the wholesaler will pay a price *p* equal the marginal cost for each kilogram of improved seed multiplied by agent.

This is a nice situation, but not likely to represent the reality in Mali, where it is most likely that all the potential participants in improved seed industry would not have the same information. For example, the multiplier can undertake some hidden action (moral hazard) or have some private information (adverse selection) about his land, his equipment and his farming abilities that the wholesalers might not have. We need to look for more realistic contract designs with asymmetric information.

3-3-2 Contract under Asymmetric Information

Under asymmetric information, one person has private information or can take hidden action that is very costly for the uninformed person to get or to verify. This situation of asymmetric information can affect the uninformed person's profit in the first stage of the game and the overall existence of his business in the next stage (since such behavior may lead the uninformed person to abandon the game). The size and quantity of the mini-tubers are both an increasing function of agent's effort level including his ability and actions (which represent a cost for agent). He is the one who is perfectly informed about his actions and skills. Under this situation, it is most likely to observe a contract between the multiplier and the wholesaler in which only the agent has perfect information about his abilities and actions, thus giving rise to adverse selection or moral-hazard problems.

To model this situation, I will refer to the model of producers' sharing the price risk of a final product developed by Brent Hueth and Ethan Ligon to deal the problem of quality measurement resulting from the asymmetric information (moral hazard problem) in the case of fresh-market tomatoes in the US. But, instead of price risk sharing, I will use the sharing of storage time between the principal and the agent as a way to monitor the quality and to make the agent invest in a specific asset of storage facilities linked to production of seed potatoes.

Seed potatoes and consumption potatoes are harvested at the same time of the year. Buying seeds just after harvest, the wholesaler will have to store them for 5 to 7 months before selling to the farmers for their next year's production. Also diseases such as potato virus X (PVX), potato virus S (PVS), and potato spindle tuber viroid (PSTV) can infect seed potato stocks during the storage. In this situation, the wholesaler is obliged to have some specific storage facilities because of the climatic conditions in Mali and to control and to disinfect the stock regularly during storage to prevent these diseases.

In addition, just after harvest, the probability that size will correctly predict the quality is very low. Knowing that, the agent can cheat on the size by using more fertilizer to reach the requested size and quantity without correctly following the other required steps. If it happens that the seeds are of bad quality, the wholesaler will be the only one to incur all the risk by losing his business and all the investment in the storage facilities, while the multipliers can just go back to producing potatoes for consumption.

After a couple of months of storage, however, the potatoes grown with excessive fertilizer will deteriorate relative to those that were grown correctly, providing a way of ex-post monitoring of whether the agent followed the recommended practices. Thus, having agents store for two months serves two purposes: (a) it makes monitoring of agent behavior easier, and (b) it gives a signal to the wholesaler of the agent's credible commitment to the contract, by putting transaction-specific assets at risk[10]. This would seem to possibly create incentives for the emergence of a new market that of certified storage warehouses, where both multipliers and wholesalers could pay to have their potatoes stored. The multiplier would pay for storage for a couple of months, and then sell the potatoes to the wholesaler, who would then in turn pay the storage facility.

Now let's look at the contract under hidden information ***(adverse selection)*** under this scenario.

The principal will maximize an expected profit subject to the agent's participation and incentive-compatibility constraints[11]. Let's divide the possible candidates for the

[10] Note, the disadvantage of this arrangement is that the costs of the whole system could increase if both the multiplier and the wholesaler each have to invest in storage facilities.

[11] The incentive compatibility constraint is the compensation that principal will pay to agent to take on additional risk in producing a high-quality product. The risk arises because the agent has to put in more

seed-multiplication contract in two groups: group 1 (the high-ability multipliers) and group 2 (the low-ability multipliers) and assume that all multipliers are candidates for the contract. Let's say that the wholesaler's prior belief is that each group constitutes about half of the population. The possession of a storage facility is the signal that multipliers send to wholesaler. This signal doesn't affect the productivity, but constitutes a good signal about how serious the multiplier is and it is more costly for a low type than a high type to invest in such storage because it is difficult of the low-ability multipliers to make a profit out this kind of investment with their potential skill. Without any signal, both groups will want to have the contract and be paid at the same price. Alternatively, even under the specialized storage system that I described earlier, the willingness of the high-ability types to pay two to three months of storage would serve as a similar signal, as it would represent a bond, money that they are willing to put at risk in the transaction.

I will focus only on the case of separating equilibrium wherein the high-type multipliers invest in storage facilities and the low-type ones do not. Under this circumstance, the wholesaler can update his belief system and offer different contracts according to the type. The posterior beliefs will be: $\mu(e_h \mid sf \geq 0) \equiv 1$ and

$\mu(e_h \mid w \mid osf \leq 0) \equiv 0$

Where *sf* = storage facilities; the system of beliefs says that people who build storage facilities are high-ability types and the multipliers without storage facilities are low-ability types.

Principal's maximization problem becomes:

effort to create a high-quality seed, yet because of random factors beyond the agent's control, such efforts do not always result in a high-quality product. Thus, if the agent is compensated based on output, his risk increases, and a risk-averse agent will require increased compensation to take on that risk.

$$Max\pi_w \equiv P_Y Q(e,x) - c(Q_Y(e,x)) - w(e)$$

Subject to:

The agent's participation constraint (IR)

$$E(U(we,e,x)) = E(p_Y Q_Y(e,x) - V(e)) \geq EU_0$$

And the Incentive comparability constraint (IC)

(IC_h)=

$$E(U(we_h,e_h)) = E(p_h Q_h(e_h)Y_h(e_h) - V(e_h) \geq EU(we_h e_l)) = E(p_h Q_h(e_h)Y_h(e_h) - V(e_l))$$

(IC_l) = $E(U(we_l,e_l)) = E(p_l Q(e_l)Y_l(e_l) - V(e_l) \geq EU(we_h,e_l)) = E(p_h Q_h Y_h(e_h) - V(e_l))$

In other words, the equilibrium payoff for each type must be greater than the deviation payoff, which means that the high type will receive *ph* for their quality *Yh* while the low type will get *pl* for the low quality *Yl*. This is what the agent can earn as an alternative ***before*** the contract is concluded.

Now what about his action after the contract is signed? This part will be analyzed in **the moral hazard** framework. Moral hazard occurs when a hidden action of the informed party affects negatively the outcome of the contract. In the case of the improved seed production, even if the multiplier invests in storage facilities, the outcome Y is a random variable since Y= θ f(e,x), where θ is a random variable. If the set of results (outcome) is finite (which we assume is the case here), then one can write the probability of size *Yi* conditional on the effort level as: $\Pr ob[y = y_i \mid e] = \alpha_i(e), i \in \{1,2,....n\}$

Where α_i *(e)* is the probability that agent dedicates effort level i.

Because *Yi Є [10-15mm],* it must be true that $\sum_{i=1} n\alpha_i(e) = 1$. This assumes also that $\alpha_i(e) \geq 0 \forall e,i$, that is, we cannot rule out any result for any given effort level (Macho-Stadler, 2001). Because effort is not a perfect predictor of outcome and vice versa, there is always possibility of moral hazard. If there was no random effect, the principal could simply reward based on outcome and this would solve the incentive compatibility problem. Even though the storage facilities can signal and help in monitoring and reducing the noise of θ that affect both the size and quantity, it doesn't tell completely about how well the multipliers will follow the terms of the contract ex post. I will analyze this part using the note on chapter 7 of Milgrom and Roberts (1992), with the agent risk averse and the principal risk neutral.

The principal's profit:

$\prod_{pri}(e_i) = e_i \mid y_i + \varepsilon$

Where $\prod_{pri}$ = Principal's profit $e_i \mid y_i$ = agent's effort level given seed potato quality *Yi* and E(ϵ) = 0 and Var(ϵ) = σ^2

We restrict our attention to the linear compensation scheme, that is $We = \varphi + \beta \prod_{pri}$

Where φ = constant payment to the agent (to insure him against the risk)

β = a portion of principal's profit to create an incentive for high effort level from the agent. $0 < \beta < 1$

Here the multiplier aims to maximize his expected utility:

$E(U) = E(w(e)) - r/2Var(\prod_{pri}) - g(e_i \mid y_i) - K > 0$

Where

r = a measure of risk-averseness,

ei|*yi* = effort level;

K = the reservation utility, and

$g(e_i|y_i)$ is the disutility of effort. We assume that $g'(e|y)>0$ and $g''(e|y)>0$.

To get the optimal contract, the principal will first solve the implementation problem and then choose the optimal effort level. So he will either maximize his profit or minimize the wage payment to agent.

In the implementation part, he will try to minimize his cost subject to the IR and the IC constraint.

$$Min We = \varphi + \beta \prod_{pri}$$

Subject to:

(IC) $E(U) = E(w(e)) - r/2Var(\prod_{pri}) - g(e_i \mid y_i) \geq E(w(e^{\bullet})) - r/2Var(\prod_{pri}) - g(e^{\bullet} \mid y_i)$

(IR) $E(U) = E(w(e)) - r/2Var(\prod_{pri}) - g(e_i \mid y_i) \geq o$

Using the first order approach to deal with a continuous (IC), the multiplier's problem becomes: $\underset{e}{Max} W(e \mid \prod_{pri}) = E(w(e)) - r/2Var(\prod_{pri}) - g(e_i \mid y_i) - K > 0$

Given $W(e|\Pi pri) = \varphi + \beta\Pi pri$

The first-order condtion with respect to *e* is as follows:

β- $g'(e|y) = 0$, which implies that $\beta = g'(e|y,)$ so marginal cost = marginal benefit at the optimal effort level e*

Now I plug this result in the (IR) and I know that it is binding.

(IR): $g(e \mid y) + r/2Var(\prod_{pri})g'(e \mid y)^2 - g'(e_i \mid y_i)\prod_{pri} = 0$

Now let's look at the choice of effort level, given the result in the implementation part.

The principal will choose the effort level that maximizes his profit:

$$\underset{e}{Max}\, E(\prod_{pri} - W(e \mid y) = e - (\varphi - \beta \prod_{pri}) = e - g(e \mid y) - r/2Var(\prod_{pri})g'(e \mid y)^2$$

$$FOC = 1 - g'(e \mid y) - rVar(\prod_{pri})g'(e \mid y)g''(e \mid y) = 0$$

Solving the FOC for *g'(e|y,)* I get $g'(e|y) = 1/1+rVar(\Pi_{pri})g''(e|y)$, but from the implementation part, I found that $\beta = g'(e|y)$ which implies that $\beta=1/1+rVar(\Pi_{pri})g''(e|y)$. We already know that β is the portion of principal's profit paid to the agent to induce a high effort level and that $0< \beta<1$, which makes economic sense because the incentives are not fully aligned with profits due to optimal risk sharing. The derivatives of β with respect to $Var(\Pi_{pri})$ and *r* will both be less than zero, which makes sense also because as the variance increases, the incentive to accept the contract decreases and the same for the risk averseness, since agent is risk averse.

In the case of potato seed production, since the agent is risk averse and his expected utility is decreasing with the variance of the principal's profit, he will try his best to avoid this profit variation. Under this contracting scheme, the multiplier, even though risk-averse, is induced by the payment scheme to share the risk with the wholesaler (his/her wage depends in part on the variation of principal's revenue) in order to align the agent's incentives with those of the principal. The empirical question is whether an incentive system exists for the agent that aligns the agent's interests with those of the principal and still results in a profit level for the principal that allows him to be competitive with importers of improved seed potatoes. Investigating that question is the subject of the proposed empirical analysis described in the next chapter.

Chapter 4. Research Methods

This proposed study will use the step-by-step approach for subsector analysis, from familiarization with the sub-sector potato to identifying sources of leverage. It especially explores opportunities for leveraged interventions in improved seed potato production and distribution process in Mali. This research then falls into the category of baseline studies and systems analytic description models. It will pull together what is known about the parameters of improved potato seed production while identifying the forces of possible emergence of a market for domestically produced improved seed potatoes in Mali. To do so, it will use a descriptive process to first assess the feasibility of physical steps of mini-tuber multiplication. Then, we will stimulate different contracting schemes, building on the theoretical models of the principal-agent relationship described in the previous chapter, and compare them to suggest desirable institutional arrangements to deal with the potential asymmetric information problems inherent in the process of seed potato production.

4-1 Research Design

To test our hypotheses, we will proceed in two steps. Since the second hypothesis is conditional on the first one, we will first investigate the cost of conducting the physical steps of mini-tuber multiplication in Mali under perfect information. Here the question is whether, in the absence of any principal-agent problems, it would be feasible to produce improved seed potatoes at a cost that would be competitive with the imports. For this first hypothesis, we will assume that information is not a problem and focus on analyzing the costs in terms of money and time necessary to execute the physical steps. The costs include inputs, labor, storage, transportation, packaging, and equipment. If this part reveals that the physical production of improved seed potatoes is feasible at a competitive cost under perfect information, then we will look at the second hypothesis. In that second part, we will assess ways to deal with asymmetric information issues, i.e. the nature of institutional arrangements to be established between wholesaler and multipliers. The end objective is to see if the domestic improved seed potato production has a comparative advantage over imports of improved seeds.

4-1-1 Analysis of the Feasibility of Physical Multiplication of mini-tubers in Mali

For this part, we will develop a stimulated budget for production of mini-tubers using data from both researchers and field trials arrayed in table 6.

Since the yield of mini-tubers is function of the generation and the type of cultivation, the budget for seed multiplication will look like table 7.

Table 6. Cost of Multiplying one Hectare of Seed Potatoes in Mali					
	Time	**Labor**	**Materials**	**Products**	**Total**
	# of days/ hours spent	**(FCFA x # of workers /hour)**	**(FCFA) PV of materials**	**(FCFA x quantity of prd/ha)**	**(FCFA/ha)**
Cultural Practices					
- Land preparation					
- Planting					
- Weeding					
- Watering					
- Mounding					
-Organic Fertilizer					
- Chemical fertilizer					
- Insecticide					
- Transportation					
Harvesting					
-Uprooting					
-Collection of tubers					
-Transportation					
-Sorting					
-Packaging					
Quality Control					
-Before harvesting					
-After harvesting					
- During the storage					
-Before replanting or selling					
Storage					
- Storage rooms					
- Insecticide/fungicides					
- Electricity or other cooling sources					
-Sorting					
- Sacking/storage cases					
- Others					
TOTAL PRODUCTION COSTS/ha					

Notes:

1) The family workers and the paid workers will be all evaluated at the same price, i.e., the current market wage for temporary workers because that is the only way we can take into account the family labor in estimating the cost.
2) PV = present value of the material or equipment used for that task. It will be estimated based on the life time of the equipment and its cost.

Table 7. Budget of Multiplying Mini-tubers Through Different Generations					
	1st generation	**2nd generation**	**3rd generation**	**4th generation**	**Total**
Area planted (# ha)					
Production					
Yield (Kg/ha)					
Price to multiplier (FCFA/kg)					
Losses (%)					
Inputs					
Seeds (Kg)					
Estimated price (FCFA/kg)					
Chemical fertilizer NPK (Kg)					
Organic Fertilizer (FCFA/cart)					
Insecticide (FCFA/liter)					
Herbicide (FCFA/liter)					
Others inputs					
Labor (FCFA/pers/day or hours)					
Land preparation					
Planting					
Mounding					
Watering					
Harvesting					
Collecting the tubers					
Sorting					
Packaging					
Irrigation					
Motor fuel (FCFA/liter)					
Oil (FCFA/liter)					
Maintenance					
Water fee (in irrigated areas)					
Quality Control					
Before harvesting					
After harvesting					
During the storage					
Before replanting or selling					
Storage					
Insecticide/fungicides					
Electricity/other cooling sources					
Sorting					
Packing/storage cases					
Equipment					
Land (rental cost or opportunity cost)					
Animals (ox and donkey)					
Cart					
Small materials (weeding hoe)					
Plow					
Storage rooms					

Previous work done by SOC International has shown that is possible to produce two generations of potatoes per year in the south of Mali. Since the mini-tuber production takes a long time, to save time one can also assess the possibility of double culture in the Sikasso region. However, from the same source, it has been also shown that the production during the rainy season is low compared to the dry season production because of high temperatures. In addition, because of the abundance of insects and fungus during the rainy season, one should expect an increase in pesticide costs as well. But, are the time saving, and the saving in storage cost enough to balance the low yield and additional costs? The answer to this question will allow the choice between the two production methods. This overall part of the research will allow confirming whether, in the absence of asymmetric information, it is physically feasible to produce improved potato seeds at price that is competitive with imported ones in Mali.

4-1-2 Analysis of Different Contracting Schemes

If our first hypothesis is confirmed, i.e., in the absence of asymmetric information, it is physically feasible to produce improved potato seeds at a price that is competitive with imported ones in Mali, we need to turn to the question of what are the institutional arrangements necessary to make it work as a domestic industry (business) in Mali. To answer this question, this research will analyze the case of imperfect information contracting schemes. It will first identify the sources of incentives to participate and to cheat and investigate the cost of monitoring. It will then analyze different contract forms able to deal these hidden actions or information effects. To do so, we will propose different contract menus for each case and let the potential multipliers self-select among them. An example of contract menu might include, different price according to the size, the quantity, and time of delivery, level of investment in seed multiplication, etc. Then we will use the conjoint analysis[12] method to analyze the data for different contract menus proposed. Here we will use both the analytical and simulation techniques of conjoint analysis for predicting seed multipliers' likely reactions to contracts and for assessing contract ideas in a competitive environment of improved seed potato production. The choice-based methods of conjoint analysis will be used to collect the data for choices. With these data we will do an analysis of variance among the different contracts and compare the cost of the preferred contract with the costs of importing improved seeds. If the chosen contract reveals itself to have a comparative advantage relative to imports, it will be proposed to the actors of the sub-sector or the policy makers in the agricultural sector. In the opposite case, the research will be able to identify the constraints that prevent the preferred contract from being competitive, and other actions can be conducted to find solutions to these problems.

4-1-2-a. Potential Menu of Contracts to be Analyzed

We will use conjoint analysis to analyze how the potential multipliers will self-select among the following contracts, called choice sets. The menus or attributes of these contracts are based the most important factors that can affect seed potato quality. In Mali, seed potatoes have to spend five to seven months in storage before the next planting season because of climatic conditions. Also buying seed potatoes just after harvest are risky for the wholesalers, because at that time the size of the mini-tubers, the only observable quality indicator, cannot signal quality well. So the ownership of storage facilities and knowledge of storage/handling techniques constitute important attributes to

[12] Conjoint analysis is "a technique that permits decomposition of consumer's overall judgment about a set of multi-attributed alternatives into separate and compatible utility values corresponding to individual levels of the various attributes" (Rao). See below for a further discussion of this technique.

consider including in a contract for developing a market for domestically produced improved seed potatoes. In addition to storage and handling, a potential multipliers' potato growing history (number of year of production, quantity produced, area, etc.) can convey a lot about the potential seed multipliers' farming skills. Therefore, potato farming history will be one of the attributes of the contracts to be presented to the multipliers. Also literacy will be an important signal of a potential multiplier's ability to follow correctly all the instructions about the inputs to be used and the steps to follow. So, the multiplier's education level will be the third attribute of our contract. And finally, in rural areas, farmers' associations (AV) have easier access to credit, technical assistance and other advantages than do individuals. A multiplier's membership in such an association can signal about his/her access to technical assistance during the production process.

Since all the above factors can play important roles in getting good quality seed potatoes, we will screen for all four. That is, for a farmer to be eligible for a seed potato multiplication contract, he/ she should own or have access to a reliable storage facility. Also, he or she should have a minimum 5 years of potato growing experience. In addition, he/she should have a minimum education (for the purpose of illustration, let's say CEP[13] level) that allows him/her to read and write down the information or follow the instruction relative to growing good quality seed potatoes. And finally to have a signal that he has access to technical assistance during the growing process, he/she should be member on an AV. The potential multipliers who meet all these four criteria will have to self-select among the proposed contracts with three main characteristics or attributes:

[13] CEP is the certificate of the exam that students have to pass to get into middle school, starting with 7th grade in Mali.

- Price for mini-tubers that the wholesaler is ready to pay to the multiplier for a given quality. We will use three different prices to represent the levels of the price attribute.
- Size of the mini-tubers at delivery, where two size ranges will represent the levels of size attribute.
- Time spent in storage at the multipliers' cost, where the number of months will represent the different levels.

Let's name the attributes successively by P for price, S for size and T for time and let's define three levels for price and two levels for size and storage time attributes.

Table 8. Attributes and their Levels

Attributes	Price of mini-tubers : P			Size of the mini-tubers: S		Time spent in storage: T	
Levels	P1	P2	P3	S1	S2	T1	T2

Note: For the price attribute, price levels are as follow P1>P2>P3

For the size attribute, S1 = 8 mm $<x<$ 25 mm and S2= 25 mm $\leq x \leq$ 45 mm, where x represents the size.

For the time spent in storage attribute, T1= two months, T2= 4 months, and the rest of the time will be at the wholesaler's expense, depending on how early the mini-tubers have been harvested. An example of choice set (contract choice) can be contract= {P1, S1, T2} or {P2, S2, T2}. Our goal in using the conjoint analysis will be to analyze the trade-offs among the three attributes that will allow us to get a contract which will have a required size of mini-tubers at a reasonable cost of production. We choose only levels for size and time attributes to make the ranking easy for the potential multipliers. With three levels for all three attributes we will have 3x3x3 = 27 contract choices that the multipliers will have to rank. That is too demanding for both multipliers and the researchers in terms of time and energy. So to keep things at a manageable level, we decided to have 12 choice sets by limiting the levels for size and time at two alternatives each.

With each of these contracts, we want to have an idea of the quality of seed potatoes that will be produced by our potential multipliers and then to anticipate the competitiveness of the potatoes produced under each contract, in terms of quality and cost, with the imported seeds.

An illustration of how the analysis will be carried out using conjoint-analysis based simulation is as follows:

- Suppose we have 15 multipliers that meet our screening criteria
- We have three attributes P: (P1, P2, P3), S= (S1, S2), T= (T1, T2)
- We will have 3x2x2 = 12 choice sets or 12 contract menus that could be proposed to each potential multiplier to rank according to his/her preferences (table 9).

Table 9. Data for Conjoint Analysis Table

Choice sets	Prices	Size	Times	Preferences
1	P1	S1	T1	
2	P1	S2	T2	
3	P1	S1	T2	
4	P1	S2	T1	
5	P2	S1	T1	
6	P2	S2	T2	
7	P2	S1	T2	
8	P2	S2	T1	
9	P3	S1	T1	
10	P3	S2	T2	
11	P3	S1	T2	
12	P3	S2	T1	

Each of these contract menus will be presented on a card that each of the potential multipliers will rank. The preferences (rankings) will be used to fill in the cells in table 10..

Table 10. Choice Set Rankings by Multipliers

multipliers	Ranking for the 12 proposed contracts menus											
	1	2	3	4	5	6	7	8	9	10	11	12
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

For our preference analysis, we will use the Part-Worth[14] (P-W) model. Part-Worth is a derived value that a respondent places on one level of each one attribute (Green et al., 1999). In terms of utility, the P-W model reflects a utility function that defines a different utility value for each of the levels of a given attribute, allowing one to calculate the marginal utility of going from one level of an attribute to another, while holding the other attribute levels constant. Here we will use analysis of variance of the data in table 10 to create our P-W table. With the P-W functions, we can find the trade-off between two different contract menus, i.e. what is the change in utility of a price level or size level

[14] The Part-Worth model is the simplest of the utility estimation models of conjoint analysis. This model represents attributes' utilities by a piecewise linear curve. This curve is formed by a set of straight lines that connect the point estimates of the utilities for each attribute levels.

or time level from a contract menu A (corresponding to a choice set) on the preference curve that will correspond to an increase in utility with a contract menu B--in other words this is the marginal rate of substitution on the indifference curve from one point to another.

Table11. Part-worth Table of each Level of Attribute from the Survey

	Part-Worth						
	P (prices)			S (sizes)		T (time in storage)	
Multipliers	P1	P2	P3	S1	S2	T1	T2
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

From table 11 we can compute the Relative Importance of each level of the attributes (RIMP) for a given variable (e.g., size) by dividing the absolute value of the range of the part-worth of each attribute (for example, size) by the sum of the absolute values for range all part-worth of all attributes. For example if the range of part-worth for Price =25, for storage time =20 and for size= 18 so the RIMP of Price will be

$RIMP_p$ = …25/(25+20+18) = 39%

The P-W will allow us to know the trade-off to make among the attributes to get the multipliers to accept the contract. We then need to use this information to analyze whether we can get a contract that is acceptable to the multiplier and still produce mini-tubers with quality and price competitive with the imported seeds.

4-2 Data Sources and Collection Procedures:

This research will entail collection of both primary and secondary data. The primary data will be cross-sectional, both quantitative and qualitative, which will be collected through fieldwork. The data will be collected at different levels from actors involved in the seed production in general, with specific attention to the physical steps and the costs involved in each, and the information flow between multipliers and wholesalers for contract design. We will meet with the researchers at IPR/IFRA to get a general background on the seed production process from tissue multiplication to micro-tubers and the required technical steps to multiply the micro-tubers into mini-tubers. Then we will try to get their point of view about the key elements necessary for contract design in the improved seed production process to move the seeds from their laboratory to farmers' fields.

The next step will be to meet with potential multipliers, the businessmen in the agricultural input sector and in potato subsector, and farmers in the main potato production area. Questionnaires and discussion guides will be made for each group of participants according to the type of information needed at a given level of the production process. Then the data will be collected through both formal and informal surveys.

Our survey sample we will include both men and women potato producers, businessmen/women in the horticultural farming field, and researchers interested in the potato subsector. A sample of randomly selected experienced potato producers in the main potato production areas (Sikasso, Niono and Kita) will be drawn from villages that are easily accessible and with access or connections with extension services or other structures providing technical assistance in horticultural production. These are the types of farmers most likely to enter into the seed potato multiplication business. The businessmen/women (potential wholesalers of improved seed) will also be chosen from important market places and the group interests in the potato subsector. The sample size in each case will be based on statistical criteria, the availability of resources (financial and material) and time.

In addition to the formal survey, an informal survey (discussion) will be conducted with some researchers from IPR, IER, and other research institutions working on potatoes.

4-3 Data

The data to be collected will include:

- The estimated cost of production at both the wholesalers' and multipliers' level (information collected from the researchers). These data will include: labor, transportation, storage, cost of marketing (taxes, packaging, transportation, losses). In simulating a contract, the cost of labor will be the payment or compensation paid to multipliers for their efforts. In case of imperfect information, there will be additional cost of enforcing the terms of the contract. For that, we will need data about the cost of monitoring, etc. The cost of production at the multipliers' level will include effort in terms of time and labor and the opportunity cost of land.

- Estimate the same cost of production from field trials at two or three different places, depending on the resources and time availability.
- The expected yield of mini-tubers by generation and growing period (rainy season vs. dry season), and the costs involved in each growing period.
- From specialists in potato production, we will gather information on how timing regularity and conduct of the specific practices of cultivation, the type of soil, and the period of growth affect the quality and quantity seed potatoes. What are the other possible factors that can affect the quality beside multipliers' effort?
- For farmers' perception about domestically produced improved seed potatoes, we will collect: a) the price they are willing to pay of given size of mini-tubers produced domestically (through contingent analysis) b) quality requirements (high germination, high-yield, disease free, etc.), and c) access (location of distributors and mode of payment)

4-3 Analysis

For the first part of the study (the symmetric information case), we will use simple budgeting to do a cost-benefit analysis for the different production types. Then we will compare the total cost of production of the seed potatoes because the final price of improved seed potatoes produced should allow the producers to cover the cost involved under different production types. This will be done first between the two production methods (single and double cropping) to choose the one that is more efficient. Then, the chosen one will then be compared with the imported seeds' price.

For the analysis of the asymmetric information case, we will need to do this analysis in a stepwise basis. The highest ranked contract will be the one that offers the highest price and involving the lowest storage cost and the smallest mini=-tubers. But will the mini-tubers produce under this contract be competitive with imports in terms of cost and quality ? If not, we will then look at the tradeoffs to see how much one needs to give up in terms of price to be competitive. Or how much compensation the growers demand to go from a low size to a higher size, etc.

Chapter 5. Expected Results and Contributions to the Literature

The first consideration when purchasing seed potatoes for planting is disease because diseases can destroy completely a potato field, and diseases appear generally at critical periods during the growing cycle. However, other factors, such as size of seed tubers, affect the quality and productivity of seed lots because they can simultaneously signal the health status, level of maturity, the handling and storage conditions of seeds and to some extent the farming skill of seed-growers. Buying from a grower with a good reputation and/or who is under a well-defined contract will reduce increase chances of obtaining good seed.

The ultimate goal of a domestic seed industry is to get seeds from growers who can produce good quality seeds that meet consumers (potato growers)' needs for high-yielding and disease-free seeds. To ensure good quality of seeds, the production process, i.e., farming steps, must be followed correctly, diseases and other pests must be controlled and the seed stocks must be stored and handled carefully. Successful production of high-quality disease-free seed potatoes requires good management and strict disease-control procedures. Seed growers should strive to produce seed with disease levels well below the tolerances and with sizes within the recommended intervals. All seed growers must be aware of sanitation and farming procedures and apply them rigorously. This will enhance their reputations as seed growers, increase the value of their seeds and minimize potentially costly disease outbreaks. And finally, new seed potato industry managers or wholesalers need to consider both where and how they will market their seeds. This information will assist them in deciding the quantities, qualities, and cultivars to be grown.

Through this research, we want to be able to:

1) On the base case of symmetric information, determine the cost of production of improved seed potatoes, i.e., high- yielding and disease-free seeds, in order to see whether they are competitive with imported seeds. In other words, we want to confirm that if all the participants in the seed potatoes sub-sector had the same information on the seed production process and/or if it were possible to monitor the multiplication process at no cost, Mali could produce domestically produced improved seeds of price and quality that would be competitive with the imported seeds.

2) If the production cost under symmetric information is competitive with imported seeds, we want to look at contracting schemes to deal with asymmetric information, which is likely to be the main constraint to producing improved seed potatoes in Mali domestically. For this part of the study, we will use conjoint analysis to identify the set of contracting schemes for seed potato multiplication to deal with the potential problems of hidden action and moral hazard inherent in the process.

3) Get Malian potato growers' perceptions and expectations about domestically produced improved seed potatoes. This will be done using the conjoint analysis preferences-based method.

In conclusion, my research will contribute to the scientific literature both in economics and agronomy in the following areas:

(a)) Appropriate contract and institutional design in the context of asymmetric information and uncertainty typical of agricultural markets in low-income countries. Debate rages in agricultural and development economics about how to design effective markets reforms in developing countries where uncertainty and asymmetric information are pervasive. I will contribute to this literature by identifying the key factors constraining emergence of a market for a new technological input (improved seed) in a country like Mali. For example, what combination of monitoring and contract incentives will induce farmers charged with multiplying the seed stock to respect the very precise production practices needed to assure seed quality? This case of seed potato production in Mali will help extend this type of analysis (contract design) to other developing countries, where many people are still reluctant to contract in the agricultural sector because of risk and the high cost of monitoring.

(b) Appropriate design of improved seed production systems in developing countries.

The problems faced in developing a viable domestic seed potato industry are not unique to Mali. Certification, costs and benefits to producers of various degrees of "improvement" in the seeds that they use, and role of local producers vs. large commercial firms in improved seed production are common to many low-income countries (Sperling et al., Mayona et al.). The issues are more pronounced in crops like potatoes, where seeding rates, and hence seed costs, are particularly high. Thus, understanding the conditions necessary for a viable local improved seed potato industry development in Mali will likely yield insights on how to improve seed systems in other similar low-income countries.

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