Socio-economic, agronomic and molecular analysis of yam and cowpea diversity in the Guinea-Sudan transition zone of Benin

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Socio-economic, agronomic and molecular analysis of yam and cowpea diversity in the Guinea-Sudan transition zone of Benin

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Abstract

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Management and use of yam and cowpea genetic resources analysed in this thesis are important to realize agricultural development in Benin, both on the short and long run. In this thesis the diversity of local varieties of yam and cowpea, often ignored by classical research, is analysed. Different methodological approaches, including technography, diagnostic study at village level, and joint farmer-researcher managed experimentation, have been combined with socio-cultural, market and consumer studies. Molecular tools have been used to assess the level of genetic diversity in these two crops.

Socio-cultural determinants, market and consumers' preferences, and the morphological and agronomic characteristics of different varieties of these two crops are all relevant for social acceptability and adaptability, and for the adoption of new varieties by local subsistence farmers. Different yam and cowpea varieties are used for rituals each year. The yield performance varied from one variety to another, and within one variety, from one year to another (or one place to another) depending on variability in agro-climatic conditions. While any successful variety of yam or cowpea should be adapted to stressful agro-climatic or poor soil conditions, it should be also adapted to the often specific needs of the farmer and to his/her socio-cultural environment. Moreover, varieties need to satisfy consumer preferences and market demands. Often, one single variety of yam or cowpea cannot meet all these criteria. Given these multiple purposes and multiple objectives, adequate management of diversity of varieties is essential to farmers, as a strategy to cope with food security and income generation all year round.

Prices of different varieties of yam and cowpea on the market reflect the food technological or taste characteristics perceived or recognized by consumers in these varieties. The market provides important information on diversity of varieties and on their characteristics.

Based on the morphogenetic and physiological characteristics recognized by farmers as limitations, or as natural constraints in the proper use of seed tubers of different yam varieties, this thesis undertook a participatory technology development programme with farmers to improve the knowledge of both the researcher and the farmers of seed tuber propagation through induced sprouting, and through use of different parts of the tuber as planting materials. The thesis also pays attention to farmers' own experimentation in developing new yam varieties by domesticating wild yams, and shows that this activity – probably of ancient provenance in Benin – remains effective for farmers excluded by poverty from market participation. The improvement of the performance of these local

varieties remains a major future task for researchers and policy-makers in Benin.

Two major conclusions can be drawn from this thesis. The first is that both social and natural sciences are necessary contributors to the understanding of diversity in yam and cowpea varieties as managed and maintained by farmers. This diversity is expressed at the molecular level and at farm level, but is also highly relevant on the market and in the socio-cultural life of the farmers. The second conclusion relates to findings concerning the possibility of engaging farmers and researchers in joint study of yam and cowpea diversity, with beneficial practical consequences. Joint experimentation focused on varietal characterization, and the joint participatory technology development, indicated that more effective research results can be obtained when farmers' perceptions and depth of experience is fully incorporated in research design. In this regard, technography and diagnosis remain continuously reviewed, allowing the incorporation of new ideas or innovations and new stakeholders in the experimentation process. The results assessment with and by farmers remains an essential aspect of judging work in farmer conditions to improve local livelihoods. In particular, the thesis emphasizes that – through domestication of yam – the poor show that they can contribute actively to development of scientific perspectives. These aspects of the Convergence of Sciences as focused upon yam and cowpea varietal management embrace both an inter-disciplinary and trans-disciplinary research perspective. Cooperation and co-knowledge generation with farmers needs follow-up, and a scaling-up to reach other farmers. Specifically, it needs to be incorporated in the curricula of national research training systems.

Keywords: Cowpea (*Vigna unguiculata* (L.) Walp.), yam (*Dioscorea spp.*), agro-biodiversity, farmer perception, market and consumer preferences, socio-cultural preferences, human and social capitals, genotype by environment interaction, socio-technical knowledge, domestication, inter-(trans)disciplinarity / Beta-gamma science.

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Contents

CHAPTER 1

Problem definition

Introduction

Yam (*Dioscorea* spp.) and cowpea [*Vigna unguiculata* (L.) Walp.] are basic foods for the population of Benin. There is a strong interest among farmers and consumers, and at the national research system level, in promoting the maintenance of the genetic diversity of these crops (INRAB, 1995; 1996; Détongnon *et al.,* 2000; MEHU, 2002). Management of diversity of these crops is mainly done by farmers. However, little is known in detail about how farmers actually manage yam and cowpea diversity, despite the fact that the management and use of agricultural biodiversity is an important national policy issue (INRAB, 1995, 1996; Détongnon *et al.,* 2000; MEHU, 2002).

Farmers in Benin are poor (Aho *et al*., 1997), and they face many problems regarding the agronomy of these crops. They try to cope with these problems by taking initiatives to improve their knowledge and technology, despite the facts that they are hardly involved in the formal science production system and that the impact of introduced technology is estimated to be very low. Concerted actions in favour of joint participation of farmers and researchers in the development and introduction of new technologies (including new varieties) might be an interesting way forward. To build such partnerships is the central aim of the Convergence of Sciences project, of which this thesis is a part.

The two dominant models of agricultural sciences – those supportive of industrial agriculture in Western societies, and those behind the Green Revolution in irrigated agricultural systems in Asia – are not well adapted to diversified and risk-prone environments in Sub-Saharan Africa (SSA). It has been argued that the professional norms in the established agricultural sciences (i.e., modes of thinking, values, methods, and patterns of behaviours) are part of the emerging problem of non-adapted technology offered to small farmers, and that it is necessary to set-up new priorities in agriculture (Chambers *et al*., 1994). This does not mean that agriculture in SSA has not been innovative. Farmers in SSA are today well recognized as innovators and experimenters (Richards, 1985; Rhoades and Bebbington, 1988; Millar, 1994; Rhoades, 1994; Scoones and Thompson, 1994), but often their modes of innovation and experimentation differ from standard science. Consequently, it is necessary to search for convergence between elite crop science (‘Western science’) and local science in SSA, and its neglected indigenous knowledge base. Convergence of Sciences (Hounkonnou *et al*., 2006) tries to identify where mutual accommodation is possible.

An important main aim of Convergence of Sciences (CoS) is to create a better understanding by potential clients and suppliers of technology of what science could deliver to poor farmers, thus improving the demand factor in technology generation. The mechanism of the CoS approach is to establish joint, shared frameworks for understanding and action between farmers and scientists, leading to joint crop improvement, a better use of innovations, and better awareness of crop characteristics thus far insufficiently valued by scientists. The approach is intended to help form a client constituency for the products of science and technology.

This thesis, part of the output of CoS, aims at generating a new form of participative research integrating social and biological sciences and involving farmers, consumers and researchers, focused on sustainable use of genetic resources of yam and cowpea in Benin.

The overall methodological framework is technographic (i.e., evidence-driven analysis of actual technology processes), and based on a realist perspective (Pawson and Tilley, 1997). This perspective argues for the simultaneous advancement of what Pawson and Tilley term Context-Mechanism-Outcome configurations (CMO). Researchers need to grasp the totality of CMO, by a balanced approach to all three aspects. Present outcomes of current research for yam and cowpea improvement are demonstrably inapplicable to farmers. This requires attention to the mechanisms for generating innovations. But understanding what might effectively be changed – forming hypotheses about cause and effect in crop improvement – requires also careful scrutiny of contextual positioning of technology processes. The task of the first chapter is to undertake this contextual positioning.

Using a technographic survey approach (Projet CoS, 2004), this first chapter arrives at an overall contextual positioning of the following four issues:

- The importance of yam and cowpea as basic foods;
- The role of yam and cowpea varietal diversity in the farming systems of Benin;
- The weaknesses and constraints of crop improvement processes, as affecting yam and cowpea;
- How current crop improvement processes fail to include and satisfy farmers' and consumers' needs regarding the two focal crops.

Importance of yam and cowpea, and rural poverty, in Benin

White and yellow yams (*Dioscorea rotundata* and *D. cayenensis*) may have been first domesticated in the forest-savannah ecotone in the eastern part of West Africa. The countries on either side of the Dahomey Gap (an incursion of savannah to the Atlantic coast, dividing the African humid tropical forest zone into Upper Guinean and Congolian formations) possess an immense and rich socio-cultural heritage of yam, and are home to much of the crop's genetic diversity. Other species (i.e., *D. dumetorum*, *D. alata* – the latter an Asian exotic) are also cultivated by farmers in this region. Benin is the fourth yam producer in the world after Nigeria, Ivory Coast and Ghana. The area of production mainly lies between the latitudes 9° and 11° N. Despite earlier expectations that the crop might diminish in importance, yam production in Benin increased from 680,000 metric tonnes in 1983 to 1,250,000 metric tonnes in 1995 (FAO, 1996). This production increase of 83% has been realized on an increased cultivated area of 63%, showing some limited degree of intensification. Yam forms a basic carbohydrate staple for millions of people in the region, and is eaten boiled or processed into various forms of flour and starchy paste.

West Africa is also a region in which cowpea [*Vigna unguiculata* (L.) Walp.] may have been first domesticated and where much of this crop's genetic diversity is to be found (Ng and Maréchal, 1985; Ng, 1995; Padulosi and Ng, 1997). Pasquet *et al.* (1997) analysed the complex of cultivated and wild cowpea in Africa and concluded that the domestication took place in West Africa from a stock of wild or forage cowpea. Carbon dating of cultivated or wild cowpea from the Kintampo rock shelter in central Ghana (Flight, 1976) revealed the oldest archeological evidence of cowpea found in Africa, and showed the existence of gathering or cultivation of cowpea by African hunters or food gatherers as early as 1500 BC (Padulosi and Ng, 1997). Benin is one of the important cowpea growing countries in West and Central Africa (Singh *et al.,* 1997). In Benin, about 75,000 metric tonnes of cowpea are produced on 102,000 ha. Production still falls short of national demand (Kossou *et al*., 2001). From 1975 to 1995, cowpea production in Benin increased from 19,000 to 65,000 tonnes (Pallix *et al*., 1995). The average increase in relative yield is about 3.5%, equivalent to an increase in yield per hectare of about 434 kg ha^{-1} in 1981 to 622 kg ha^{-1} in 1995 (Pallix *et al*., 1995). The cultivated area increased from 47,000 ha in 1975 to 99,000 ha in 1995, an average annual increase of 3.8%, suggesting little if any intensification. Cowpea grain and leaves are processed and used in various dishes in Benin.

Both yam and cowpea are ancient crops in the region around the Dahomey Gap, and deeply embedded in rural social life. The first harvest and first consumption in each season of both yam and cowpea are therefore associated with many traditional rituals. These rituals remain important as sources of social cohesion, in which people from different lineages meet and strengthen their culture. These two crops also significantly contribute to rural food security. This security arises from crop diversity at farm level, which ensures a diversity of uses, and prolonged seasonal availability of food and income. In fact, farmers value certain varieties because these varieties will allow them to spread the harvest over time, will prolong the availability of food and will provide the opportunity of selling produce almost year round. Moreover the farmers' varieties differ in storability. Area (and in the case of yam, intensity) are increasing, year-on-year. But there is a fear that crop diversity may be in decline, thus undermining food security. This is a central concern in this thesis.

Rural poverty, food security and economic importance of genetic diversity

Rural poverty is a crucial national problem in Benin, and the distribution of the poverty profile has been analysed over the country (Aho *et al*., 1997). One of the zones most affected by poverty is the central zone, including the districts of Glazoué and Savè where the current research was undertaken (Bankolé *et al.*, 1997; Larivière *et al.*, 1997). In the context of the poverty as an aspect of traditional farming systems, agro-biodiversity ensures food security over time and enables farmers to cope with various agricultural and environmental risks. Without access to local agro-biodiversity farmers would face increased poverty. But at the same time yam and cowpea are increasingly in demand in urban areas, to satisfy the needs of a growing population for staple food. Whether there is tension between farmers' desires to protect local poverty-alleviating biodiversity and increased market demand for a few superior crop types is something this thesis will explore further.

Overall, it will be shown that genetic variation between and within crops offers possibilities to diversify both food and income sources, and thus generally has a positive impact on poverty at farm household level. Genetic variation may also be used to optimize the use of household labour by distributing labour demands for planting, weeding and harvesting more evenly over time (Altieri and Merrick, 1987). Smale (2002) states there are several reasons why the diversity of crop genetic resources grown on farms is of economic importance. The first of these reasons relates to crop productivity. The patterns of crop varieties and the genes they carry determine the annual yields and the crop vulnerability to biotic and abiotic stress. The second reason is that yield growth and yield instability have (both positive and negative) economic value; maintaining diversity on farms may entail efficiency trade-offs in the short term. To understand these costs and benefits we need, first of all, a clear and context-specific picture of what farmers seek to conserve and why.

Management of agricultural risks and genetic diversity maintenance

Farmers' environments are characterized by heterogeneous soil conditions, erratic rainfall, and socio-economic variations resulting in complex stresses and high production risks that vary over time and space. The use of genetic variation is a way of dealing with environmental and socio-economic variation, thus reducing risks of crop production (Clawson, 1985; Brouwer *et al*., 1993; Van Noordwijk *et al.*, 1994; Almekinders and Elings, 2001). Chambers (1989) analysed the complex, diverse and risky environments in which most African farmers operate. Under these conditions, farmers want seeds of numerous different cultivars of each crop to cope with both physically variable environments in which they plant each crop and seasonal uncertainties in complex, diverse and risky regions often cut off from external inputs, as well as to realize diverse socio-economic goals. Crop biodiversity confers potential resistance to droughts and other environmental stresses, and thus has economic importance in production systems, regardless of whether crop populations are characterized predominantly by old varieties, modern varieties or landraces (Meng *et al*., 1998). Moreover, maintaining genetic variation within the farming systems may also prove valuable, as a basis for adaptation to future changes (Dennis, 1987; Benzing, 1989).

Scientific theories and crop genetic resource management

Weaknesses of elite crop science

Farmers maintain agro-biodiversity in central Benin largely through self-provisioning in planting material, or through informal networks of exchange. The current situation of demand for off-farm seed in Benin is only partly known. Information on the real seed needs of farmers, on the varieties available and on their agronomic and technological characteristics is scarce. Seed growers in the formal seed system lack information on what their (largely potential) market might one day demand. At the level of the individual farmer, many problems limit demand for off-farm seed: inefficient capacity to utilize improved varieties because of lack of inputs (e.g., fertilizers), an information gap concerning the characteristics of the varieties available, and lack of financial resources to purchase the improved seeds.

The weaknesses of agricultural innovation in Benin are now recognized (Projet CoS, 2004). The low productivity of many introduced varieties in the local farming systems, their disease and pest susceptibility, and their poor taste quality are commonly acknowledged (Projet CoS, 2004). It is therefore relevant to ask what role farmers and consumers might play in improving the performance of the current crop science system in Benin.

Cultural and market changes and conservation of crop genetic diversity

Cultural change or loss of local cultural values may change the preferences and practices that make diversity of crops valuable (Bellon *et al*., 1998). This, in turn, may lead to loss of crop genetic diversity. In the context of economic development and socio-cultural change, some scientists claim that it is impractical to conserve biodiversity in farming systems in developing countries. This thesis will attempt to throw further light on these apparently somewhat contentious issues.

On the one hand, many believe that the diverse cultivars are a public good and advocate germplasm storage *ex situ,* in 'out-of-place' facilities, as the sole strategy to conserve and protect the free flow of diversity (Frankel, 1974; Williams, 1984, 1988). Similarly, several of the active proponents of proprietary rights for indigenous and peasant farmers also advocate *ex situ* storage as a suitable conservation solution, thus agreeing on the means of conservation, if not the ends to be served (Kloppenburg and Kleinman, 1987; Kloppenburg, 1988; Fowler and Mooney, 1990).

On the other hand, other commentators claim that *ex situ* conservation alone is insufficient, for a variety of reasons related to the biology of crops and the social and technical features of storage (Prescott-Allen, 1982; Wilkes, 1983, 1991; Nabhan, 1985; 1989; Brush, 1986, 1987; Altieri and Merrick, 1987, 1988; Oldfield and Alcorn, 1991; Cleveland *et al.*, 1994). It is argued, from this perspective, that *ex situ* conservation halts evolution of diversity, by cutting off conserved material from many environmental influences, including exposure to genetically compatible wild relatives. They point out that such stores might be vulnerable to intentional targeting, for example through terrorism or civil war, or through coincidental mishaps such as power failures. Critics suggest that 'in-place', or *in situ* conservation based on continued farm production, must therefore complement the centralized collections of stored resources.

Social and economic theories for crop genetic diversity

Most studies on the relationships between the market and the long term use of crop genetic or varietal diversity in farmers' systems have viewed the increased adaptation of farmers to market demands and the associated introduction of modern varieties as a cause of increased loss of genetic diversity. Why? The assumptions of this paradigm are that farmers' adaptation to market demands implies specialization in the few crop varieties that the market values. For this paradigm, the market demand only values a few traits in a few varieties. The consequence would be that farmers will tend only to produce the varieties the market recognizes, resulting in 'genetic loss' or 'genetic erosion'. A second assumption associated with this paradigm of thought is that higher demand for high yielding varieties or modern varieties, as market access improves, will result in a more stable price, reducing 'price risk' (or price variability), and hence decrease the incentives to grow traditional (risk-obviating) varieties (Bellon and Taylor, 1993; Arslan, 2003). This argument rests on an assumption (tested below) that food markets fail to value variation in characteristics of the varieties sold on the market.

Modernization theory, in particular, advances the idea of socio-environmental change as socially even and historically linear (Watts, 1993; Zimmerer, 1997).

Proponents believe that the growth of markets and commerce will uniformly convert the environments of peasants and indigenous production from traditional to modern. The fear is that "people might cast off their traditional varieties, sort of like last year's automobile model" (Zimmerer, 1997). Zimmerer challenges this opinion by showing that the world-renowned diversity of crops in the Andes may not be as endangered as is widely believed. He develops a lengthy history of small-scale farming of Quecha farmers in Peru to make this point.

Sociological theories assert that the making of cultural identity, which includes the cultivation of diverse crops and varieties, must be studied in careful and historical detail rather than be assumed to result from the mechanisms of modernization. Zimmerer then offers an analysis of how farmers themselves experience social inequity and the salience of new cultural meanings. For example, the 'better-off Quechua' farmers from the Andes have adeptly taken advantage of their culturally high-status foodstuffs, forging a compelling link between ethnicity, power and inequity, and biodiversity. While farming many fields for commerce they have gained a variety of benefits from their diversity-rich, self-provisioning plots (Zimmerer, 1991, 1992, 1997). It has been found by Zimmerer and others that social theory is necessary to fully analyse the relation of markets to biodiversity. The theory as deployed by Zimmerer and others seeks to make sense of recent economic trends in developing countries, especially those of Latin America and Africa, which show scant or no improvement in peasant incomes and prospects for development (De Janvry, 1981; Wilson and Wise, 1986; Reinhardt, 1988; De Janvry *et al*., 1989; Deere, 1990; Roseberry, 1993; Zimmerer, 1997). The approach fits rather well the case in Benin, where there is indeed much cultural complexity in yam and cowpea production, and some of that complexity is reflected in markets.

Non-elite crop science

Yam domestication is an instance of what might be termed non-elite crop science in Benin (i.e., farmer practices based on some apparently systematic knowledge of plants). Yam domestication is part of the origins of agriculture in this area of West Africa. Recent research on the genetic origin of the cultivated varieties revealed that of the 16 wild yam species of the genus *Dioscorea* identified in West Africa (Hamon *et al*., 1995), two of them (*D. abyssinica* and *D. praehensilis*) are associated with the emergence of yam cultivation in the region (Terauchi *et al*., 1992; Ramser *et al*., 1997; Tostain *et al*., 2004). The germination and development of true seed of yam obtained from the aerial parts after pollination is infrequent. It is assumed that domestication originally involved the gathering and planting of wild tubers. Farmers today continue to gather wild yams during hunger periods, and often carefully re-plant the plants from which part of the tuber has been removed. Some farmers also continue the practice of bringing in planting material from the wild to solve problems of decrease in yield and vigour of cultivated varieties, or the loss or lack of planting materials (Dumont and Vernier, 1997, 2000; Vernier *et al.*, 2004). Maintaining this indigenous knowledge might serve some useful purposes. At very least, this thesis will attempt to establish why this knowledge still seems important to poor farmers in Benin. Some farmers domesticate yam species to counter the loss of productivity over time observed in some cultivated varieties. Socio-cultural and economic reasons are also cited. Many 'domesticators' put forward that they are still attached to domesticating yams by tradition, as knowledge bequeathed by their ancestors, or to nourish their curiosity. Economic reasons also are given. Many poor farmers lack sufficient tubers for planting, and justify continued domestication as compensation for seed tubers of cultivars (including new varieties) they are too poor to buy, i.e., domestication is a creative source of cheap planting materials and helps farmers to cope with hunger (Houndekon and Manyong, 2004). This thesis will argue that ignoring this knowledge within agricultural research practice remains an important weakness of crop improvement oriented on yams in West Africa.

For cowpea, several independent studies concur in reporting that cowpea is an ancient West African domesticate (Murdock, 1959; Anderson, 1960; Portères, 1962; Stanton, 1962; Harris, 1967; Waillancourt and Weeden, 1992; Perrino *et al.*, 1993; Coulibaliy *et al.*, 2002). A history of domestication tends to align with a rich current local knowledge concerning selection criteria. As will be shown, this is the case with cowpea in Benin. Farmers are aware of a number of biotic and abiotic stress factors that reduce the growth and the yield of their cowpea varieties. Some cowpea varieties develop site- or area-specific traits and behaviour and are require to be planted at different phases of the cropping season. Breeding or research programmes on cowpea tend not to cover sufficiently adequately the full range of cultural requirements or environmental conditions. For this reason improved varieties frequently fail to meet consumer expectations or to express fully their increased yield potential (Russell *et al.*, 1989; Franzen *et al.*, 1996; Hardon, 1996; Kitch *et al.*, 1998). A fuller understanding of how farmers select their own cowpea materials ought to be useful in guiding breeders to a fuller appreciation of the range of conditions they need to meet.

Elite crop science system in Benin

Benin crop innovation system

A central purpose of the present study is to lay the groundwork for a better integration of elite and non-elite yam and cowpea knowledge systems in Benin. Technographic survey (brief systematic description of a technology system as a set of social and technical relations) is the basis for establishing a context covering both elite and non-elite science as it currently exists in Benin.

The elite crop science system for varietal innovation is composed of several sub-systems. Table 1 and Figure 1 provide a view on the formal agricultural research, crop improvement / breeding and seed activities in Benin from 1980s to 2000s. Scientists of different disciplines manage this system. The sub-systems are the international institutions (e.g., IITA, the International Institute of Tropical Agriculture), the formal crop improvement institutions of Benin (the phyto-geneticists, breeders, and R&D [Research and Development] team of INRAB and the certification services), and the formal seed sub-system (INRAB, certification service, Direction of Agriculture, seed producers, extension services of the ministry of agriculture, and a reference group of farmers consulted in innovation issues).

Table 1. Implementation of agricultural policies and programmes.

	Agronomic research			Crop improvement / breeding			Formal seed commercialization programme		
	1980s	1990s	2000s	1980s	1990s	2000s	1980s	1990s	2000s
Cowpea	+	+	+	+	+	-	+	+	-
Yam	+	+	+	-	-	-	-	-	-
Maize	+	+	+	+	+	+	+	+	+

+ = the policy or programme is present;
- = the policy or programme is absent.

For cowpea, the following groups of actors have been identified: individual and organized farmer groups, state institutions (extension services, INRAB, etc.) involved in extension of improved technologies, private institutions dealing with processing and marketing of by-products; and the group of NGOs, commodity networks, and donors (PEDUNE/PRONAF, the Benin-Netherlands Cowpea project, IITA, etc.) (Projet CoS, 2004). The indigenous innovations mainly address pest control and enrichment of the existing pool of varieties from neighbouring villages, markets or countries. Alternative pest control systems based on use of botanical pesticides have been developed by specific projects (Project CoS, 2004).

Non-elite innovation is widespread in Benin (as already briefly indicated above, and to be elaborated further in later chapters of this thesis) but a predominant feature is that it can hardly be described as a system in the same terms as the elite innovation system. Practices of discovery and knowledge maintenance are embedded in more general patterns and practices of small-scale farming, and in certain cultural institutions (e.g., associated with life cycle rituals). The situation is perhaps comparable to indigenous health practice in Africa half a century ago. But today, many local health practitioners are much more aware of the systemic features of their knowledge and practices, and

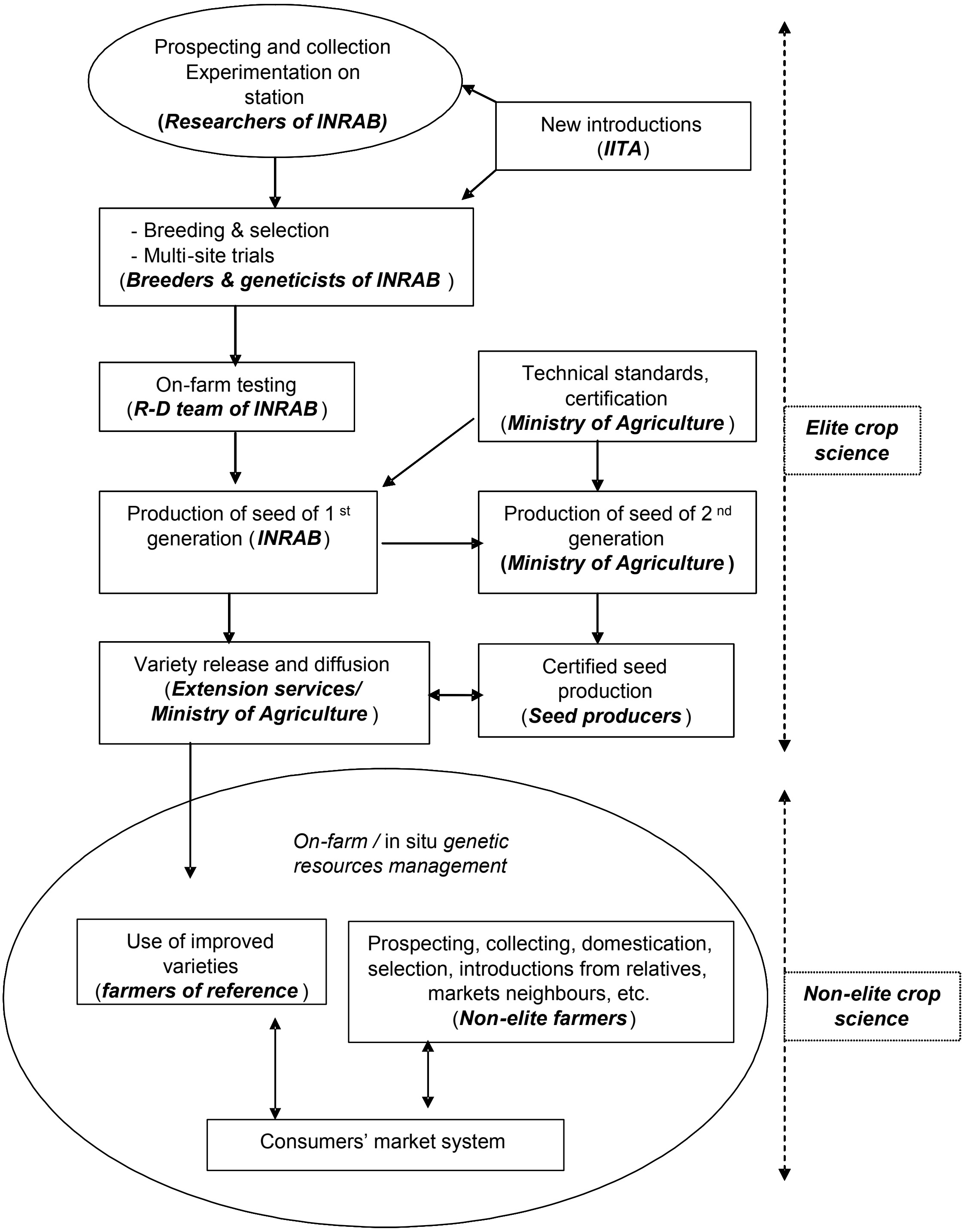

Figure 1. Yam and cowpea genetic resource innovation and management system in Benin. (INRAB=National Institute of Agricultural Research of Benin; IITA=International Institute of Tropical Agriculture).

have in many cases gone a considerable way towards the professionalization of their practices. African healers associations are increasingly recognized by governments and aid agencies as useful potential partners in health care delivery. Farmers have been slower to build networks, alliances and associations for the recognition and dissemination of indigenous agro-technical knowledge and discovery processes, but it is a development that may yet take place. This thesis aims to provide documentation potentially useful in any such development of peasant self-awareness.

The current dominant characteristic of elite crop science system for varietal innovation is its focus upon receiving new introductions from international institutions. National crop improvement for cowpea and yam dropped out of the system in the last decade (Table 1). A main conclusion from technographic survey is that the formal crop improvement for Benin is best viewed as an adaptive seed delivery system. An important feature of the non-elite science system, as represented by farmers or groups of farmers collecting, domesticating, characterizing, and selecting yam and cowpea, is that it incorporates a major emphasis on in situ plant improvement, and is not dependent on seed delivery alone. It is a major point for debate whether the 'old' system of farmer improvement based on phenotype selection is as redundant in poor countries as some biotechnologists suppose (cf. Tanksley and McCouch, 1997). This thesis will argue that judicious buffering of existing farmer-led non-elite crop improvement may still represent good value in terms of poverty alleviation.

Researchable constraints

Scientists within the national agricultural system raised various problems related to the low productivity of yam and cowpea production in Benin. These problems are identified as the researchable constraints.

For yam, the characteristics of existing varieties are not well known, and thus farmers and consumers are not able to easily make their choice. This lack of knowledge on existing plant materials, their agronomic characteristics, factors causing losses of tuber quality or decrease of market and culinary values, and on farmers' and consumers' preferences, have hindered scientists in developing appropriate methods to increase yield and reduce post-harvest losses. Many yam varieties cultivated in the past, can nowadays only be found among a few farmers in small quantities. Moreover, the wild species – ancestors of cultivated varieties – are most likely experiencing severe erosion due to the disappearance of forest reserves. In short, the genetic resources of yam are at risk (INRAB, 1996).

For cowpea, researchers realized that there was a lack of knowledge on characteristics of existing cowpea genetic resources, on integrated control methods of cowpea pests, and on nutritional and culinary qualities of cowpea varieties. This lack of knowledge limited the development of varieties adapted to consumers' needs. Low productivity of cowpea was due to several factors: susceptibility to insects during production and storage, spread of the parasitic weed *Striga,* non-adaptability to drought, inadequate fit of the growing cycle to the rainfall pattern, and non-existence of material suitable for multiple purposes (grain and forage) (INRAB, 1996).

Demand and supply for agricultural innovations

The elite system approaches these constraints by screening varietal introductions, cropping technologies, and post-harvest technologies developed elsewhere, then testing them in most appropriate zones and systems of the country (INRAB, 1995). These technologies are supposed to satisfy farmers' needs in increasing the agricultural productivity. For cowpea, IITA developed and distributed improved cowpea materials and new germplasm lines over the country. A general remark is that most of these introduced improved varieties have not lived up to expectations in terms of increasing farmer productivity, and that, moreover, they are susceptible to pests and diseases. It should also be noted that public sector research intervention has been more intense on some crops than on others. Table 1 suggests that, in the past, yam has been neglected in public intervention, compared (especially) to maize. Yam appears to be something of an orphan crop for researchers in Benin, despite a huge increase in output in recent years. This fact, in itself, suggests need for some re-thinking of the way public assistance to agricultural research is structured.

Rationale for co-construction of knowledge and technology

Using farmers' knowledge in science-based knowledge production

Indigenous crop improvement technologies have been the subject of lengthy observations, and validated and proven over a long time. As Nyira (1994) states, these technologies are of an integrated nature combining recurrent selection, field agronomy and post-harvest technologies. This integration is a neglected aspect of farmer knowledge. Stimulating *in situ* selection (by farmers) may be good for genetic resource conservation since it may serve to keep local landrace materials 'in play' (some by out-crossing with the introduced materials). As Weltzien *et al.* (1996) suggest, the role of the breeder would then be to sift locally maintained materials and make useful genetic variation available to farmers. Contrary to the views of some bio-engineers, this is to argue that plant improvement remains a technology guided by evolutionary principles, and that effective partnership between farmers and breeders remains desirable.

Farmers work in risk-prone environments. Some scientists perceived that it is difficult for formal sector plant breeders to provide the kind of seeds needed by the majority of farmers, because the formal sector is geared to generate a limited number of varieties, each of which is distinct, uniform and stable, and has a high yield potential if grown with application of external inputs (Cromwell, 1992). For a long time, agricultural research has disregarded diversity in farmer's fields and variations in experimental results. As a result, general solutions to problems have been sought, thereby reducing the potential local effectiveness of many agricultural interventions (De Steenhuijsen Piters, 1995). In a context of persistent diversity of farms, and variations in yield, the causes of diversity and variations were considered residual factors (Bolhuis and Van der Ploeg, 1985). Notions of agricultural improvement are predicated not on helping in specific situations but on the ambition to control and standardize the environment of production and to homogenize farm management (Huxley, 1986). Agricultural research has thus tended to disregard that the farmer's physical environment is diversified, and in accordance with that variation, the farmer needs a diversity of plant materials. Many studies tend to show the non-adaptability of standardized technologies to local needs and preferences. These studies then highlight indigenous technology development as an alternative path.

A key requirement for any such approach is a new cooperation between farmers and scientists. A first step – it is here argued – is to understand better the diversity-maintaining behaviour of farmers, and to explore the extent to which this correlates with realities of the physical and socio-economic environments and farmer strategies for coping with farm risks.

Modes of managing crop genetic diversity by scientists and farmers

Behind the advocacy of *in situ* conservation and its coupling with sustainable development lies little analysis of the changing ecological, social, and cultural roles of biodiversity in developing country farming. While it is thus possible to criticize the weakness of *ex situ* programmes, the policy recommendations that promote *in situ* conservation cannot offer much in the way of specific empirical insights. It is thus important to know the realities of managing the crop genetic resources by scientists and farmers, in establishing what each group might contribute from the perspectives of elite and non-elite crop science. Actual evidence of farmer crop management, and how this affects availability of crop genetic resources, is thus a major concern in the present thesis.

Lack of specific adaptation and decentralization of developing knowledge

Elite crop science, more specifically formal breeding or crop improvement systems, have failed to a significant extent to take into account specific adaptation of farmers' environment and specific crop conditions in the objectives of breeding programmes. "Interactions between genotype and environment are factors almost universally accepted as being [of major importance in] limiting response to selection and, hence, the efficiency of breeding programmes" (Ceccarelli, 1989; Ceccarelli *et al.*, 1997). Genotype by environment (G×E) interactions become important when the rank of genotypes changes in different environments. This change in rank has been defined as crossover G×E interaction. Formal breeding has taken a negative attitude towards G×E interactions, in the sense that only breeding for low genotypes by environment interactions (that is high average grain yield across locations and years) is selected, while lines with good performance at some sites and poor performance at others are discarded. Because lines with good performance in unfavourable sites and poor response to favourable conditions have a low average grain yield, they are systematically discarded. Yet they might be the ideal lines for farmers in unfavourable conditions. What this implies is that specific adaptation to difficult conditions must be found through direct selection in the target environments – not just on experimental stations.

A key aspect of decentralization is farmers' participation in characterization and selection under their own conditions (Ceccarelli *et al*., 1996). The objectives of farmer participation are not only to improve the functional forms of formal research but also to empower marginalized people so that they can make their own decisions, thus strengthening their self-confidence in their own research capacities, and so creating conditions for them to make more effective demands on research. Decentralization appears as a *sine qua non* for participatory research and technology development; user participation requires that the research must be decentralized to enable the user groups to be involved and meet the demands of site-specific adaptation.

The empowerment paradigm states that the poor in society can best be helped by getting them involved in decision-making and implementation of development activities (Nkum, 1998). One of the processes of empowerment might well be the involvement of farmers in agricultural knowledge production. Empowerment through participatory research and knowledge development is to make science respond more directly to the ideas and needs of farmers most affected by underdevelopment (Vernooy, 1997).

Current stakes of involving farmers in knowledge and technology development

Taking into account farmers' poverty, their production problems, and their own initiatives in science and technology, on the one hand, and the estimated low impact of introduced technology and farmers' lack of participation and involvement in the formal science production systems, on the other hand, some world-wide movements in favour of farmers' participation emerged from the late 1980s onwards. This is usually called the 'populist approach'. The populist approach is to 'learn from farmers' innovations', to put farmers' agendas first, and to support practical participation by farmers (Scoones and Thompson, 1994). The thesis underlying *Farmer First* is that much of the problem with conventional agricultural research and extension has been in the processes of generating and transferring technology, and that much of the solution lies in farmers' own capacities and priorities. The interest and support this populist philosophy received from the late 1980s has led to a virtual revolution in the agricultural sciences; this has been termed by some scientists a 'paradigm shift' (Scoones and Thompson, 1994). Proponents of the 'Farmer First' approach argue that greater attention needs to be paid to on-farm research conditions, and that farmers need to play a more active role in agricultural experimentation (Richards, 1985; Scoones and Thompson, 1994). The claim is made that greater participation of farmers in on-farm, adaptive research will result in a technology development process more attuned to local conditions and priorities.

In practice, the focus is on bridging gaps between development professionals and resource-poor farmers, and on finding new ways to understand local knowledge, strengthen local capacities and meet local needs. While many view this perspective as a step in the right direction, "others have argued that such approach fails to confront the impact of power on relations between different groups within farming communities or between local people and outside change agents" (Scoones and Thompson, 1994). Further, it may no always capture the complex socio-cultural and political-economic dimensions of knowledge creation, innovation, transmission and application with rural societies and scientific organizations. Thus the purpose of the symposium *Beyond Farmer First: Rural People's Knowledge, Agricultural Research and Extension Practice* was to challenge the populist conception of power and knowledge, to analyse questions of 'difference' by asking 'whose knowledge counts?', and to dispel the notion that agricultural transformation is a straightforward process to be improved only by sensitive external support agencies (Scoones and Thompson, 1994). Thus, a persistent challenge has been to find ways of getting agricultural researchers to participate and understand processes of farmer experimentation, and to seek ways of articulating on-farm elite crop research with farmers' own research projects and modes of inquiry (Richards, 1994; Scoones and Thompson, 1994). Against this background, and as applied here to yam and cowpea genetic resource management and use by scientists and farmers, the aim of the Convergence of Sciences (CoS) project is a better understanding by potential clients and suppliers of technology of what science could deliver to poor farmers, to provide a better demand 'pull' in technology generation.

The purpose of this integration is to contribute to better crop improvement, better use of innovations, and better awareness of crop characteristics insufficiently valued by scientists.

Relevance of the study

The uptake of introduced varieties among small farmers in Benin has been disappointing. Farmers appear to have rejected new varieties outright, or abandoned them after a trial period. It is therefore important to have a better idea of what causes these negative responses. This study will, in particular, focus on crops where it is known that farmers have in some cases ignored new introductions because they have evolved endogenous strategies to meet both subsistence requirements and market opportunities. The study will then argue that it may make sense to reinforce farmers' capacities through seeking to converge elite and non-elite scientific approaches. This implies efforts to diversify elite crop improvement strategies, and to develop complementary strategies of *on-farm*, *in-situ* and *ex-situ* management, especially for indigenous crops relatively little studied by science, in order to enhance food security. The study offers evidence relating to the characterization and assessment of neglected local varieties, in order that scientists in Benin may develop concrete and effective cooperative breeding programmes responsive to local needs.

Rather specifically, the thesis will address a lack of knowledge on the rate of variety exchanges between farmers and on the genotype by environment interactions bearing upon local specificity and adaptation. The thesis explores the topic at the level of crop genetic diversity and in relation to the logic of farmer crop variety choices, believing that the findings will be relevant to crop system management and to the development of an expanded agenda for breeding and selection of yam and cowpea in Benin.

Formerly, the national agricultural research institute in Benin has adopted a unidirectional view of breeding and selection, not necessarily in accordance with the various needs and conditions of the different client groups. This unidirectionality underlay earlier rejection of several agricultural innovations. This thesis offers a new, unifying perspective, in which scientists and farmers can merge interests in developing strategies for the utilization of yam and cowpea genetic diversity in the area of study.

Research questions, objectives and hypotheses

Research questions

- What are farmers' perceptions of the amount of yam and cowpea varietal diversity they possess? What are their specific preferences and varietal selection criteria?
- What economic, agronomic and technological variables explain the demand,

supply and adoption of yam and cowpea crop varieties?

Research objectives

- To analyse farmers' perceptions on the concepts of genetic diversity management for yam and cowpea, and how they use this diversity for effective management of household resources;
- To analyse the adoption processes for new varieties of yam and cowpea in each of several selected villages;
- To quantify and characterize the varietal and genetic diversity of yam and cowpea;
- To analyse the effect of socio-cultural, market, and agronomic factors on the diversity of cultivated varieties of yam and cowpea.

Working hypotheses

- Level of varietal diversity is related to socio-cultural perceptions and different use values in each farming system.
- Adopted varieties are agronomically and economically more efficient and respond to specific preferences of farmers better than alternatives, thus implying that diversity in the field is the conjoint result of agronomic and taste characteristics of each yam and cowpea variety.
- That market price for yam and cowpea in Benin offers a valuation of specific variety traits for yam and cowpea, and that this is useful evidence regarding the comparative merits of products researchers and farmers provide. Specifically, the study seeks to provide market evidence that the products of non-elite plant selection are not inferior to research products.
- The preference and characterization criteria that determine the choice and the maintenance of a variety in the farming system differ between farmers and scientists.

Outline of the thesis

This thesis consists of eight chapters. Drawing on the technography approach, Chapter 1 has dealt with problem definition. Chapter 2 deals with the research process. The diagnostic study (Chapter 3) focuses in on the specific field problems to be addressed, mapping actors involved and selecting villages for in-depth studies. The diagnostic study is followed by chapters reporting on the experimental phase, and on related inter-disciplinary studies.

Chapter 4 analyses the role and place of religious, cultural and social factors in crop variety choice. It shows the link between cultural diversity and maintenance of crop variety diversity. Chapter 5 deals with demand-driven forces relating to market preferences. Factors determining the variety choice of actors are assessed through convergent action research.

Chapter 6 deals with the experimental research and co-research activities with farmers on yam varietal characterization and technology development, and offers results of supportive molecular analysis. Chapter 7 addresses the same issues for cowpea, offering results of characterization undertaken with farmer inputs, and molecular analysis.

Chapter 8 has both summary and forward-looking aims, reflecting upon CoS ambitions with regard to farmer experimentation, and envisaging further applications in the field of crop diversity management.

CHAPTER 2

Analytical framework and research process

In light of the multidimensional character of the problems related to yam and cowpea genetic resources management by farmers or by scientists as revealed in Chapter 1, this chapter presents methodological background and the research process followed in this thesis. This chapter comprises two parts. The first part is an analytical framework reviewing some scientific, interdisciplinary and participatory research approaches related to science and technology development. The second part describes the different phases of the research process applied in this thesis.

Analytical framework

Need for a trans-disciplinary research method

Varietal diversity management is multi-faceted. Therefore, it is necessary to rethink the traditional research method. Booth and Rodgers (2000) suggested that past institutional research structures have created a widespread reductionist, single-problem, approach to research, where the tendency is to break problems into component parts with the hope of reintegrating them at a later stage. Most of the time, this strategy is unsuccessful in the face of challenges of resource management involving multiple actors. Past research on farming systems raised the issue of an interdisciplinary approach as crucial, and noted that addressing production problems in the context of farming systems necessarily requires the participation of researchers from a range of disciplines and from the rest of research organization (Tripp, 1991a, b). The barrier to the interdisciplinary approach is that scientists trained in a discipline learn to speak a specific language and adopt analytical and methodological constructs communicated within that discipline. This constitutes a form of professional socialization that serves as an important part of the training experience; but it also presents obstacles to interdisciplinary research. A major task of the researcher within the Convergence of Sciences programme is to overcome these barriers.

Social construction of science and technologies: Research approaches

Analysing science and technology development, Callon and Latour (1981) developed the actor-network perspective – put simply, their insight is that doing research is to build a network. They defined an actor as ‘any element which bends space around itself, makes other elements dependent upon itself and translates their will into a language of its own'. The process of translation described is 'all the (necessary) negotiations, intrigues, calculations, acts of persuasion and violence' (Callon and Latour, 1981). The action should not be seen as a simple implementation of an intention, but rather a directed construction of real-world relations; such relations form a network. For technological change, the actor network theory studies the process through which a new artefact is developed. The artefact to be developed cannot be distinguished from the project participants' attempts to translate the world according to their intentions (Latour, 1996; Callon, 1997; Law and Callon, 1997).

Salient features of the constructivist research process have been described by Lincoln and Cuba (1985) and reported by Tacconi (1998). This work emphasizes that research is carried out in the local conditions using both qualitative and quantitative methods. It is suggested that it is preferable to have the theory (i.e., grounded theory) emerge from the data and from the research process. The design of the research process, or emergent design, is allowed to unfold while the research is carried out. The interpretation of the data is negotiated with the people from whom the data have been derived. This process leads to what is termed a negotiated outcome of the research (Tacconi, 1998).

In agricultural sciences and technology development, the actor perspective on the research process or outcome is of importance. Leeuwis and Van den Ban (2004) suggested that in regard to innovation farmers are likely to take into account three main elements: the technical domain (such as increase in yield), the economic domain (i.e., the profitability, marketability, and the social-organizational relationships with input providing organizations, households, community, farm labourers, state, ancestors, spirits, gods). This theory on perception considers that what farmers do depend in part on their perceptions of the manifold socio-technical and socio-economic consequences of certain practices, the perceived likelihood that these consequences will emerge, their valuation of such consequences in relation to a set of aspirations, and the perceived effectiveness of social environment, social relations and social pressures.

As a method of working with farmers, based on a cognitive approach to how actors form knowledge, the Farmer Field School (FFS) was first developed in Southeast Asia (Röling, 2002). FFS is considered a training method designed for the farmer to help him develop an understanding of the crop, pests, natural enemies of the pests, the environment, relevant components of the ecosystem, and the interactions between these aspects. "The method is learning-by doing. The trainer does not teach, but facilitates a learning process". FFS is crop specific, and the farmer is from the outset regarded as a potential expert (Röling, 2002). FFS approaches build on earlier anthropological interest in understanding farmer knowledge formation processes, especially through local experimentation (Richards, 1985).

A need to integrate local knowledge based on farmer experimentation with results from the formal research process has been advocated as essential to the development of a well-adapted technology for farmer conditions. Richards (1994) analysed the dynamics of farmer experimentation (be it intentional or unintentional) and defined the content of 'local knowledge' as the "knowledge that is in conformity with general scientific principles, but which, because it embodies place-specific experience, allows better assessments of risk factors in production decisions". "For local knowledge to be valuable in development there must be some way to judge its quality, and the quality of inferences drawn there from". This requirement for validation is no different from the normal criteria applied to test and judge any other scientific finding: replicability, peer critique, etc. (Richards, 1994). The integration of local knowledge within classical scientific research design is an essential approach in the Convergence of Sciences (CoS) research process.

CoS advocates co-research linking farmers and researchers, both to make use of farmer knowledge and also to ensure that discovery is focused on problems meaningful to farmers, the eventual clients for technology development. But before cooperative research can be undertaken it is first necessary to contextualize possible domains of application of the method. The actor-network theory suggests that actors in a research process enjoy considerable power to 'coerce' other elements to fit the vision. This applies as much to co-research with farmers as to conventional laboratory work. So considerable effort must be made at the outset to ensure this 'coercion' has defensible aims. CoS seeks to link problem definitions to real national and local needs, especially the kinds of poverty alleviation and food security aims encapsulated in the Millennium Development Goals. How can we ensure that problems chosen do relate to such needs and goals, and are not simply ambitions determined by the internal development of science, or the enthusiasms of a particular research team?

One answer is to make the pathways through which problems are approached open and transparent, and available to critical comment. The first step in the CoS process has been described as technographic survey. Technography is a word used by anthropologists of technology, and others, to describe in objective terms how actual technological systems operate, including paying attention not only to machines and techniques but also to institutional values and task-group organization and culture. Technographic survey – a rough sketch of a larger technological system in technographic terms – has been proposed as an initial tool of problem identification suited to further targeting of CoS activity (Richards, 2006).

Technography is used to describe the basic field within which technological interventions take place. Technography attempts to map the actors, processes and client groups in a such a way that the analyst can see beyond the technology itself to the problems technological applications are supposed to solve, and to understand what parties and interests are being mobilized in arriving at solutions. Technography aims at understanding how the elements combine with a focus on socio-technical systems. A socio-technical system has a distinctive culture, where the cultural elements need to be listed out and described. Technography considers the following general points: technological systems as designed and built by people embody purposes, and have social consequences. Socio-technical systems are hybrid, and understanding them requires us to address elements and interaction of elements (tools, machines, organisms, and social groups). Technography is methodologically plural, based on approaches deriving from physical science, bioscience, and social science (Richards, 2006).

In the larger CoS framework of which the present thesis is a part, technographic survey was used as a way of trying to grasp the general character of a national innovation system directed at the problems of food-insecure small farmers in Benin, with an objective of spotting opportunities to develop cooperative research activities. The results and consequences are briefly described below.

Convergence of Sciences as reflected in this thesis, takes into account not only farmer knowledge, but also the contribution of different bodies of knowledge and multiple actors around the research subject. In this convergent action research process, an interdisciplinary approach to scientific research and development is needed, bringing together expertise from the social sciences, economics and biological sciences (Beta-Gamma integration). In this context, a starting point is to take farmers as key actors in the knowledge-generation process, since they already carry out Beta-Gamma integration. No technical decision (e.g., to choose one crop variety over another) is made, by farmers, without this decision being affected by social and cultural considerations. This thesis begins from the point that farmer knowledge is a valuable knowledge, that deserves to be taken seriously in agricultural science.

Research process

The research proceeded through four different steps: technographic survey, a diagnostic study phase, an experimental research phase, and an evaluation and validation phase (Figure 1).

Phase 1: Technographic survey

This thesis takes its bearings from a technographic study. The technographic study served as a way of answering the question “how, at a national level is yam and cowpea diversity management and related technology development handled?”. Various actors (farmers, researchers, traders, consumers) were identified, and their interests and

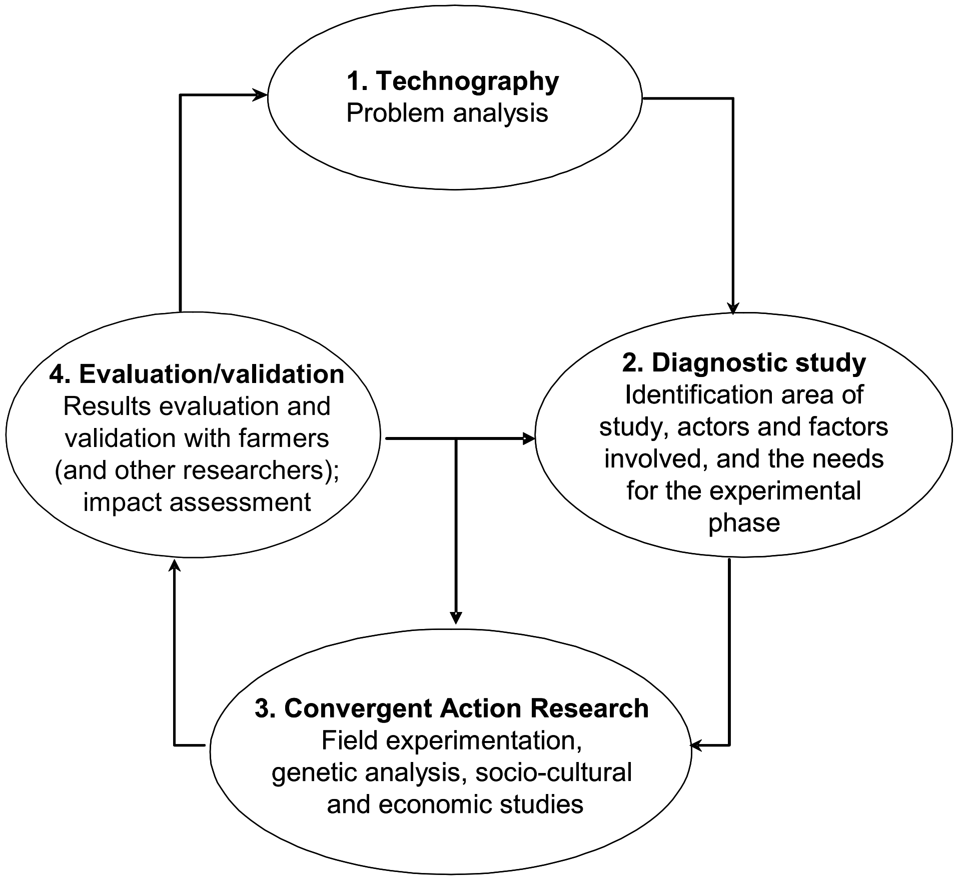

Figure 1. Overview of the research process in this thesis.

innovations sketched. During the field survey phase for the technographic study in Benin (Projet CoS, 2004) farmers drew attention to the non – adaptation of improved varieties to their preferences and consumers' preferences, which often resulted in the rejection of these varieties. Different consultations with researchers then confirmed the low adoption of improved varieties and the need to characterize the different traits and assess the potential diversity of little known local varieties. These needs fitted the national interest in sustainable agro-biodiversity use and maintenance.

Phase 2: Diagnostic study

The second step was a diagnostic study focused on the issue raised during technographic survey – how to close the gap between existing improved varieties and what farmers indicated they might really need. This led to detailed work on research problem definition and identification of analytical and experimental frameworks with farmers. The diagnostic study focused on the varietal diversity management by farmers in the Guinea-Sudan transition zone of Benin, shown (in the technographic phase) to be a major zone for the production of two major indigenous staples, yam and cowpea, where research efforts had seemingly had little impact. The purpose of this diagnostic study was to identify key factors influencing the level of diversity maintained by farmers, and to build from this farmer interaction a critical analytical frame for the in-depth research. The diagnostic study created a common understanding with potential farmer co-researchers and common ground for sharing knowledge on inter-disciplinary issues for in-depth research. The diagnostic study provided information on the various contexts vital to understanding how and why farmers' motivations change over time and how they proceed in the face of various constraints. The diagnostic phase set the research agenda for the in-depth phase of the research programme, by clearly identifying mutually acceptable topics for joint learning, and created mutual confidence between farmers and researchers necessary to handle the rigours of the experimental phases. The diagnostic study resulted in selecting four villages: two for yam (Yagbo and Kpakpaza in the district of Glazoué) and two for cowpea (Dani and Diho in the district Savé). Among these villages, Yagbo was selected as the experimental village for yam and Dani the experimental village for cowpea. Full details of this diagnostic study are presented in the following chapter.

Phase 3: Convergent action research

The third step was the implementation of the in-depth research and experimental phase, involving the different actors identified. The on-farm experimental phase was based on joint learning – i.e., it grew out of information on what factors farmers considered important, and on definite information about how farmers managed different agronomic and genetic variety traits.

Joint experimental research process

The joint experimental research process went through an interactive farmer-researcher research design phase. Farmer-researcher managed trials were set up for yam in Yagbo village and for cowpea in Dani. Joint researcher-farmer characterizations were made on these fields. This step comprised both varietal characterization and participatory technology development. The following bullet points sum up the main components of the experimental phase.

- *Collection of yam and cowpea planting materials* Plant materials (of yam and cowpea) were collected in the Guinea-Sudan transition zone of Benin. These materials were used for the participatory characterization, using morphological descriptions, agronomic analysis and molecular tools.
- *Participatory varietal characterization* Morphological and agronomic characterizations were performed through joint observation and measurement of yam and cowpea plant characteristics. Analyses were performed to define the patterns of

variation among the varieties, based on the agronomic, phenological, and morphological traits.

- *Participatory technology development* For the participatory technology development, seed tubers of contrasting yam varieties were stored under different conditions, to study the breaking of post-harvest dormancy (a problem farmers indicated was of central significance to them). Seed tuber performance after storage was evaluated with farmers. Different tuber parts (proximal, medium, distal) were also tested for their ability to produce vigorous sprouts, and thus emerged plants.
- *Genetic characterization* To highlight genetic diversity, and bring out the untapped potential of local diversity, a molecular analysis was conducted on farmer varieties. The diversity based on this molecular analysis was compared with the diversity assessed with the morphological and agronomic characterization.

Socio-cultural, market and consumer studies

- *Socio-cultural analysis* Emphasis was also put on the role diversity of crops played in the social and cultural identity of the group to which farmers belong. Farmer participants made clear that the two crops were highly embedded within their cultural and religious value systems. Within each community and for each divinity, crop and food-related religious and cultural factors were assessed, to place particular varieties in the context of local traditions, food habits, ritual ceremonies, and religious festivals.
- *Market and consumer studies* Yam and cowpea varieties are sold on local markets and on a large scale on the regional market of Glazoué in the central region of the Benin, the area of this thesis research. Yam and cowpea varieties sold on these markets come mainly from local villages. Producers, traders and consumers in the area recognized as experts on variety characteristics, since their buying decisions constantly evaluate the preferred characteristics of different farmer-named varieties, and these evaluations are reflected in local pricing structures. In this thesis traders are treated as being as much experts on local varieties as are farmers. Price data of five years were collected on these varieties sold on the regional market were analysed in detail to bring out the structure of traders and consumers' preferences.

On-farm surveys on farmer diversity management and on farmer own experimentation

- In order to compare different strategies of on-farm diversity management, complementary studies were conducted in the four villages. The main aim of these studies was to bring out how farmers manage different agronomic aspects and the different factors that determine the choices farmers usually make.
- It became clear during the diagnostic phase that it would be necessary during the

research process to study in depth a lively local experimental culture which owes little or nothing to formal models or outside influences – namely the issue of how farmers undertake the continuous domestication of wild yam materials to produce a steady stream of new domesticates. Locally, this knowledge tends to be looked down as an activity of the very poor (for those with money it is much easier to buy planting material on the open market). This thesis tries to bring out that CoS cooperative research with farmers in Benin builds on an important local tradition of 'people's science' (Richards, 1985), and that this tradition should now be given much greater respect (locally, as well as internationally).

Phase 4: Evaluation and validation

Evaluation for CoS activity is two-fold. First the products of co-research must pass the test of scientific accreditation (i.e., the data must be publishable according to the criteria of scientific peer review). But second (an equally important) validation of the results must take place with farmers, and there should be some attempt to assess the impact of CoS activity on the livelihood of farmers from the learning group, and in the community more generally. This is, of course, a longer term process, and cannot be concluded within the space allocated to the production of the present thesis. But a foundation has been laid for follow-up. How farmers evaluated findings is discussed, and some attempt was made to apply a social capital framework to knowledge gains and livelihood improvement. Through the evaluation, new research hypotheses and new areas of interests for farmers emerged, upon which future CoS type activities might build.

CHAPTER 3

Yam and cowpea diversity management by farmers in the Guinea-Sudan transition zone of Benin*

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Abstract

The maintenance and utilization of crop genetic diversity is important to ensure food security. The relative importance of yam and cowpea cultivars and the influence of the socio-cultural and local economy context on the diversity maintained were analysed in Benin. Whereas the diversity is large, some varieties were rare, other ones on the way of being abandoned or already lost. Socio-cultural as well as economic and agronomic characteristics explained why some of them were still maintained. For example, the early maturing yam variety Laboko was planted by most farmers to have roots available in time for religious purposes. Some specific cowpea varieties played a role in the funeral of the parents in law. Farmers' preferences were translated into criteria they use to appreciate cultivars. The diversity of the varieties sold on the market and their availability over time reflect farmers' strategies and conservation practices. The large price differences between varieties confirm the variation in quality as perceived by consumers. The most widely grown yam variety, Florido, is available on the market throughout the year but has a very low price. Market price differences among cowpea varieties are much smaller than those of yam varieties. The processes of loss and replacement of some local varieties are described and the need for conservation is addressed. Different factors that may influence the level of the varietal diversity in these crops, such as the need to synchronize harvesting with the high market prices, were analysed in depth. As opposed to mono-disciplinary approaches to farmers' problems and constraints, farmers show an inter- or trans-disciplinary behaviour and express their preferences through multi-criteria processes.

Keywords: *In situ* conservation, farmer varieties, agro-biodiversity, *Dioscorea* spp., *Vigna unguiculata*, seed systems, market preferences, research institutions, learning process.

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Introduction

The conservation and utilization of crop genetic diversity are important to ensure food security and food sovereignty. Until now, there is limited knowledge on how farmers manage this diversity in yam (*Dioscorea* spp.) and cowpea (*Vigna unguiculata* (L.) Walp) in Benin and how they make decisions relating to this issue. Often, new varieties from research programmes are not adapted to the various local conditions and therefore do not satisfy farmers' needs. The reason for this is that the perceptions of various stakeholders, including the farmers, have largely been excluded from the process of cultivar development. To overcome this problem an innovative research approach has to be designed that maps all actors and stakeholders around a technology (in this case cultivar development) and combines all their knowledge. We therefore conducted a diagnostic study on yam and cowpea diversity management in Benin. The study aimed at understanding the varietal diversity management practices by farmers and, implicitly, creating a method and a space of dialogue between farmers, researchers, extensionists for participatory technology development and sustainable conservation and use of genetic resources.

Yam is a major root crop and cowpea is a major grain legume crop in Benin, where both crops constitute an important part in the daily diet for millions of people. Yam has important socio-cultural and religious values in Benin. Yam cultivars in Benin belong to several plant species, mostly to *Dioscorea cayenensis – Dioscorea rotundata, D. alata,* and *D. dumetorum. D. cayenensis* and *D. rotundata* are considered a complex of two species morphologically and genetically polymorph of the 'white yam' (*D. rotundata*) and the 'yellow yam' (*D. cayenensis*) (Terauchi *et al*., 1992; Zoundjihékpon, 1993).

Research institutions such as the International Institute of Tropical Agriculture (IITA) (Akoroda, 1998) showed the interest of introducing improved varieties they developed hoping that farmers would adopt them. For yam, most of the successful development of new varieties remains the work of farmers in Benin. Seeing that yam cultivation is highly devastating forests and fertile lands, the Research-Development team of the National Agricultural Institute of Benin (INRAB) introduced the exotic yam variety *D. alata* cv. Florido into the farming systems of the central part of Benin in 1989, hoping that farmers would reduce or stop clearing new fertile forest lands by adopting that high-yielding variety (Roesch, 1992). The *D. alata* varieties originate from South-East Asia (Aké Assi, 1998).

Benin is also one of the important cowpea growing countries in West and Central Africa (Singh *et al.,* 1997). Cowpea is cultivated for its grains and young leaves, but is also used as forage. IITA developed improved cowpea materials and new germplasm lines and distributed them over the country (Singh *et al*., 1997; Agli *et al*., 2001). The

INRAB research programmes released several improved, high-yielding cowpea varieties, but these varieties did not perform well on farm (Anon., 1999, 2001).

The current situation for both crops is that there is a wide diversity of local varieties. However, their yields are low and consequently there is a large pressure on land use. Introductions of new varieties by formal institutions may not be successful when these varieties have been tested under much higher levels of soil fertility than common in subsistence farming. Moreover, in the case of yam, the new varieties, requiring high soil fertility and producing large roots, may taste poorly and their seed roots cannot be stored very well. Consequently, new introductions may be unsuccessful. It is therefore necessary to analyse the farmers' preferences. Thus, the specific objectives of this study were:

- To identify and characterize the diversity of yam and cowpea in the farming systems;
- To discuss the level and impact of adoption of new varieties released from research institutions;
- To identify how the diversity of these two crops is managed.

This chapter presents the methodology followed to conduct this study and the local realities of yam and cowpea diversity management. It also analyses the different socio-cultural, economic and agronomic factors playing a role in this diversity management, and assesses specific objectives and research needs for the analytical phase of the research programme to be carried out later.

Materials and methods

The diagnostic study focused on the management of the diversity by the farmers and the views of farmers on the important characteristics, given different ethnic backgrounds, different levels of land pressure and different levels of institutional intervention. Studies on both crops included a preliminary study and an in-depth study in different villages. The location of these villages is indicated in the map (Figure 1).

Villages of study

Criteria that have been used to select villages, included extent of yam and cowpea production, the presence of research or level of intervention, land pressure, proximity to regional market, and ethnicity. For the preliminary study on yam, Ouèdèmè and Yagbo in the Glazoué district were selected. The choice of these two villages for the yam study was based on the fact that during the initial interviews with the farmers of Ouèdèmè, the farmers stated that they did not have any more yam land in Ouèdèmè and they had to search for appropriate land in or towards Yagbo. The dominant ethnic group of Ouèdèmè and Yagbo, however, is Mahi-Fon. Consequently, for the in-depth

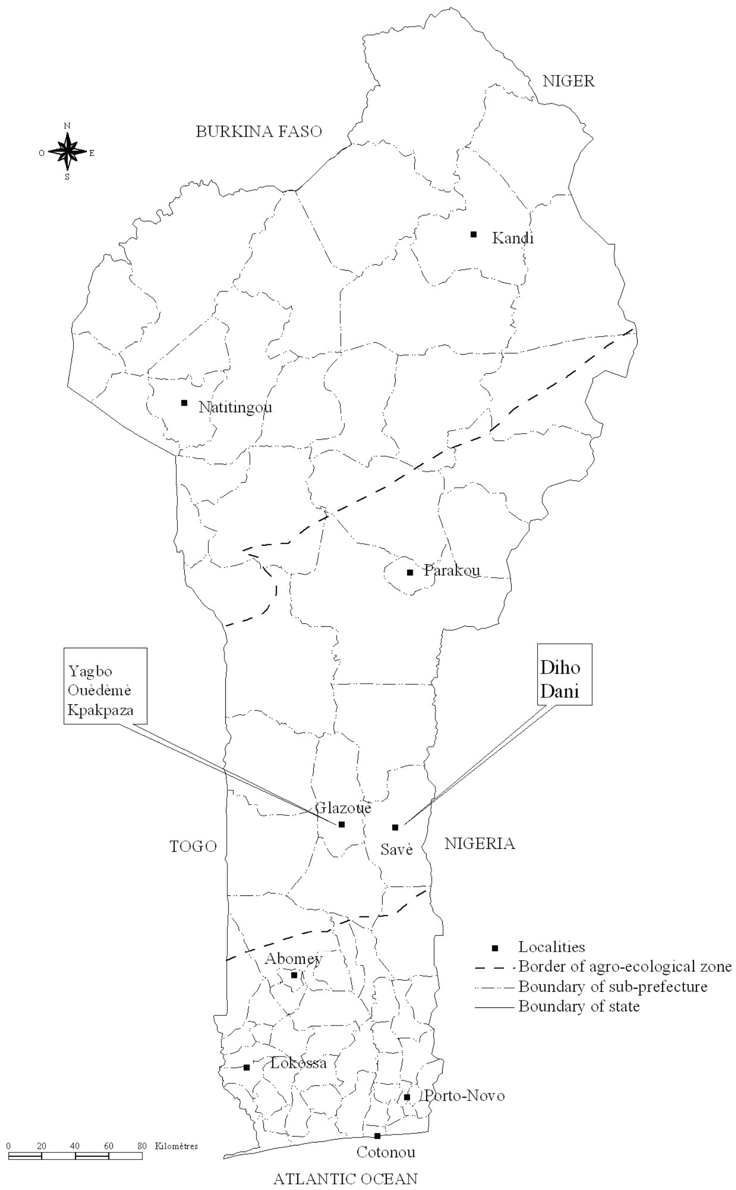

Figure 1. Map of Benin showing the location of the villages of study.

phase, we replaced Ouèdèmè by Kpakpaza. Kpakpaza is dominantly Idatcha and characterized by higher levels of land degradation and institutional intervention on the crop. The main features of these villages are described in the Table 1.

For the preliminary cowpea study, the Dani village of the Savè district was selected. Farmers of Dani developed an interest in cowpea production and technology development and in participating in projects. Dani benefited from interventions such as varietal introduction, use of chemical and botanical pesticides from NGOs, and projects on introduction of varieties and technologies. The in-depth phase was conducted in Dani and Diho villages. The characteristics of these villages are listed in Table 1.

Table 1. Characteristics of the villages where in-depth research was conducted on yam and cowpea.

Characteristic	Yam farming system		Cowpea farming system	
	Kpakpaza	Yagbo	Diho	Dani
Location to district centre (km)	6	30	4	8
Dominant ethnic population group	Idatcha	Mahi	Tchabè	Idatcha
Land colonization	Old	Recent	Old	Recent
Land pressure / degradation	High	Low but increasing	Low but increasing	High
Level of institutional intervention in the crop	High	Low	Low	High

All selected villages lie in the transitional climatic Guinea-Sudan zone between 7° and 10° N latitude. The annual rainfall varies between 1100 mm and 1200 mm. The natural vegetation is mainly an arborous savannah. The average monthly minimum temperature is 22 °C. The average monthly maximum is 32.8 °C (unpublished data from ASECNA-Benin on the years 1960 to 1997 of the Station of Savè). The yearly average relative humidity is 60%.

Choice of farmers and data collection

In each of the three villages, a list of farmers producing the targeted crop was obtained with the help of the village chief and advisors. For the preliminary study, 10 farmers in Ouèdèmè, Yagbo and Dani, and 15 farmers in Kpakpaza and Diho were randomly selected from the list to analyse the place of the crops in the local economy through a pair-wise comparison. During the in-depth phase, 40 farmers were selected in each of the four villages (Yagbo, Kpakpaza, Dani and Diho) to analyse the importance of diversity they hold. Individual and group discussions, field visits and questionnaires were used for data collection. Key informants and stakeholders were also consulted.

Through focus group discussions and also through individual discussions with the different ethnic groups in Yagbo and Kpakpaza for yam, 26 different criteria were identified to appreciate farmer's selection and preference. Also for cowpea in Dani and Diho, 24 different criteria were identified to appreciate farmers' selection and preference. These criteria were submitted to the evaluation by 20 farmers (10 men and 10 women) in each of the four villages.

Through recurrent discussions, we reiterated our engagement to ground the research on farmers' knowledge and preferences. Our relationship with the farmers developed into a sort of contract based on mutual benefit. Such contracts with farmers appear as pre-requisites for joint learning and platform generation and form the frames on which the research trials and activities are developed.

Socio-cultural survey

The objective of this survey was to provide a good understanding of the relationships between the culture of the ethnic communities of the villages under study and the maintenance of the varietal diversity in their farming systems. So in addition to individual and group discussions with the ethnic group communities in the village under study, it was necessary to go and discuss with other members of the particular community in other villages where some rituals usually take place.

Market choice and data collection

The regional market of Glazoué was selected to appreciate the market dynamics and the diversity management within the area. The prices of the different varieties of the crops (yam, cowpea) sold on this market were regularly collected. This paper presents the data collected from January to July 2003. The beginning of this period coincides with the time when all yam varieties have reached maturity and can be harvested and sold at the market; it ends with the time when all harvested yam varieties become scarce in the farming systems and the first newly harvested variety (Laboko) appears on the market. So this period gives a good picture of the level of yam diversity sold on the market and the development of the price over a whole cycle of market availability. This period also provides the range of cowpea varieties that are sold on the market. In June, the early-maturing cowpea varieties grown during the first rainy season appear on the market.

Analysis of data

The pair-wise ranking method (Russell, 1997) was used to analyse the position of yam and cowpea in the local economy. A matrix table of all crops grown in each village was constructed. Farmers were asked to compare each of the crops to the other ones with regards to the values (consumption, market, cultural, etc.) and the priority each farmer gives to the crop. Each crop was compared in turn with each of the other crops. The process was repeated for all crops until all possible comparisons had been made. The number of times each crop was found to be more important was counted for each individual farmer. This value represents the individual score for each crop. An aggregation was then realized on the scores for each crop over the farmers participating in the exercise. This aggregated score represents the village score. The ranking of these scores provides the position of the crop in the local economy. The same process was applied to criteria farmers consider for variety choice in the four villages (Yagbo, Kpakpaza, Dani and Diho).

Frequency distributions were used to analyse the variety diversity held per farmer and the area share of each crop variety. The local taxonomy, name and meaning, was used to identify each crop variety. The Spearman's rank correlation test was used to test the consistency of farmer ranking of criteria of selection and preference. The market prices of each variety were analysed for each month over the period January – July.

Results and analysis

Local realities of yam diversity management

Yam production area, diversity and constraints

The pair-wise comparison of crops by farmers in Ouèdèmè and Yagbo showed that yam took the second place after maize in Ouèdèmè and the fourth in Yagbo in the local economy (Table 2). The farmer's logic behind this result is that even if the diversity in yam enables farmers to have their needs gradually satisfied over different periods of the year, there is a period of yam scarcity (from April to the middle of July). During this period, farmers lack yams used as pounded yams. In contrast, maize can be consumed and conserved during the whole year.

Table 2. Crops and their rankings on the basis of pair-wise comparisons by 10 farmers in the villages Ouèdèmè, Yagbo, and Dani, and by 15 farmers in Kpakpaza and Diho.

Crop	Ouèdèmè	Yagbo	Kpakpaza	Dani	Diho
Maize	1	1	1	2	1
Yam	2	4	2	-	5
Cashew	3	2	-	1	2
Rice	4	7	3	8	10
Cassava	5	3	4	2	8
Cowpea	6	5	7	5	3
Pepper	7	10	9	10	4
Cotton	8	-	-	-	-
Onion	9	-	-	-	-
Sorghum	10	-	-	-	9
Groundnut	10	8	6	4	6
Soya	-	5	5	7	-
Egoussi	-	9	10	8	7
Bambara groundnut	-	-	8	6	-

In Yagbo and Kpakpaza, Figures 2 and 3 show the relative importance of yam varieties in the farming systems in these villages. In Yagbo, more than 50% of the farmers cultivated Laboko, Anago, Ala N'Kodjéwé, Kokoro and Florido. Considering the total cultivated area, Florido is the dominating variety. The mean area cultivated for each variety is about 0.90 ha (SE=0.27). However, most of the cultivated varieties are held on little area. In Yagbo, 75% of the varieties occupied only 14% of the total area cropped to yam (Figure 2). In Kpakpaza, Laboko is cultivated by most farmers. It is followed by Gnidou and Florido. Florido, Gnidou, and Laboko were grown at the largest scale and occupied 6.25, 5.95, and 4.53 ha, respectively (Figure 3). On average, each variety occupied 1.56 ha (SE=0.52). However, 75% of the varieties occupied only 25% of the total area cropped to yam.

In Yagbo, on average one farmer held 6.4 (SE=0.39) varieties. Some farmers held up to 13 varieties at once (Figure 6). In Kpakpaza, on average, one farmer held and grew 4.5 (SE=0.26) varieties. Some farmers grew up to 8 varieties.

The only way new varieties from a formal system are introduced is from international organizations such as IITA. Based on extensive discussions with researchers testing yam varieties, extension workers and farmers, it became apparent that these new introductions are generally useless. They state that the main constraints to yam production are that it is highly demanding in labour and fertile land, while the

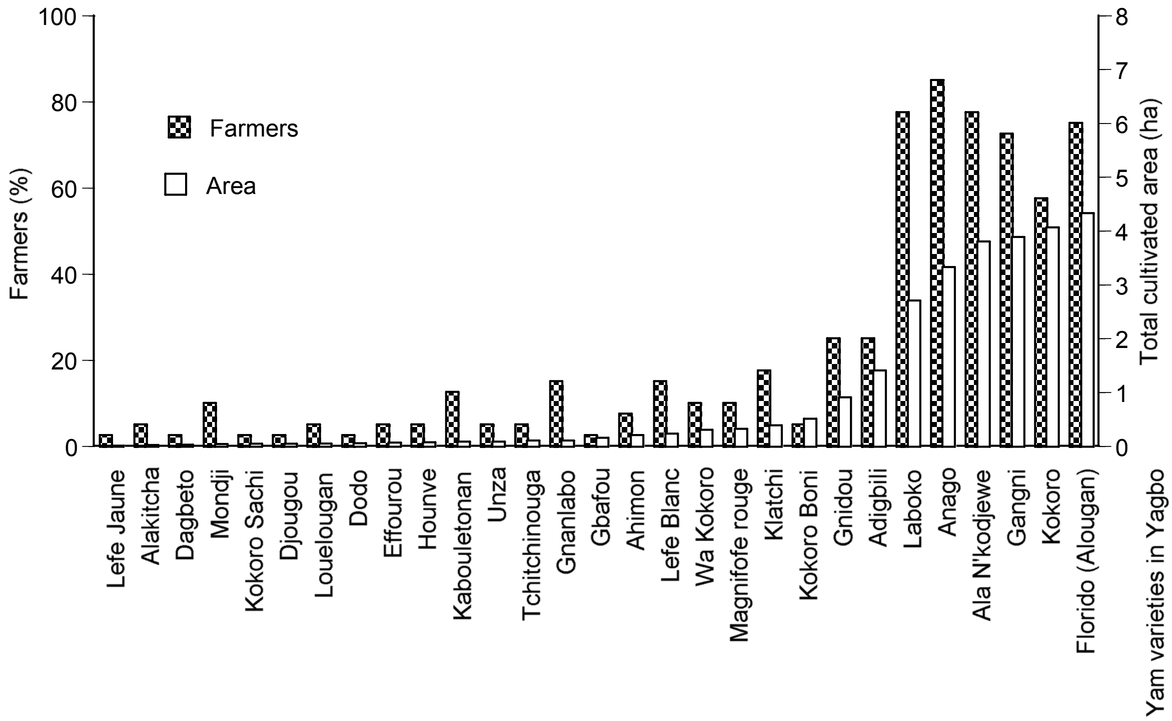

Figure 2. Yam varieties, total cultivated area per variety and proportion of farmers (n=40) growing a particular variety in Yagbo.

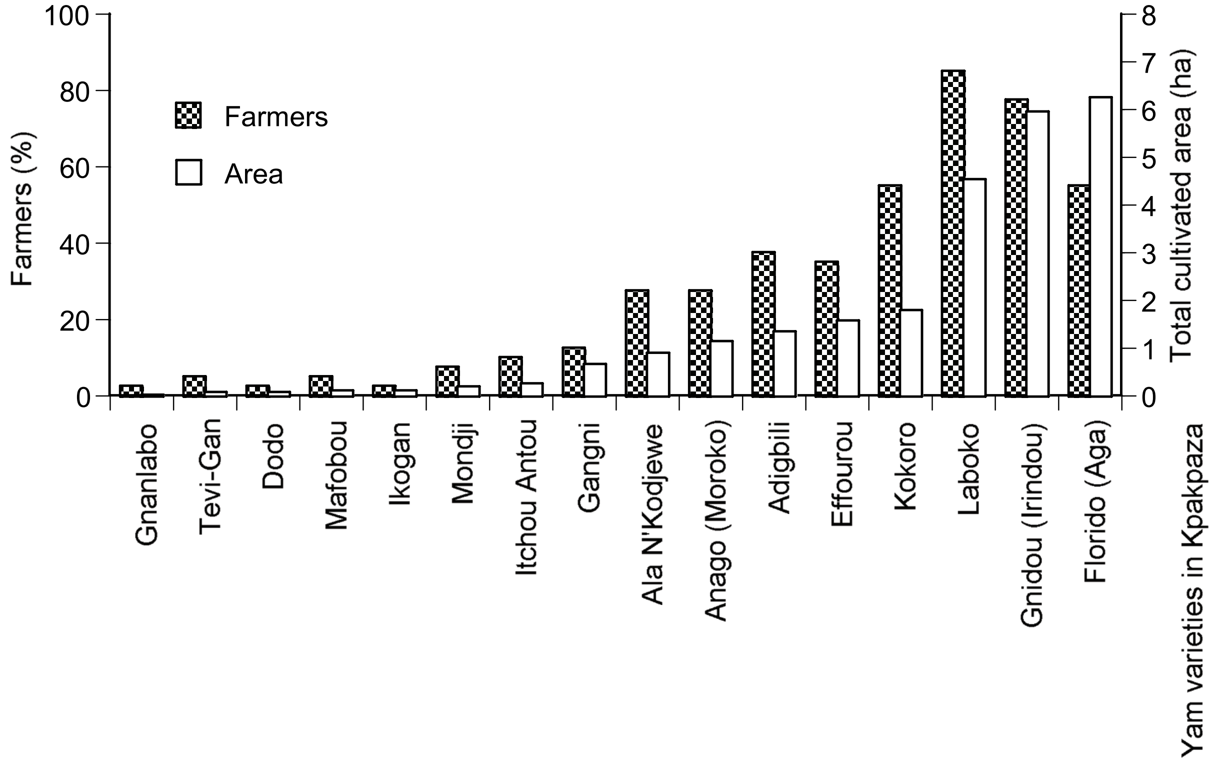

Figure 3. Yam varieties, total cultivated area per variety and proportion of farmers (n=40) growing a particular variety in Kpakpaza.

use of inorganic fertilizer reduces the quality of the pounded yam and contributes to the loss of the organoleptic quality, factors that farmers usually consider important in yam diversity management. In fact, while the first harvest of the early-maturing varieties satisfies farmers' food needs after the long period of scarcity, the second harvest only serves to collect seed roots for the next planting period. So it is necessary for farmers to plant the late-maturing varieties to ensure food security during the dry season. Late-maturing crops are only harvested once, with the large roots being used for consumption and the small ones as seed roots for the next crop. Farmers choose their varieties in taking into account factors that may significantly influence not only the yield, but also their management practices (time for planting, conditions and duration of the storage, seed practices, the availability of seed roots and roots for consumption and sales) over the whole year. Farmers define their objectives in selecting and maintaining the different types (two harvests for early-maturing and one harvest for late-maturing) and the number of varieties that ensures the food security in the household through the year.

Several constraints contributed to the reduction of the diversity. These include: climatic and agricultural risks, the high costs of seed roots, loss of varieties, lack of fertile land, and reduction of labour capacity of the farmer.

Yam domestication knowledge

Yam domestication is a farmer'-managed process of transforming wild yam genotypes into cultivated varieties and maintaining these new domesticated varieties in the farming systems. Yam domestication is based on farmer's knowledge and increases the level of diversity we may find at farmer level. Farmers of Kpakpaza and Yagbo are experienced in domesticating yam. Farmers state that the duration of the domestication process varies from 3 to 5 years. During this process, farmers try to transform the thin shaped root of the wild variety into a big rounded one that does not sink deeply into the soil. To maintain the size of the variety of the process at the desired level, farmers use obstacles as pieces of pottery in the mound. During the same process of domestication, the water content and the taste change. In Kpakpaza, the variety *Itchou Antou* is an example of a successful domestication process managed by a farmer, called Antoine, 34 years ago. In Yagbo, 12 farmers were identified who have been involved in the domestication process. Eight of them continue practising it; two abandoned it because of having enough varieties, and two abandoned it because the result was not successful.

The variety Ala is obtained by 50% of these domesticator farmers, Laboko (33%), Anago (16%), Mondji and Kaboulètonan (8%); 16% of the farmers obtained varieties to which they have not given a name. Considering the fact that domestication usually results in varieties resembling the well-known varieties, farmers of Yagbo village raised the question whether the wild yams are really wild or have been the results of an evolutionary process transforming cultivated varieties into wild ones. They supported this hypothesis by the fact that their ancestors would have cultivated in that area in the old time.

The existence of forest reserves is important for *in situ* conservation of wild yams. The ecological difference between Kpakpaza and Yagbo for the domestication practice is that in Yagbo there are reserves of forest and bush from where farmers access easily to wild yams.

Socio-cultural values and farmers' preferences

In the Mahi-fon socio-cultural communities where this diagnostic study was undertaken on yam, the term 'alougan' represents the species *D. alata*. Alougan means 'the king of the dry season period'. The complex of species *D. cayenensis* – *D. rotundata* is named 'tévi'. These local names help scientists and also farmers to easily identify the characteristics of the landraces. Tévi is domesticated from the wild yams *D. abyssinica* and *D. praehensilis* by West African farmers since the beginning of agriculture in the region.

Yam is used for several types of food: pounded, prepared, peeled and dried yam, and 'wassa-wassa'. The varietal diversity responds to these diverse needs.

Yam diversity satisfies several religious and healing values. In the Mahi ethnic community each household believing in divinities has the obligation to give the first harvest of yam as food to their divinities (locally called 'fâ', 'vodouns', twins) and to their ancestors having protected the household and the community during the whole year. The fâ officiating priest ('bokonon') is consulted at any occasion when a member of the family is in difficulties on what to do to overcome these difficulties. To satisfy this obligation, each household has to plant the early-maturing yam variety Laboko. From 14 July, as soon as each variety reaches its physiological maturity and is suitable for pounded yams, it is harvested to satisfy this ritual obligation each year. Eating pounded yams is part of the culture in several communities in the area of study. Within the Mahi community, it has become the tradition that all progenitors of this community meet each year to celebrate a festival of eating the first harvest of pounded yams each 15th of August. This festival is also an occasion for policy-makers to meet and express their attachment to the large community Mahi. In the Idatcha community, planting different early-maturing and pounded yams plays another protecting role. In fact, there are some risks of insecurity related to yam agricultural practices. During harvesting or the evaluation of the seed roots stored under branches or leaves for planting, the risks of being attacked by snakes and scorpions are very high. Kokoti plays the role of convent of preventive or curative treatment in Kpakpaza. During the ceremony of Kokoti, the pounded yam varieties Laboko, Gangni and Mondji are accepted. Kokoro and Dodo are not used. As long as this ceremony has not taken place, the chief of Kokoti cannot eat pounded yam at the risk to shatter the beneficial effect of Kokoti. During the ceremony of Kokoti, each household in the community has the obligation to harvest from the field the yam to offer to Kokoti on the day of the ceremony. That principle makes it necessary for each household of that community to plant those varieties.

When a farmer starts to become interested in yam production, from year to year, (s)he progressively acquires and increases the quantity of seed roots that (s)he is able to plant. So having sufficient seed roots for planting is seen as constituting a patrimony of yam seed. The constitution of this patrimony of yam seed involves developing a social relation through social networks. These comprise the parental relations: one can have it as inheritance or gifts from his father, mother or uncle. Some friends exchange seed roots among themselves or can have it as a gift or purchase from one to another. The exchange of the seed material goes also through labour relations between farmers of different communities within the same village, between villages, regions or countries.

Farmers have very specific preferences for yam varieties; the ranking of the relevance of the different characteristics is consistent (Spearman test: $r=0.88$) for the two villages investigated (Table 3). Adaptation to soil fertility, resistance to abiotic and biotic stresses, the earliness, the possibility to store and pound the roots and the market price are the most important characteristics determining the choice of a specific variety.

Table 3. Criteria for keeping yam varieties in Yagbo and Kpakpaza and their rankings on the basis of pair-wise comparisons by farmers.

Criterion	Yagbo (n=20)		Kpakpaza (n=20)	
	Total score	Ranking	Total score	Ranking
Adaptation to poor soils	402	1	354	5
Resistance to pests and diseases	391	2	339	7
Market value	387	3	353	6
Earliness	383	4	400	2
Ability to be pounded	382	5	329	8
Number of harvests per year	366	6	368	4
Rate of emergence	366	6	318	9
Storability	351	8	407	1
Resistance to heat and drought	339	9	392	3
Speed of emergence (days after planting)	338	10	299	10
Weight of individual root	281	11	232	15
Ability to be boiled (taste)	264	12	224	16
Ability to be transformed into ‘cossettes’	264	12	174	19
Easiness to harvest (less labour and less breaks)	210	14	286	11
Period of harvest	199	15	261	13
Number of roots per plant	194	16	242	14
Healing value	187	17	270	12
Root size	173	18	174	19
Ability to be fried	171	19	175	18
Need for large mounds	149	20	137	22
Need for large planting material	143	21	160	21
Root length	135	22	107	24
Colour of root flesh	124	23	117	23
Smoothness of the root skin	113	24	94	25
Need for care during growing season	99	25	214	17
Non-forking of roots	89	26	74	26

Spearman rank correlation coefficient: r = 0.88** (*P*=0.01).

Dominance of the D. alata *cv. Florido in the farming systems*
While the *D. alata* cv. Florido (Alougan from Côte d'Ivoire) became very popular, the local *D. alata* cvs Landou, Hounvè and Sonouko were abandoned. None of the respondents cultivated them anymore. Discussions with farmers provided information on the determinant factors for maintaining the *D. alata* cv. Florido in their farming systems. In general, in the area of study, if a forest or fallow land is cleared, yam is the first crop to be installed as it is demanding highly fertile land. By contrast, from the discussions with farmers, Florido is adapted to all kinds of ecology and mainly to poor soils. Florido can be cultivated on a land after successive cultivation of other crops. Florido has a high reproductive capacity and can be grown on several types of mounds (small, medium, big). It is less demanding in propagation material as any part of the root can be used. It is also characterized by a relatively high rate of emergence after planting. Florido is also adapted to all farming systems in which inorganic fertilizers are applied, mainly the cotton farming systems. The harvest also appears relatively easy to farmers and the product can be stored for a relatively long period. Its current dominance on the regional market of Glazoué is remarkable (75 to 98% of yam volume sold).

Local realities of cowpea varieties choice by farmers

Cowpea production area, diversity and constraints
In the local economy in Dani, cowpea is both a food and a cash crop. Cowpea occupied the fifth position after cashew, cassava, maize, and groundnut based on the pair-wise comparison (Table 2).

In Dani, more than 50% of the farmers cultivated the cowpea varieties Tawa gros grain and Moussa. These two varieties were grown at the largest scale, 12.3 and 12.2 ha, respectively (Figure 4). However, 75% of all varieties were grown on less than 25% of the total area cropped to cowpea. On average, farmers cultivated 2.85 (SE=0.23) varieties at once (Figure 7). There were farmers who cultivated up to 8 varieties.

In Diho, the varieties Tawa gros grain and Mata were cultivated by 80 and 40% of the farmers respectively (Figure 5). The other varieties representing 77% of the cultivated varieties were grown at the smallest scale (29% of the total cultivated land). On average, one farmer held 1.7 (SE=0.17) varieties at once (Figure 7). There were farmers who grew up to four varieties.

In these two villages, the varieties grown included early-maturing and late-maturing varieties. The late-maturing varieties were Atama, Djètoko, Egniawo, Moussa, and Mata.

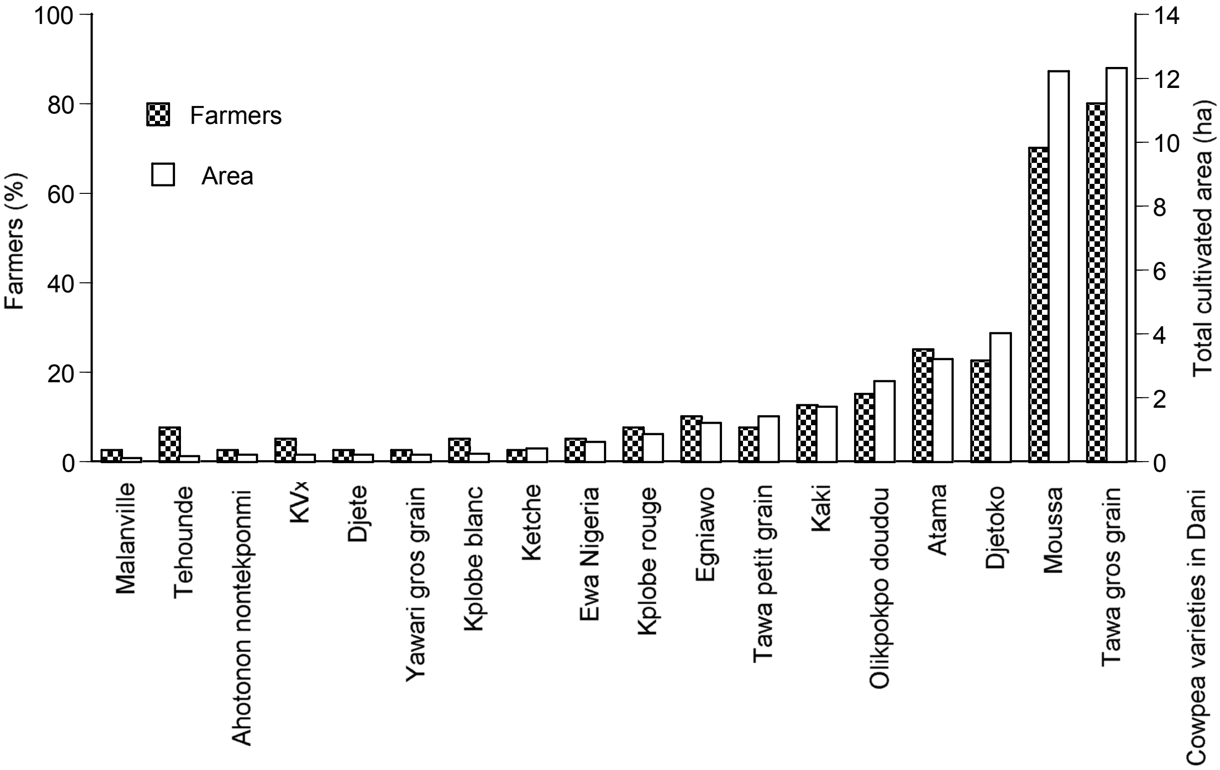

Figure 4. Cowpea varieties, total cultivated area per variety and proportion of farmers (n=40) growing a particular variety in Dani.

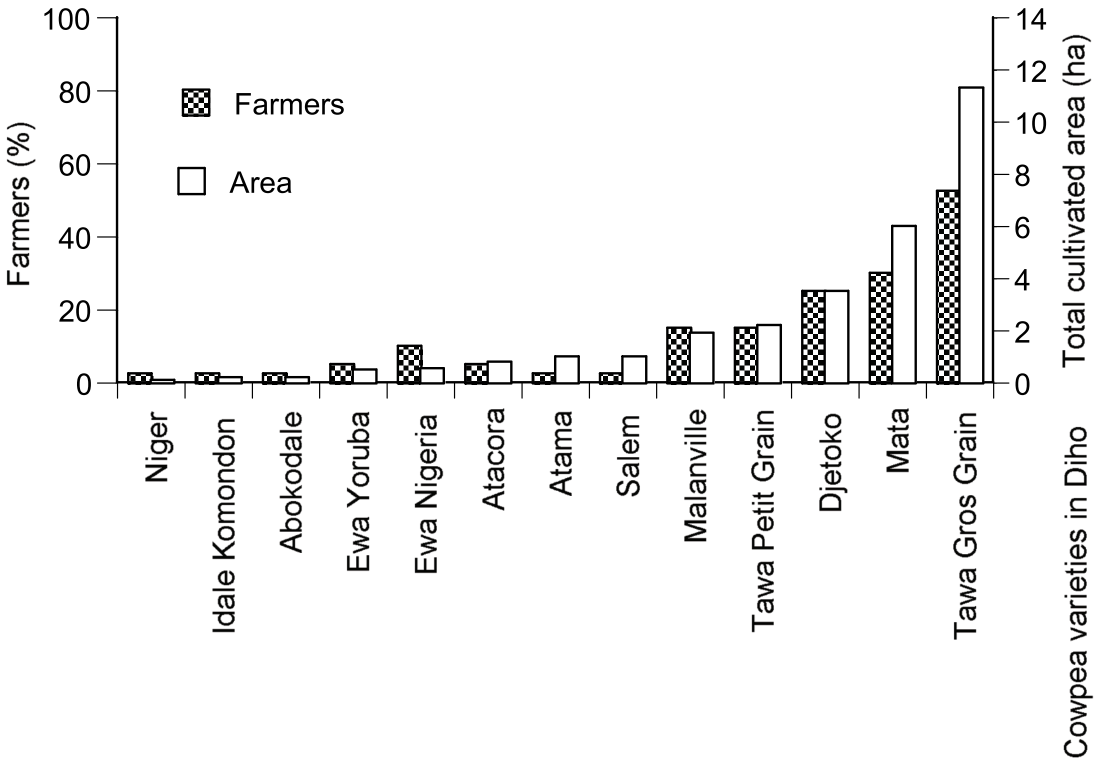

Figure 5. Cowpea varieties, total cultivated area per variety and proportion of farmers (n=40) growing a particular variety in Diho.

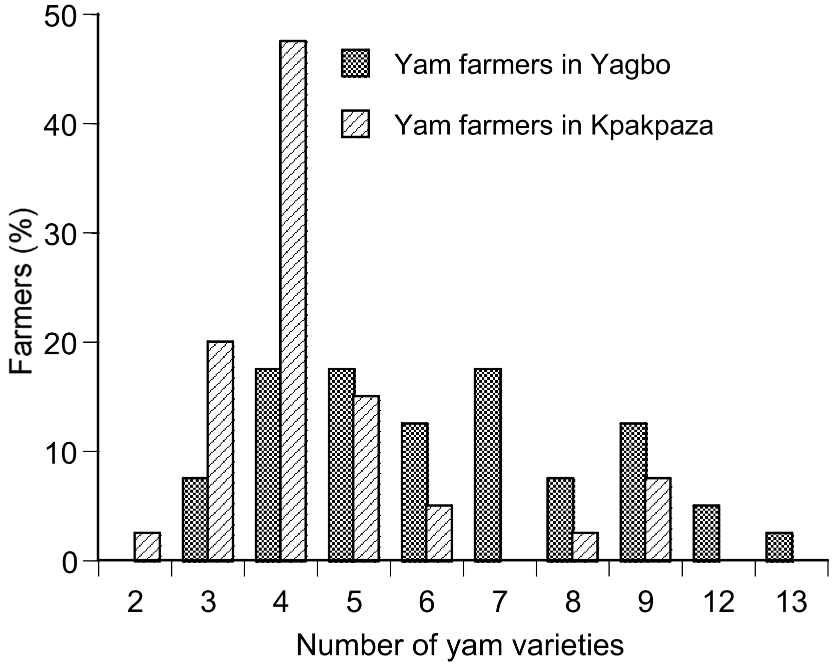

Figure 6. Percentage of farmers in Yagbo (n=40) and in Kpakpaza (n=40) growing 2, 3, up to 13 yam varieties.

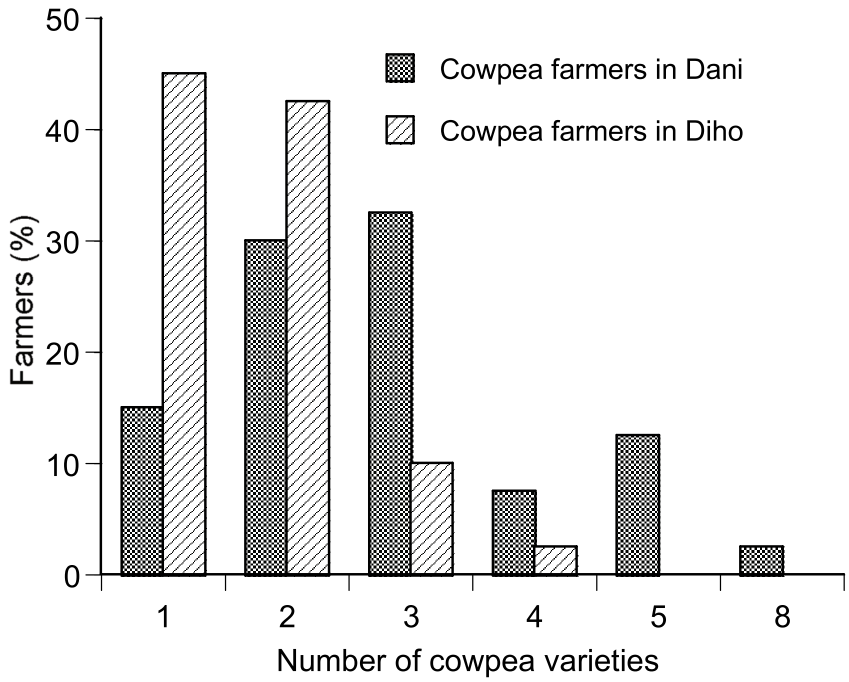

Figure 7. Percentage of farmers in Dani (n=40) and in Diho (n=40) growing 1, 2, up to 8 cowpea varieties.

Socio-cultural values and farmers' preferences

Apart from its market value, cowpea is grown for several uses: cooked *abobo*, cake (*ata* or *ikra*), or doughnuts (*abla*, *ihayahaya*, *adjabla*, *tchohounbo*, *lèlè*). It is also used as organic fertilizer. Its tender leaves used to serve as vegetable for human consumption, whereas the foliage and hays were used to feed animals. Nowadays these uses are no longer common because of the massive use of pesticides for plant protection.

Atama and Djètoko are said to be local varieties. They are used for the funeral of the parents in law. Kpohoundjo develops a lot of leaves and is used as green manure. Tawa is appreciated for the preparation of *doko* because its hilum is white, without any mark. Atama, Djètoko, Egniawo, Téhoundé, Moussa, and Kpohoundjo are appreciated for cowpea doughnuts because the grains are very big and provide a good mixture with flour maize or cassava. The local variety Mata has a high healing value. In Diho village, farmers use that variety on abscesses and on the sickness caused by the Guinea worm (*Dracunculus medinensis*).

Farmers use cowpea seeds from different sources for new planting. Farmers usually take them from the previous harvest or buy them from the market. Other farmers use their social relations in having some seeds from their relatives or friends.

Farmers have very specific preferences for cowpea varieties; the ranking of the relevance of the different characteristics is consistent (Spearman test: r=0.86) for the two villages investigated (Table 4). Above all, the harvest and post-harvest characteristics of cowpea varieties are relevant in addition to yield, resistance to pests and diseases and healing value.

Farmers in Dani indicated that most of the introduced improved varieties are highly susceptible to pests and diseases during production and to post-harvest pests. Nowadays, the local varieties are not any more excluded from the resurgence of these pests and diseases. An analysis of the situation reveals that the compulsory use of chemical pesticides on cowpea is inherently linked to the recent development of cotton pests for which there has been a heavy use of pesticides. Many insect pests may recently have shifted from cotton to cowpea, as the pesticide use is heavy in cotton fields. It is also observed that cowpea fields are adjacent to cotton fields. This proximity of cotton and cowpea fields can be a factor that increases the impact of pests from cotton to cowpea. The pesticides advised for cowpea by extensionists are not within reach of these farmers. IITA advised farmers of Dani to apply botanical pesticides on cowpea. But farmers realized that the use of botanical pesticides is more labour demanding and relatively inefficient, compared with the synthetic pesticides that they used to apply on cowpea.

Table 4. Criteria for keeping cowpea varieties in Dani and Diho and their rankings on the basis of pair-wise comparisons by farmers.

Criterion	Dani (n=20)		Diho (n=20)	
	Total score	Ranking	Total score	Ranking
Storability	374	1	345	2
Yield	330	2	286	8
Resistance to pests and diseases	329	3	323	3
Easiness to shell	323	4	268	12
Easiness to harvest	316	5	287	7
Healing value	314	6	361	1
Easiness to winnow	296	7	272	9
Resistance to drought	293	8	304	5
Resistance to abundant rain	290	9	270	10
Resistance to weeds	264	10	312	4
Number of growing seasons per year	254	11	265	13
Earliness	251	12	292	6
Market value	241	13	258	14
Resistance to bird damage	231	14	151	20
Number of harvests per growing season	219	15	270	10
Taste after cooking	207	16	215	15
Suitability of cooking of local food ‘abobo’	197	17	191	16
Cooking duration	162	18	118	21
Smelling during or after cooking	160	19	172	18
Suitability for cooking of the local food ‘abla’	143	20	176	17
Suitability for cooking of the local food ‘ata’	127	21	167	19
Grain size	92	22	68	24
Grain colour	73	23	73	23
Hilum colour	34	24	76	22

Spearman rank correlation coefficient: r = 0.86** (*P*=0.01).

Market dynamics of yam and cowpea varieties

Yam market

The yam market is characterized by high diversity. Of the 24 different yam varieties that appeared on the market during the period January–July, 22 belong to *D. cayenensis – D. rotundata*, one to *D. alata* (Florido), and one to *D. dumetorum*. In terms of frequency of yam varieties on the market of Glazoué from January to July, we distinguish three groups. The first consists of varieties that are sold almost on every market day (Florido, Gnidou, and Kokoro). They appeared on 74–84% of the market days during that period. Florido and Gnidou are on the market till July, and particularly Florido till the new harvest and appearance of Laboko. The second group consists of the ones that are present on 39–68% of market days during the period (Anago, Laboko, Ala, Gangni, and Klatchi). They appeared on the market till the end of April. The characteristics of yam varieties determine the price on the market (Table 5). Laboko is given the highest price. It is essentially designated for pounded yam. Kokoro is essential for peeled and dried yam. Florido appeared and began dominating the market since February, but it had the lowest price. Kokoro and Florido were both designated for making peeled and dried yam. The price of Kokoro is more than the double of the price of Florido. Although Gnanlabo received a high price after Laboko, it is rare on the market. The scarcity of Gnanlabo on the market reflects its situation in the farming systems. In fact, Gnanlabo demands a specific fertile land which becomes rare in the area of study.

Cowpea market

The cowpea market is also characterized by a high diversity. The most frequent cultivars (71–100% of the market days) during the period January–July were: Egni-awo, Aïglo and Kaki. Egni-awo was present on all the market days. The second group composed of Tawa, Malanville and Kplobè. They were present on 29–55% of the market days. Djètoko had the highest price. Boto and Kaki got the average lowest price during this period (Table 6).

In relation to the cultural preferences, there is a socio-ethnic market orientation on cowpea. Farmers of Dani village direct their strategies towards the choice of cowpea varieties they cultivate in mainly satisfying the regional markets' preferences. The white types that are predominant for Glazoué and Savè markets (Yoruba / Nagot zone), the red ones for sale on Bohicon and Abomey markets (the Fon ethnic group zone), the black varieties that are the less cultivated are mainly intended for home-consumption. In Diho village, the preferences become more and more based on the short-maturing of the white types to satisfy urgent financial needs. In this context, farmers have the possibility of a double cropping per year.

Temporal availability of yam and cowpea varieties

Figure 8 shows the temporal availability of yam and cowpea diversity on the market of Glazoué over the period 1 January – 30 July. It appears that during the dry season, in the middle of March, most farmers in the area sell their yam and cowpea varieties.

Table 5. Yam varieties sold on the market of Glazoué, and the ranges of their average price over the period 1 January 2003 – 30 July 2003.

Price range (F CFA kg^{-1})	Yam species and varieties
	Dioscorea cayenensis / D. rotundata
190–200	Laboko
150–160	Gnanrabo (Gnanlabo), Okogan
120–130	Moroko (Anago)
110–120	Klatchi, Dodo
100–110	Gangni (Cangni), Ala N'Kodjèwé, Adigbili, Amoula, Kablètonan, Kokouma, Mondji, Sotobowa
90–100	Mafobou, Effourou, Irindoun (Gnidou), Ahimon (Arimon), Ikinni, Okoékojè, Kokoro
80–90	Agatou
	D. dumetorum
80–90	Essourou / Eréfé
	D. alata
30–40	Florido (Aga/Alougan)

Table 6. Cowpea varieties sold on the market of Glazoué, and the ranges of their average price over the period 1 January 2003 – 30 July 2003.

Price range (F CFA per tongolo[1])	Varieties
> 210	Djètoko, Olikpokpodoundoun, Ewa Egbessi
190–210	Malanville
170–190	Noukoun vovo, Wankoun, Aïglo, Tchadjilé-djofè, Matamariko, Tawa/ Dani, Egni-awo, Togo-grain
150–170	Moro, Mahouna, Kplobè, Kaki, Boto
< 120	Atama

[1] Tongolo is a local, cubic measure. On average, one tongolo of cowpea is about 1 kg.

After then, there is a decrease in the number of varieties they sell. This reflects the situation in the households during this period. May is usually perceived as the 'month of starvation'. In June, the harvest of the early-maturing cowpea varieties appears on the market. The end of July is marked with the ritual entry of the earliest maturing yam variety, Laboko.

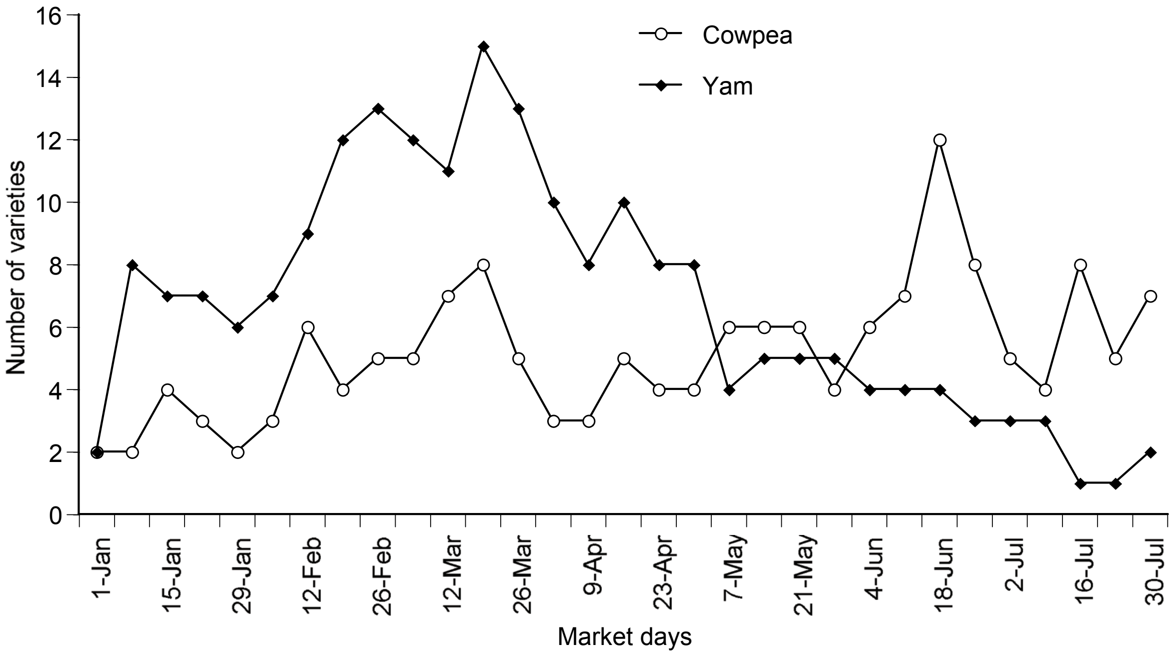

Figure 8. Temporal availability of yam and cowpea varieties on the market of Glazoué, in the period 1 January 2003 – 30 July 2003.

Discussion

Adoption of formal varieties bred outside Benin

Both for yam and cowpea, the introduction of formal varieties, bred by international organizations and introduced through the national system of variety testing, is unsuccessful. Discussions with local stakeholders showed that adoption will not take place as long as there is no close communication between the farmers and the breeders, as the farmers' idea about the ideal crop for their conditions strongly differs from the ideotype of the breeder who is breeding for completely different agronomic circumstances and is not taking into account the way the harvested products are used locally.

Importance of local varieties

These preliminary results show the existence of several local yam varieties in the farming systems to satisfy food, religious and economic needs of farmers and to meet the increasing demand for pounded, fried, peeled and dried yam. Of the 33 yam varieties identified, Florido is the only exotic variety recently introduced. However, the relative importance and dominance of this variety in the farming systems and on the market is remarkable. Yam domestication is a practice that improves the level of yam diversity in Benin (Dumont and Vernier, 2000; Tostain *et al.*, 2003). For cowpea, of the 25 varieties identified in Dani and Diho, only two are improved varieties. This result shows the diversity of local varieties in the farming systems in Benin.

Farmers' preferences

For yam, farmers maintain their desires in satisfying different yam foods and income generating in time, in addition to socio-cultural value that farmers preserve. On cowpea, according to Anon. (1990), farmers prefer more early-maturing varieties instead of late-maturing varieties to solve the problems of shortage and resistance to drought. However, farmers express some contrary needs and make different choices because of other factors of economic or market importance. In Dani, farmers appreciate also late-maturing varieties for which the harvesting coincided with the period of increasing cowpea price on markets. This strategy of synchronizing the harvesting time with the high market price enables farmers to avoid investing supplementary storage costs. So the agronomic performance of cultivated varieties, their suitability to satisfy the household or community needs the market demand form the basis of farmers' preferences.

Market preferences

For yam, Doumbia (1998) revealed a price difference according to the species and also found that Florido occupied the second position of most marketed yam varieties after Krenglè in Ivory Coast. This position of Florido in Ivory Coast is due to its high rate of multiplication and resistance to Internal Brown Spot disease, which attacks and depreciates other varieties of *D. alata*. The conventional economic explanation for the loss of crop diversity on the farm is that such losses are demand driven; this means that farmers specialize and replace their diverse set of landraces for high yielding modern varieties that provide them with high income (Bellon, 2001). We realized that not only the market as a single factor is playing that role, but also the inadaptability of the variety to several uses in the farming systems.

On the market, price premium is given to varieties with different characteristics. This study shows that the market prices are differential to each crop and to the varieties within each crop. On cowpea, grain colour, grain size, hilum colour, and resistance to weevils are important characteristics to consumers. Faye *et al.* (2002) reported similar results on cowpea in Senegal and found that buyers are willing to pay a premium for grain size and white skin colour but discount price for other colours and number of bruchid holes on the grain. Coulibaly and Löwenberg-De Boer (2002) revealed that grain colour and hilum colour are important when the intended use requires hulling. When the grain is hulled, poor pounding and winnowing may still leave some flecks for which consumers have a low tolerance.

Local variety replacement by farmers

The process of variety replacement is frequently cited by farmers through different interviews. On yam, the case often stigmatized by farmers themselves is the adoption of the *Alougan from Côte d'Ivoire* (Florido) replacing the local *Alougan (Landou)*. Strategies for genetic resources conservation should be developed and targeted on these varieties in loss. We realized that the process of variety replacement can easily occur within each plant species or plant group where for the same use, two or more varieties have different other characteristics. Richards (1995) analysed the importance of displacement of African rice (*Oryza glaberrima*) by Asian rice (*O. sativa*) and showed that throughout the forest zone in Sierra Leone, *O. sativa* replaced *O. glaberrima* by 90–100%. *O. glaberrima* is low-yielding, but adapted to pests, weeds, poor soils and drought. Friis-Hansen (1999) analysed the replacement of a diversity of indigenous sorghum landraces by one modern variety and highlighted how local varieties can be threatened by a new introduction. As a response to the 1991/1992 drought in Southern Africa, an NGO distributed 40 tons of an improved sorghum variety by way of emergency seed supply. After three years, it was noted that the improved variety was cultivated on between 75% and 90% of the farmers' sorghum fields and only 11 out of the 16 local varieties were still present in the village and confined to the remaining area (Friis-Hansen, 1999).

Loss of local varieties

Several varieties have been discarded by farmers, other ones are lost or on the way of being lost. Some are being grown on very small plots of land and/or by one or a few farmers. The total loss of some varieties may be accompanied with the loss of local knowledge related to them. But till now, the indigenous knowledge and utilization of the various varieties are poorly documented. There are voluntary losses where the variety is abandoned by the farmer himself because the particular variety does no longer satisfy farmer' preferences or can no longer cope with agronomic constraints. There are also accidental losses where the farmer loses the varieties due to external factors (i.e., erratic rainfall, pests/diseases). Worede (1997) reported on the irreversible losses within Ethiopian gene pools (i.e., sorghum, wheat, maize) and realized that the crucial factors are the displacement of indigenous landraces by new genetically uniform crop cultivars, the drought, change of land use and destruction of habitats. Ortega (1997) showed that the introduction of improved potato varieties has given rise to genetic loss in many parts of Peru. However, sometimes, the introduction of new varieties can also broaden the genetic base at local level or the loss of a variety at a local level may not mean a total loss at the region or national level.

Farmer's behaviour towards the maintenance of diversity

Several behaviours contribute to maintaining yam and cowpea diversity. Farmers can have innovative behaviour by testing exotic varieties. Some farmers are deviant in being the first in adopting and maintaining new varieties. Dennis (1987) characterized this deviant behaviour as 'contrarian behaviour'. According to Dennis (1987), in the 'contrarian variety use', the farmer is either the only one who grows a variety or is one of the few farmers growing a variety in a given year. These behaviours contribute to the maintenance or to the broadening of the variety diversity. Dennis (1987) argued that the existence of 'contrarian' innovators is central to the idea that the genetic diversity is consciously maintained by farmers. The 'contrarian' farmer needs to be distinguished from the outright conservative who is slow to adopt outside varieties or who is apt to have lower variety turnover on his farm. He also needs to be distinguished from the modern or directional innovator who tends to discard traditional and other older varieties with new government releases. The case described by Dennis (1987) is related to rice. For yam and cowpea, farmers have several behaviours by preserving at once the socio-cultural value, the food security over the year, guaranteeing a regular income, by taking profit from different varieties having different agronomic characteristics.

Knowing that farmers' behaviour is based on very specific needs, preferences and socio-cultural aspects, research in cooperation with farmers becomes necessary to establish new ways of a dialogue between researchers and farmers in evaluating the characteristics of the varieties farmers maintained in their systems.

On-farm maintenance of agro-biodiversity

The sustainable conservation and utilization of local genetic resources are important issues. In analysing the validity of theories around the issues raised by on-farm conservation of genetic resources, Wood and Lenné (1997) revealed that traditional farming has three positive characteristics. The first is constant search by farmers for *novel variation* or genetic novelty. 'The abilities of farmers to *experiment* with this variation' is the second characteristic. The third characteristic is that 'farmers manage a *dynamic portfolio of varieties*'. The result of farmer experimentation is a dynamic, open system of on-farm management of genetic resources, with both recruitment and loss of local varieties. Richards (1989) suggested that farmers' ability to experiment is a neglected resource. Monde and Richards (1994) provided examples of this kind. Farmers' selection criteria and maintaining practices are not well-known by scientists in Benin. Wood and Lenné (1997) suggested that there is a serious lack of specific technical research for on-farm conservation and suggested that it should constitute a research agenda. Wood and Lenné (1997) argued that there has been very little institutional research specifically for on-farm conservation; and as result of past neglect, no agreed set of scientific principles and practice yet exists for on-farm conservation of genetic resources.

The on-farm maintenance of biodiversity requires understanding by the farmer how specific varieties should be grown, stored and maintained in order to maximally realize the characteristics these farmers value. Therefore a farmer-driven research agenda is necessary for optimal adaptation of these varieties to their cropping system.

Consequences for future research

The purpose of this diagnostic study was to identify key factors that influence the level of diversity maintained by farmers, and from there to build the critical analytical frame for the in-depth research. The diagnostic study created a common understanding and ground for sharing knowledge on inter-disciplinary issues and inter-institutional level for the in-depth research. Farmers' research committees have been established and these have indicated several fields of research. Yam farmers indicated they wanted better understanding of the performance of seed roots from different varieties as affected by the part of the seed root used (apical, middle or lower part) and the way seed roots of early or late varieties should be stored to obtain high levels of emergence and high vigour. For cowpea, farmers indicated that they wanted more insight into the photoperiodic behaviour of late varieties when planted during the second rainy season. They also wanted to grow the crop with high yield, fewer applications of insecticides and having the possibility to store for a long period. For both crops, it is needed to test different varieties through participatory variety characterization in considering farmers' planting dates and agricultural practices.

Critical reflection on the diagnostic research

The diagnostic study has been helpful in selecting appropriate villages that are contrasted on a number of facts: level of institutional intervention on the crop, the ethnicity, the land pressure or degradation, the proximity to the regional market or road. This provides the various contexts in which farmers' motivations change over time and how do they proceed face to various constraints. Some issues such as socio-cultural factors (i.e., cosmo-vision) are to be addressed at community levels. It has also been necessary to review the interviewing methods and tools in accordance to the issue at stake with farmers. The diagnostic phase set the research agenda for the in-depth phase of the research programme, identified the topics of joint learning and created mutual confidence with farmers for the experimental phases. As opposed to mono-disciplinary approaches to farmers' problems and constraints, farmers inter-play with an inter- or trans-disciplinary behaviour and express their preferences through multi-

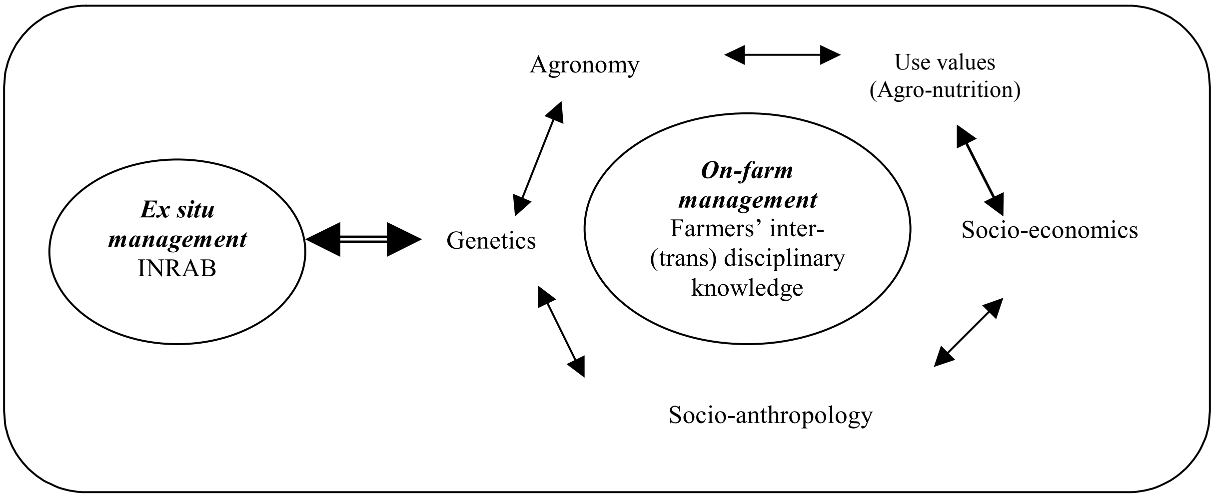

Figure 9. Mapping knowledge on yam and cowpea diversity management practices.

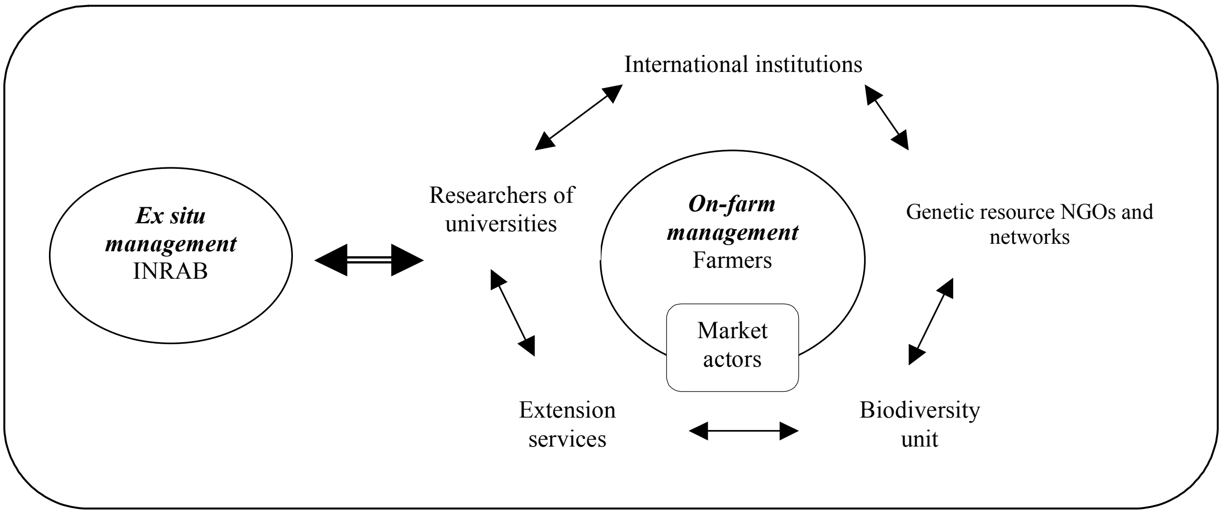

Figure 10. An integrated multi-stakeholder process for yam and cowpea diversity management.

criteria processes (Figure 9). From that analysis of farmer's perspective, the analytical frame for the in-depth research is constructed. The on-farm experimental phases are based on factors that farmers consider and how farmers manage different agronomic and genetic variety traits through joint learning. In addition to farmer seed system, other key institutions are supposed to have significant impact on the diversity management practices. This experimental phase takes also the character of sharing issues with market actors, and to plan opportunities of dialogue between farmers and market leaders, and other stakeholders as research institutions, NGOs, and extension services (Figure 10). A critical look is given to the importance and influence of these stakeholders in agro-biodiversity maintenance.

Concluding remarks

For these two crops, only some varieties are recognized to be the property of research systems and found at farmer level (two for cowpea and one for yam). The national and international systems deploy efforts in creating a lot of varieties. Paradoxically, we found few of these varieties at farmer level. In other words, these varieties are kept in gene-banks and do not serve farmers. This is a kind of discordance between the efforts provided in the agricultural research systems and what really serves farmers' needs.

Different types of characterization are found through the different meanings given to the varieties. The variety names farmers use point to the agronomic characteristics, morphology, and genetics of the cultivated varieties. Some farmers are very conscious of the maintenance of the genetic potential in continuing cultivating varieties that other farmers have already discarded. Farmers' behaviour in the maintenance of yam and cowpea diversity is related to the preservation of their socio-cultural value, food security over the year, and to the agronomic and economic values of these varieties. For these two crops, some local varieties are discarded. The reasons for which they are abandoned and their history, the process of variety choice and selection, the socio-cultural preferences, farmers' objectives, the market demand, the conservation practices, the village seed exchange networks need to be deeply documented. It is of the national public interest to learn about farmers' management of their agro-biodiversity and the different factors that influence this management as the conservation of the national genetic resources has become a priority with the application of the Convention on Biodiversity.

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CHAPTER 4

Socio-cultural factors influencing and maintaining yam and cowpea diversity in Benin*

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Abstract

Yam and cowpea are important elements in the food culture of local communities in the transitional Guinea-Sudan zone of Benin. Yam and cowpea serve to satisfy vital needs in households and in communities, but also play an essential role in the rituals and ceremonies of the agrarian civilizations of Benin. The diversity of rituals, food habits, technological traits and food security strategies for the two crops contributes to the maintenance of varietal diversity. It is not possible for one or even a few varieties to meet all needs. The more a variety is culturally and socially embedded, the greater the chance that it will meet acceptance on the local and regional market. Farmers' ambition to meet market demands in order to satisfy socio-economic needs also sustains and increases varietal diversity. Especially female farmers growing cowpea showed positive diversity maintenance behaviour. Overall, the study shows that the management of on-farm genetic resources is a socially and culturally constructed system. Any external strategy to improve management of on-farm diversity should take into account these social and cultural aims.

Keywords: Cowpea, diversity, gender, rituals, yam.

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Introduction

This chapter describes and analyses some of the social-cultural factors in rural communities that influence the maintenance of crop variety diversity for two crops – yam and cowpea – in Benin, West Africa.

Yam (*Dioscorea* spp.) was brought into cultivation in West Africa (*D. rotundata*, *D. cayenensis* and *D. dumetorum*), South East Asia (*D. alata* and *D. esculenta*), and Tropical America (*D. trifida*). Yam is an important component of the agriculture and economy in Benin, contributing to the food security of large parts of its population, but is confined to the savannah-forest ecotone, i.e., transitional lands between the 8^{th} and 10^{th} parallel in the Guinea-Sudan zone (Igué, 1974).

Cowpea [*Vigna unguiculata* (L.) Walp.] originated in tropical Africa (Padulosi and Ng, 1997). It is widespread in the tropics and sub-tropics, and is often an important component of local food supply, especially in sub-Saharan Africa, Asia, and Central and South America (Coulibaly *et al*., 2002; Mortimore *et al*., 1997; Zannou *et al*., 2004). In Benin, cowpea is grown for seeds and young leaves all over the country. The Guinea-Sudan zone is one of the major cowpea production areas in Benin (Zannou *et al*., 2004).

In both crops, loss of genetic diversity has been reported. Eastwood and Steele (1978) and Okoli (1991) have shown loss of genetic diversity in yam. In Benin, farmers reported the disappearance of many yam cultivars, a reduction in the number of cultivated varieties and the abandonment of some others due to pest and disease problems (Dansi *et al*., 1997). The genetic diversity of cowpea is gradually diminishing because humans change or destroy the natural habitats to which wild species are adapted and because farmers replace landraces by improved cultivars (Ng and Maréchal, 1985).

Ex situ conservation in gene banks is not, by itself, an efficient tool for sustainable conservation of crop germplasm (Pardey *et al.,* 1999). On-farm conservation by farmers is needed to preserve crop diversity (Jarvis *et al.,* 2000). Convergence of farmers' needs for diversity and society's demand to maintain this diversity on farm must be realized.

Decisions regarding the use and management of plants are based on both biophysical and socio-cultural factors, and thereby at least partly on how a given community or individual perceives the natural world (Millar, 1999; Elias *et al*., 2000). Social and cultural contexts shape the roles of different individuals or groups within a household or community (Arua, 1981; Brydon, 1981; Chauveau *et al*., 1981; Uzozie, 1981; Bellon, 2001). These socially determined roles affect farmers' knowledge, actions and access to resources regarding the maintenance of crop diversity (Jarvis *et al*., 2000). Thus, studying the relevance of socio-cultural factors to on-farm crop diversity is important to understand how the social maintenance mechanism of yam and cowpea diversity in Benin might be enhanced.

Socio-cultural framework

Scientists – mainly biologists – often see morphological and genetic diversity as natural patrimony resulting from a long period of crop species evolution. But when one wants to understand how and why a given farmer or community maintains (or fails to maintain) this diversity, one moves from the material world of morphological and genetic diversity into the world of social values. In this world, five different groups of factors can be distinguished: technological and culinary traits, food security in households, socio-cultural values, market demand, and agronomic traits. In the social world, some factors are interdependent. A single factor is rarely sufficient to explain diversity maintenance or why an improved crop variety is accepted by farmers. Any given crop variety goes through a process of social translation in which different values tend to align or exercise mutual influence. Taste, for example, may be as important as actual bulk in determining local notions of nutritional satisfaction, and thus helps explain why some varieties seemingly unproductive to the agronomist are carefully maintained. This process of translation depends on the community in which the farmer lives, socio-economic conditions, and physical and economic environments. The diversity of uses and values is reflected by the crop varietal diversity as maintained by farmers.

Materials and methods

Data collection

One hundred and ninety four yam farmers (167 male; 27 female) and 136 cowpea farmers (109 male; 27 female) from four relatively large communities (ethnic groups: *Mahi*, *Idatcha*, *Tchabè*, and *Bariba*) were interviewed with open-ended questions to assess the socio-cultural and economic importance of yam and cowpea cultivars. Simultaneously, planting material was collected for participatory characterization.

Two series of detailed studies were carried out in two villages for yam (Yagbo and Kpakpaza, district Glazoué) and two villages for cowpea (Dani and Diho, district Savè) in the Guinea-Sudan zone of Benin, where communities mainly belong to the *Mahi, Idatcha*, and *Tchabè* groups. During the first series of detailed studies, 40 farmers in each of the four villages were interviewed. Of these 40 farmers, 10 farmers were female in Kpakpaza, 11 in Yagbo, 10 in Dani and 14 in Diho. For each village, the cultural embedding of crop varieties was investigated by studying associations between yam and cowpea varieties and local divinities (*Vodoun* in *Mahi*). Respondents freely listed the varieties that (s)he considered important for cultural ceremonies and specific to given divinities. The role played by yam and cowpea varieties in local traditions, food habits, rituals and ceremonial, and religious festivals was then analysed.

In order to take into account the variability in the environment of the farmers, the food security dimension, and the technological traits of the cultivated varieties, we interviewed in a second series of in-depth studies 100 yam farmers (87 men and 13 women), and 91 cowpea farmers (65 men and 26 women). The female farmers in the sampled populations have their own yam and cowpea farms. The objective of this second series of detailed studies was to link the socio-cultural and economic factors to agronomic, food security and food technological factors. The relatively high involvement of women in cowpea cultivation allowed a comparative gender analysis on cowpea diversity management. For the technological traits, only farmers who held technological knowledge on a given variety were requested to assess it. Yam varieties were evaluated for their culinary value in Yagbo and Kpakpaza, whereas cowpea varieties were evaluated in Diho and Dani, by asking farmers to provide a score for each variety trait for the varieties that farmers knew well.

Data analysis

Frequencies, percentages, and cross-tabulations were calculated, and mean comparisons were performed, using the Statistical Package for Social Sciences (SPSS 12.0.1) and the Statistical Analysis System (SAS 8e). The statistical tools to compare means included the t-test, F-test, and Games-Howell test for multiple comparisons. Gender differences in behaviour regarding yam and cowpea varietal diversity management and the strategic choices of the yam and cowpea farmers were analyzed using mean comparison in relation to relevant socio-cultural variables. On the basis of the relationships between the socio-cultural, economic, food security, agronomic and environmental factors, the cultivated varieties of yam and cowpea were classified into different categories.

Results and discussion

Socio-cultural rites involving yam and cowpea

In the research area, land, nature and supernatural forces are represented by gods (spirits), forming a unified pantheon and living as a family. Socio-cultural rites involving crops are directed to several gods and family ancestral spirits. In this section, these socio-cultural rituals are briefly described.

Fâ is a divinatory system of rites by which destinies are revealed. All religious and social activities involve consultation through *Fâ* to know the correct behaviour to follow and to protect against harmful forces.

Devotion to ancestral spirits. The ancestors are the spirits of historical or mythic persons; each ethnic community has a group of them. The ancestor cult can be conceived of as a ritual 'mapping' of features of the kinship system.

Egungun is the cult of ghosts, and represents the spirits of dead persons who have joined the ancestors after a process of sanctification. The ritual masquerades associated with *Egungun* express the desire of communities to recall departed spirits.

Devotion to non-ancestral spirits (Vodoun). The *Vodoun* are the spiritual forces regulating the natural order. They include *Sakpata*, *Hèviosso*, *Dan* and *Tohossou.* *Sakpata* is the spirit of the land, controlling, e.g., contagious epidemic illnesses such as smallpox. *Hèviosso* is the spiritual force representing the thunder, which can intercede with God to obtain rain for the crop. *Dan* is the force regulating economic prosperity, through which farmers implore benediction for the success of their farm activities. *Tohossou* is in charge of the spiritual force of each clan, and so maintains peace and prosperity in the community.

Rituals of Kokotin within Idatcha. *Kokotin* is a deity protecting against the risk of being bitten by snakes and scorpions. These are common hazards for farmers.

The divinity Ikpé of Idatcha. *Ikpé* (for *Idatcha* people) means whistle. Whistling transfers a message that celebrates the clan's *Omon–Adjagou*, guardians of *Idatcha* customs.

Kouchaati ritual within the Otammari ethnic community. The *Otammari* are migrants in Yagbo; they celebrate the *Kouchaati* ritual for initiation and social integration of young people.

Role of yam in different socio-cultural rites

Fâ. Yam production is considered an activity requiring divinatory guidance through *Fâ*, because some varieties show large yield variation and are difficult to grow for some farmers. The ability to grow a given variety is considered a gift from God. The *Fâ* priest called *Bokonon* has to sacrifice the newly harvested yam to the *Fâ* before anybody can eat it.

Ancestors. The first roots of the new yam harvest are offered to ancestors so that they can intercede to obtain from God what each community needs or desires.

Egungun. Members of communities where these divinities are to be found, are required to give newly harvested yam to the divinities before humans can eat it. The yam ritual within the *Mahi* begins on the 14th of July each year. Yam festivities reach their climax on 15th August each year in Savalou, a district in the central part of Benin. The 15th of August is the day when *Egungun* will be given the new yam; fellow masquerades come from other towns such as Porto-Novo, Cotonou and Abomey to participate in these festivities.

Kokotin. The newly harvested yam is the first important thing to be dedicated to *Kokotin* each year. The harvest must be done on the day of the ceremonies. Each male family member has to grow some early-maturing varieties each year, mainly the variety *Laboko*, in order to make this offering, and thus obtain protection for his family. As long as the rituals have not been performed, the officiating priest cannot eat the newly harvested yam. The offering of boiled yam comes before the offering of pounded yam.

Ikpé. Within the *Idatcha* community, *Laboko* is the ancestral sacred yam variety. It also characterizes the good yam grower. Farmers from this community stated: "the best grower is the person who is the first person to eat the new yam, and not all farmers can produce it". People think that it is by chance that they succeed to grow this variety. Their faith requires them to offer the variety to the divinity linking them to the High God.

Kouchaati. For the *Otammari*, the variety *Gangni* is a 'son' yam and the variety *Kokoro* a 'daughter' yam. These two varieties are very important for *Kouchaati* rituals. *Gangni* and *Kokoro* are considered an inheritance from the ancestors. A good harvest is a sign of benediction and peace from ancestors. The first harvest of these varieties is therefore given to the ancestors and divinities before any member of the community can eat new yam.

Role of cowpea in different socio-cultural rites

The *Fâ*, ancestor spirits and the *Vodoun*, are the supra-natural forces to which cultural rites involving different cowpea varieties are mainly devoted in Benin. In the area of study, cowpea is used during most rituals. Both in Diho and Dani, several cowpea varieties are used for funerals and offered to ancestor spirits and local divinities such as *Abikoun*, *Tohossou*, and *Tchango*. It is after consulting the *Fâ* oracle that it is decided to give cowpea food to twins.

The ritual ceremonies of Kiyo-Davi. This is a ceremony to uplift the souls of the deceased to the rank of ancestors within the *Mahi* community. Legend has it that these ceremonies originated in ancient times, deployed on behalf of an ancestor hunter who surprised the spirits (azizas = zina, i.e., genie) performing the *Kiyo-Davi* ceremony for dead persons. When these ceremonies are enacted the white cowpea variety *Atchawékoun* is considered sacred. It is said that each year the community 'kills' that variety before any animal can be sacrificed. This cowpea variety is necessary to ensure the benediction of the ancestors, and to ensure a blessing of peace on the family. It is necessary to enable the spirits of dead persons to return 'home' to be accepted by the ancestors. These ceremonies of deliverance are conducted by a woman called *Tassinon*. She is the chief of the altar of dead persons. The *Fâ* has to be consulted for any abnormality or irregularity during these ceremonies.

Ceremonies of twins. These ceremonies concern "bringing back the twins from the bush". Ancient beliefs in other regions sometimes saw twins as abomination to be abandoned in the bush. In the region of study, local communities saw twins as a blessing. Twins enjoy special spiritual powers, and thus often have to be ritually redeemed. The nutritionally valuable cowpea is an especially appropriate offering for twins. The variety *Atchawékoun* is mainly used. It is used to prepare seven different meals (*lèlè*, *yoyoè*, *dovolo*, *ata*, *ayiwolowolo*, *abla*, *abla-manbi-manbi*). The number of different dishes seems symbolically salient of the nutritional challenge posed by raising twins. *Atchawékoun* is also a variety that each member of the community has to cultivate in order to provide food for the divinities *Fâ*, *Hèviosso*, *Sakpata* and *Lègba*.

Ceremonies of Sakpata. *Sakpata* is considered to be a furious and hard divinity. The mark of the divinity is the manifestation of disease in humans, notably (in the past) smallpox. When an epidemic occurs, the cowpea variety *Atchawékoun* is prepared by the community to 'cool' the divinity. When *Sakpata* seems hard to appease the *Fâ* oracle is consulted to know the reason.

Determinants of diversity in yam

The socio-cultural determinants of crop diversity were analysed under three main headings: food culture, socio-cultural and income needs, and socio-cultural rites. An attempt was then made to establish connections between socio-cultural requirements, market demand, and agronomic performance. The specific needs of the availability of certain varieties of yam to carry out the common rituals are described.

Food culture and income needs

Table 1 presents the results of the interviews with 194 farmers from four ethnically different communities. Yam is a staple food for farmers in most rural communities in central Benin: 78% of farmers considered home consumption very important (Table 1). Every community needs a good supply of the varieties most suitable for pounding. Farmers' desire to eat pounded yam all year round enhances yam diversity as they then need to have early- and late-maturing varieties suited to pounding. Year round supply is assisted by selecting some types which can be processed into dried chips (*cossettes*) from which a paste can later be reconstituted. Farmers now cultivate such varieties intensively. Local religion stresses the importance of ancestors. As yam is considered an ancestral crop, it is highly preferred to other food crops. In local belief, "If one has not eaten yam for dinner, it means that the person is hungry". "The farmer who has not

Table 1. Number (%) of farmers indicating different uses for yam.

Ethnic community	Number of farmers	Home consumption (%)	Income (%)	Cultural rites (%)	Gift (%)
Bariba	74	54 (73)	39 (53)	20 (27)	26 (35)
Mahi	47	41 (87)	35 (74)	36 (77)	10 (21)
Idatcha	44	39 (89)	38 (86)	34 (77)	25 (57)
Tchabè	29	18 (62)	18 (62)	10 (34)	0 (0)
Total	194	152 (78)	130 (67)	100 (52)	61 (31)

grown yam has left his family to starve". Having abundant yam is, conversely, an indicator of wealth and well-being.

In the area, 67% of the surveyed farmers considered income from yam production very important (Table 1). For the *Bariba*, *Mahi* and *Idatcha* communities, yam is used to fulfil social obligations, for example during weddings and other ritual ceremonies. There was a specialization by farmers towards varieties having a high market price. Surplus production was sold on the market. Farmers of Yagbo and Kpakpaza were motivated to cultivate the variety *Laboko* for the market because it enabled them to be among the first farmers selling their yam on the market before the period of abundance in August–September (when prices drop).

Also, yam was seen as conferring social prestige. Farmers stated: "Being a big yam producer is a sign of social noblesse. The best producers are those farmers who are the first to have the newly harvested yam. Yam remains essentially the hope of the people who grow it".

Yam diversity in response to changes in food needs

The number of varieties cultivated and the overlap of harvest periods together indicate the way in which varietal diversity helps to fulfil farmers' various needs.

Yam diversity ensures four levels of food security over the year for farmers in Benin. These four levels correspond to four periods:

- From late June to July, when the first harvest of the early-maturing yams, e.g., *Laboko,* occurs. Farmers preferring pounded yam and unable to satisfy their needs during the period of shortage (February–June) are again able to eat their favourite food (Figure 1).
- From August to September when food is relatively abundant, as the tubers of most yam varieties, and certainly early-maturing ones, which are harvested twice, reach physiological maturity and become ready for consumption or sale. This period is marked by a drop in the price of yam on the market.

- From October to January, when late-maturing varieties are harvested, as soon as the plant senesces. Some early-maturing varieties may be either harvested once or twice: e.g., *Gnidou* is harvested once in Kpakpaza, but twice in Yagbo. Towards the end of this third period, edible or marketable tubers of early-maturing yam become scarce, and the price increases.
- From February to the beginning of June, there is a period of food shortage when yam and other crops are not available. Only *Gnidou* and *Florido* – considered to be of low socio-cultural and market values – remain with some farmers. Farmers usually consider these varieties as the ones that "support the households during the shortage period".

Table 2 shows that about half of the harvest is designated for home consumption and the other half for sale. Some farmers consume the entire harvest of several varieties. Labour constraints do not allow growing more of these varieties, especially not the early-maturing varieties of *D. cayenensis / D. rotundata*. Land clearing and heaping require a lot of labour and the appropriate period of heaping is highly restricted, coinciding with the period of the last rains in September to November when it is easier to make the heaps. Moreover, early planting of these varieties advances emergence. *D. alata* (e.g., *Florido*) includes varieties that ease labour constraints; they allow spreading of labour peaks because these varieties are mainly planted during the

Period 1 June-July		Period 2 August-September		Period 3 October-January		Period 4 February-May	
Laboko	69	*Laboko*	15	*Florido*	21	*Gnidou*	27
Anago	15	*Anago*	15	*Kokoro*	14	*Florido*	20
Gangni	5	*Ala-N'kodjéwé*	14	*Laboko*	13	*Laboko*	10
Gnidou	5	*Gangni*	12	*Gnidou*	11	*Kokoro*	10
Ala-N'kodjéwé	4	*Gnidou*	9	*Anago*	10	*Anago*	8
Adigbili	2	*Adigbili*	6	*Ala-N'kodjéwé*	9	*Effourou*	8
		Effourou	8	*Gangni*	7	*Adigbili*	5
		Klatchi	2	*Adigbili*	4	*Gangni*	5
		Florido	2	*Effourou*	3	*Ala-N'kodjéwé*	2
		Dodo	1	*Kabilatonan*	2	*Gnanlabo*	2
		Mondji	1	*Klatchi*	2	*Mafobo*	2
		Antou	1	*Gnanlabo*	1	*Dodo*	1
				Mafobo	1		
				Mondji	1		
				Ahimon	1		

Figure 1. Yam harvesting and use periods, guaranteeing household food security. The figures represent the proportions of farmers (in %; n = 100) who harvest and use a specific variety in a specific period.

beginning of the rainy season (March–early April). They also require less labour than the other varieties because they perform well on small heaps. Farmer management of these production constraints is determined by a land and labour availability schedule, but at the same time results in maintenance of high diversity of seasonally adapted yam varieties.

Technological and culinary traits

The main foods analysed were pounded yam, yam paste, fried yam, and boiled yam. Their availability varies over the year. Table 3 reveals some specialization of varieties with regard to technological aptitudes.

Table 2. Allocation of yam harvest[1] to home-consumption and selling in Kpakpaza and Yagbo.

	Variety	No. of farmers	Home consumption	Selling
D. cayenensis / D. rotundata				
	Early maturing			
	Laboko	77	4.9	5.1
	Adigbili	22	4.0	6.0
	Ala-N'kodjèwé	40	5.3	4.7
	Anago	22	6.0	4.0
	Kabilatonan	11	5.1	4.7
	Mafobo	8	5.3	4.7
	Moroko	26	4.8	5.1
	Effourou	21	5.2	4.8
	Gangni	33	5.2	4.7
	Gnidou	57	4.8	5.2
	Late maturing			
	Gnanlabo	9	6.2	3.8
	Klatchi	5	4.8	5.2
	Kokoro	48	5.3	4.6
D. alata	*Florido*	77	5.3	4.7
D. dumetorum	*Léfé*	3	5.7	4.3

[1] The whole harvest is considered on a basis of 10 units.

Period of boiled and pounded yam. During this period, yam can be consumed after being boiled or after being pounded. When yam is eaten boiled, the values highlighted by producers/consumers relate to taste, flesh colour, friability and smell. Especially the characteristic smell of a variety is considered a determinant of quality in boiled yam. Boiling is also an intermediate step in the conversion to pounded yam. The differential traits mentioned by producers/consumers when boiling and pounding are the elasticity or plasticity of the pounded product, the swelling (volume increase during pounding), and its taste (Table 3). Not all varieties are suitable for making pounded yam, nor are all appropriate to be transformed into dried yam (*cossettes*) for making yam paste. *Laboko* and *Gnanlabo* provide excellent pounded yam, but *Florido* and *Gnidou* produce a poor quality pounded yam. All types suitable for pounded yam (*Laboko, Gnanlabo, Effourou, Ala-N'kodjéwé, Gangni* and *Anago/Moroko*) are also appreciated for production of boiled and fried yam. *Florido* is commonly eaten boiled or fried.

Fried yam is a snack food. The taste and friability are the main traits. Fried yam is made both during the period when yam is pounded and the period when yam paste is consumed.

Period of yam paste. The late-maturing variety *Kokoro* was considered by farmers in the study to be the best variety for the dried yams usually called *cossettes* and for paste (Table 3). In this dried form, the variety *Kokoro* can be kept by farmers without any attack by storage borers which greatly shorten the storage period of the dried yam of other varieties. Taste and swelling are also considered. Some poundable yam varieties are also used for processing as *cossettes* and paste. When poundable varieties are used for processing the main part of the tuber is taken for making pounded yam and processing is applied only to the heads of the second harvest, or those parts considered undesirable for making pounded yam. Despite its poor technological characteristics farmers still grow *Florido* because *Florido* is harvested in the dry season when it can be readily processed into *cossettes*.

Rites and yam diversity

Farmers have established relations between the varieties they cultivate and the various divinities. Table 4 presents results from 40 farmers in Kpakpaza and 40 in Yagbo. The table indicates the particular conditions under which rituals are performed for varieties such as *Laboko* and *Moroko*. About 88% of farmers in Kpakpaza recognized that poundable yam varieties are important for the divinity *Kokotin*. Four farmers said they were also important for ceremonies devoted to twins (*Ibéji*), and two farmers mentioned *Tohossou* and funerals; one farmer mentioned the divinity *Dan*. In Yagbo, 23% stated that they venerate all fetishes (or *Vodoun*) with poundable varieties or varieties belonging to *D. cayenensis / D. rotundata* species (locally called *Tévi*), 20%

Table 3. Assessment of varieties on culinary traits in Yagbo and Kpakpaza.

	Varieties	No. of farmers	Boiled yam				Pounded yam			Fried yam		Cossettes / Paste		
			Taste	Flesh Colour	Friability	Smell	Plasticity	Swelling	Taste	Taste	Friability	Dried quality	Paste swelling	Paste taste
D. cayenensis-D. rotundata														
Early maturing	*Laboko*	45	5	5	4	5	5	5	5	5	4	4	4	4
	Gnidou	31	3	4	5	3	3	4	3	3	4	4	4	4
	Effourou	7	4	5	5	4	4	5	5	5	5	4	4	4
	Ala-N'kodjéwé	25	5	4	4	4	4	4	4	5	4	4	4	4
	Gangni	22	4	4	5	4	4	4	4	4	4	4	4	4
	Moroko/ Anago	17	4	4	5	5	4	5	4	4	4	4	4	4
D. cayenensis-D. rotundata														
Late maturing	*Kokoro*	32	5	4	4	4	4	4	4	4	4	5	5	5
	Gnanlabo	7	5	5	3	4	5	4	5	5	4	4	4	4
D. alata	*Florido*	43	3	4	5	3	2	2	2	3	4	3	3	3

1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high. The scoring represents farmers' evaluation of culinary traits for each variety. This scoring reveals the degree of satisfaction provided by each variety in considering each variety trait (n=100). Only farmers who held technological knowledge on each given variety were requested to assess it.

Table 4. Yam varieties related to ritual practices as indicated by 40 farmers in Kpakpaza and in Yagbo.

	Kpakpaza		Yagbo	
Rituals	No. of farmers[1]	Varietal group or variety	No. of farmers[1]	Varietal group or variety
Kokotin	35	Pounded, *Laboko, Moroko, Mondji, Effourou, Tévi-gan*		
Twins	4	Pounded, *Laboko*	2	*Laboko, Ala-N'kodjéwé*
Tohossou	2	Pounded, *Laboko*	2	*Laboko, Ala-N'kodjéwé*
Funerals	2	*Laboko, Effourou*	6	Pounded, *Tévi, Laboko, Ala-N'kodjéwé*
Dan	1	*Laboko*	8	Pounded, *Tévi, Laboko, Ala-N'kodjéwé*
Vodoun			9	Pounded, *Laboko, Ala-N'kodjéwé, Tévi, Gangni*
Fâ			5	Pounded, *Tévi, Laboko, Ala-N'kodjéwé*
Assangni			3	Pounded, *Laboko*
King's ceremony			2	*Laboko*
"*Vossissa*"			2	*Tévi*

[1] Some farmers mentioned more than one ritual and others mentioned no rituals at all.

mentioned the divinity *Dan*, 15% funerals, 13% *Fâ,* and 5% twins, *Tohossou*, ceremonies involving the King, and sacrifices (*Vossissa*). *Vossissa* is a kind of thanksgiving following the promises requested from a *Vodoun* have been made good.

Socio-cultural and market demands

Table 5 provides the links between the socio-cultural demand and market demand within the area of study. In Yagbo and Kpakpaza, other varieties in addition to *Laboko* were important for market, for a number of farmers. In both villages, *Laboko* was preferred for both social and economic needs. *D. alata* (water yam) varieties, such as *Florido*, locally called *Aga* or *Alougan*, were neither socio-culturally important nor considered economically relevant by farmers. This confirms farmers' statement that *Alougan* or *Aga* is preferred for its agronomic adaptation, mainly its adaptability to poor soils and its ability to be stored for long periods, ensuring the food security during the pre-harvest hungry season in the central part of Benin. The same argument holds for the *D. cayenensis / D. rotundata* variety *Gnidou*, considered to be well adapted to poor soils.

Table 5. Frequency distribution of the socio-cultural and economic demands expressed by farmers concerning use of different yam varieties in Kpakpaza and Yagbo.

		Kpakpaza (40)		Yagbo (40)	
Species	Yam varieties	Socio-cultural demand	Economic demand	Socio-cultural demand	Economic demand
D. cayenensis / D. rotundata					
- Early maturing	*Laboko*	36	34	23	14
	Moroko / Anago	14	11	16	8
	Mondji	14	13	16	5
	Gangni	13	11	17	6
	Ala-N'kodjèwé	13	12	20	7
	Effourou	12	11	16	5
	Adigbili	12	10	16	6
	Gnidou	-	6	-	3
	Tevi-gan	2	-	-	-
- Late maturing	*Gnanlabo*	-	10	-	4
	Kokoro	-	2	-	1
	Klatchi	-	9	-	6
D. alata	*Florido*	-	-	-	-

Varietal grouping

Based on the farmers' perception of these varieties in terms of socio-cultural values, technological traits, market values, food security, and adaptation to specific environmental niches, two major groups of yam varieties can be found with farmers in the central part of Benin. The first group (labelled Group 1) is composed of varieties with high socio-cultural values, high market values, lowland adaptation, high soil fertility and water requirements, mostly early maturing or used for double harvests (e.g., *Laboko*, *Ala-N'kodjéwé*, *Anago/Moroko*) (Table 6). This group is mainly used for the production of pounded yam. The second group labelled Group 2 comprises varieties of relatively low socio-cultural values, low market price, and adapted to the erratic rainfall and poor soils of the plains or slopes; these are also characterized by adaptation to long storage.

Some socio-cultural factors appeared to influence the choice of varieties (Table 7). The female yam farmers grew on average 2.0 varieties of high socio-cultural and economic values and 2.1 varieties for food security during the period of food shortage,

Table 6. Diversity of yam varieties as indicated by the proportion of farmers (%; n = 100) growing different numbers of two different types of varieties. Group 1 = Yam varieties grown to fulfil socio-cultural and economic needs; Group 2 = Yam varieties grown for food security, mainly in the dry season when food is short.

Group 1: Yam varieties of high socio-cultural and economic values		Group 2: Yam varieties for food security in food shortage period	
Number of varieties	% of farmers	Number of varieties	% of farmers
0	7	0	1
1	16	1	24
2	23	2	53
3	25	3	20
4	16	4	2
5	10		
6	2		
7	1		

whereas male farmers cultivated on average 2.8 and 2.0 varieties for the two categories respectively. The difference between these two groups of varieties grown was statistically highly significant for male growers but not for female growers, suggesting that the behaviour regarding the choice of the varieties in the two categories is different. As shown by the t-statistic for each of the other socio-cultural factors considered for yam farmers (religion, ethnicity, age, household size), the mean number of varieties cultivated for high socio-cultural and economic values appeared higher than and significantly different from the ones grown for food security in the food shortage period (Table 7). Table 7 also clearly shows that differences in number of varieties between the categories of the different socio-cultural factors were only present for Group 1. Such differences were significant for sex and ethnicity as revealed by the F-statistic and the Games-Howell multiple comparison test.

Summary of findings on yam

This part of the study concerning yam has demonstrated that yam remains an important component of the culture and religious beliefs of sampled rural groups in the Guinea-Sudan zone of Benin. The findings show a relationship between diversity of yam varieties and cultural diversity. The yam varieties preferred for cultural reasons also happen to be of high economic values as reflected in market preferences. However, the cultural and economic preferences cannot alone explain all of the diversity found in yam. The farmers' desire to guarantee food security all year round is

Table 7. Mean number of yam varieties grown from Group 1 (varieties of high socio-cultural and economic values) and from Group 2 (varieties grown for food security in the periods of food shortage) as affected by some socio-cultural characteristics of farmers (n=100).

Farmers' socio-cultural characteristics	Levels	No. of farmers	Varieties of high socio-cultural and economic values		Varieties for food security in food shortage period		
			Mean	S.D.	Mean	S.D.	t-statistic[1]
Sex	Male	87	2.8	1.56	2.0	0.77	4.50***
	Female	13	2.0	1.08	2.1	0.64	0.22
	F-statistic[2]		**F=3.21***		**F=0.25**		
Religion	Traditional	13	3.3	1.42	2.0	0.76	2.92***
	Modern	87	2.6	1.53	2.0	0.75	3.45***
	F-statistic		**F=1.82**		**F=0.09**		
Ethnicity	*Idatcha*	69	2.4	1.49	2.0	0.70	2.27**
	Mahi	24	3.3	1.49	2.0	0.80	3.97***
	Otammari	7	3.6	1.13	2.4	0.97	2.02*
	F-statistic		**F=4.98*****		**F=1.35**		
Age (years)	< 31	31	2.5	1.43	1.8	0.67	2.61***
	31–50	45	2.8	1.50	2.0	0.74	3.03***
	> 50	24	2.8	1.73	2.1	0.85	1.59
	F-statistic		**F=1.80**		**F=0.33**		
Household size	1 to 5	36	2.7	1.51	2.0	0.75	2.57**
	> 5	64	2.7	1.55	2.0	0.76	3.34***
	F-statistic		**F=0.03**		F=0.12		
All categories together		100	2.7	1.53	2.0	0.75	4.23***

Games-Howell multiple comparisons with ethnicity[2]

Varietal groups	(I) Ethnicity	(J) Ethnicity	Mean Difference (I-J)	S.E.
Varieties of high socio-cultural and economic values	*Idatcha*	*Mahi*	–0.94**	0.354
		Otammari	–1.18*	0.464
	Mahi	*Idatcha*	0.94**	0.354
		Otammari	–0.24	0.526
	Otammari	*Idatcha*	1.18*	0.464
		Mahi	0.24	0.526
Varieties for food security in food shortage period	*Idatcha*	*Mahi*	–0.02	0.185
		Otammari	–0.49	0.378
	Mahi	*Idatcha*	0.02	0.185
		Otammari	–0.47	0.404
	Otammari	*Idatcha*	0.49	0.378
		Mahi	0.47	0.404

[1] Results using SAS 8e;

[2] Results from SPSS 12.0.1; Level of significance: 1%:***; 5%:**; 10%:*

the third important factor enhancing the diversity of cultivated varieties. This factor selects for varieties that perform well when others preferred for cultural and economic reasons become scarce. All these varieties offered to farmers and consumers various food technological and agronomic traits. Perceived values allow a categorization of yam varieties into two major groups: one group with varieties characterized by high socio-cultural and economic values and another characterized by low socio-cultural and market values, but high food security value. Between them, the two groups provide farmers and consumers with a range of technological and agronomic aptitudes and provide food at different periods of the year.

Determinants of diversity in cowpea

This section analyses the importance of cowpea as a crop culturally embedded in the tradition of the peoples of the central part of Benin. As with the analysis for yam, different components of culture are considered, relating the material world of cowpea varieties to the spiritual world represented by divinities of the communities. The specific availability of certain cowpea varieties to carry out specific rituals is described.

Food culture and income needs

Food culture. Consumption of cowpea products begins with the vegetative phase, as leaves serve as vegetables. At harvest, cowpea is used in meals that often also include yam and cereal products. Cowpea products help farmers to bridge the period from one yam cropping season to the next. Cowpea is important as a buffer against hunger during pre-(yam)-harvest food shortages in central Benin.

Income needs. Some women grow cowpea in order to process it into derivate products before selling (Table 8). Cowpea plays an important role in commercial transactions. Cowpea does not have as high a financial profile as yam but its commercialization is easier, and turn-over is faster than for yam. Income from cowpea supplements income from yam sales in most villages. The income is vital to the household economy – since

Table 8. Number of farmers indicating different uses of cowpea.

Communities	Number of farmers	Home consumption (%)	Income (%)	Social rites (%)	Gift (%)
Tchabè/Nagot	54	43 (80)	47 (87)	33 (61)	33 (61)
Bariba	36	23 (64)	12 (33)	4 (11)	2 (6)
Idatcha	35	31 (89)	27 (77)	21 (60)	12 (34)
Mahi/Fon	11	8 (73)	10 (91)	8 (73)	2 (18)
Total	136	105 (77)	96 (71)	66 (49)	49 (36)

it pays for kitchen seasonings, purchase of farm tools and repayment of agricultural credit negotiated with traders and friends. Income from cowpea is also used regularly as capital for buying a share in *tontines* (i.e., a rotational credit association). In the *Bariba* community, however, low scores were obtained in the categories income, social rites and gift. This may be due to the low level of involvement of *Bariba* women during the planting material collecting phase when the *Bariba* sample was interviewed. *Labour relations*. Cowpea products are important elements in the meals often given to agricultural labourers during farm activities to ensure high quality of work. These meals are highly appreciated, and often a required condition of the labour contract to motivate external agricultural labourers, often migrants.

Social rites and gifts. Almost 50% of farmers recognized the uses of cowpea varieties in social rites as very important. Farmers interviewed from the *Tchabè / Nagot, Idatcha*, and *Mahi* ethnic communities confirmed this socio-cultural importance (Table 8). In addition, 36% of farmers provided some parts of their harvest as gifts for relatives, neighbours or friends from other communities.

Cowpea diversity and food needs

Tawa is the most frequently cultivated variety, represented in both the first and second cropping season (Figure 2). Apart from its role in providing market income. *Tawa* plays an important role in food security in the dry season. *Tawa, Kplobè, Kaki, Malanville* and *Olikpokpo-doudou* are early-maturing varieties mainly cultivated during the two cowpea cropping seasons. During the second cropping season, half of all farmers cultivated late-maturing and half cultivated early-maturing varieties.

Farmers use more for home consumption than they sell (Table 9). Yet most farmers sell cowpeas, and at least part of all varieties grown is offered for sale. In the case of *Tawa*, the proportion sold is greater than the part consumed. This is due to the fact that farmers usually consider *Tawa* to be a commercial, early-maturing variety and most farmers grow it. Late-maturing varieties are used more for consumption than early-maturing ones. The harvest of late-maturing varieties occurs at the beginning of the dry season (November–December) when an important portion is reserved for home consumption during the dry season or period of food shortage. These late-maturing varieties can also tolerate a relatively long period of storage. Moreover, they also have good technological and culinary traits, which make them preferred for home consumption by farmers.

Technological and culinary traits

The cowpea varieties *Mata*, *Atama*, *Djètoko* and *Egni-awo* are varieties providing with good taste and technological traits suited to the preparation of cowpea food derivatives (Table 10). The late-maturing variety *Djètoko* got the highest score, suggesting that it met the desired food technological and culinary preferences of most consumers and food processors. *Kplobè* is the less favoured variety for processing.

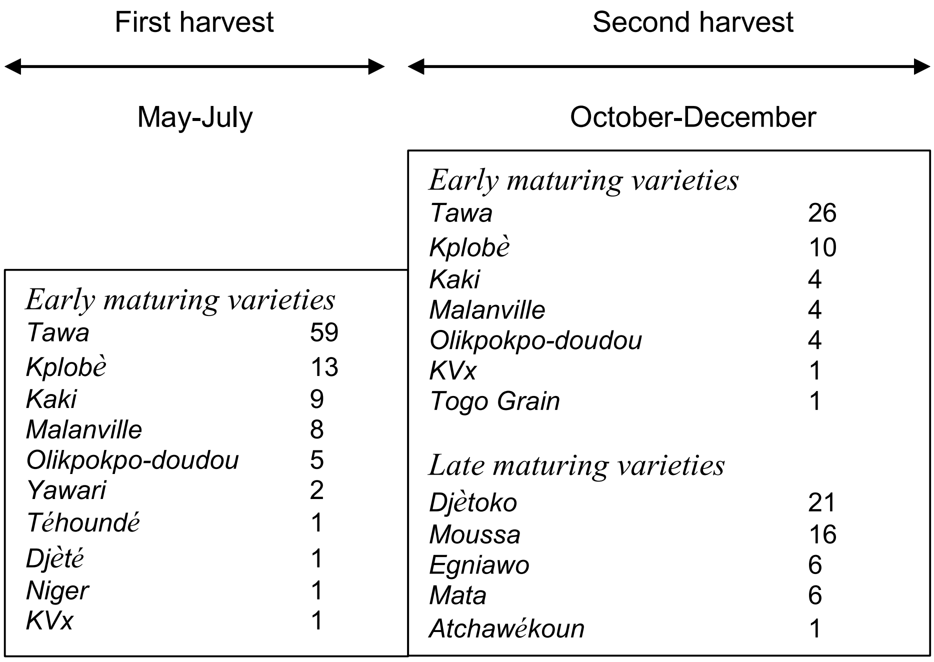

Figure 2. Cowpea harvest and use periods ensuring food security and income in households. The figures represent the proportion of farmers (in %; n = 91) who harvest a specific cowpea variety in a specific period.

Table 9. Allocation of cowpea harvest to home consumption and selling in Dani and Diho.

	Variety	Number of farmers	Home consumption[1] Mean	Selling[1] Mean
Early maturing	*Atacora*	6	5.2	4.8
	Kaki	10	5.6	4.4
	Kplobè	15	5.5	4.5
	Malanville	11	5.2	4.8
	Tawa	60	4.5	5.5
Late maturing	*Djètoko*	23	7.3	2.7
	Egni-awo	5	5.5	4.5
	Mata	6	5.8	4.2
	Moussa	18	5.7	4.3

[1] The whole harvest is considered on a basis of 10 units.

Table 10. Technological traits of cowpea varieties revealed by farmers in Dani and Diho.

Varieties	No. of farmers	Technological traits					
		Taste	Smell	*Abobo*	*Abla*	*Ata*	Cooking duration
Tawa	75	4	4	4	4	4	52
Mata	30	4	5	5	5	5	47
Djètoko	23	5	5	5	5	5	39
Malanville	6	4	4	4	4	4	45
Atacora	7	4	4	4	5	5	47
Kaki	7	4	4	4	4	4	47
Egni-awo	6	5	5	4	5	5	37
Kplobè	16	3	4	3	3	4	58

Scale applied to all traits except for cooking duration: 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high. The scoring represents farmers' evaluation of each variety trait with regard to each variety. *Abobo*, *Abla*, and *Ata* are local special foods made from cowpea. This scoring reveals the degree of satisfaction provided by each variety in considering each variety trait. Cooking duration is given in minutes. Only farmers who held technological knowledge on a given variety were requested to assess it (n=91).

Rites and cowpea diversity

Table 11 establishes the relationships between divinities and farmer cowpea choices in Diho and Dani. Various varieties are offered to specific divinities. Most of these varieties have one characteristic in common – they are white, a colour often taken to symbolize purity. This culturally rooted colour preference seems to affect cowpea diversity in the area greatly. In Diho, the variety *Mata* is considered to be the variety of the ancestors. Just after harvest, it is used for food for offering to twins, the deity *Abikoun*, and to community ancestral spirits. *Moussa* and *Atama* are used for festivities associated with the birthdays of twins and in offerings to *Tohossou*. In Dani, several cowpea varieties – *Djètoko, Atama, Moussa*, and *Tawa* – are used in funerals. White is an important colour in funerals, so white cowpea varieties are appreciated for such ceremonies. The same varieties are also used in offerings to *Fâ, Tchango* (*Shango*) and *Tohossou*. The variety *Djètoko* is important in offerings, because it is highly appreciated and cultivated extensively due to its good taste.

Socio-cultural and market demands

Different cowpea varieties play important cultural and religious roles within each community. In Diho, most farmers considered white varieties important to meet socio-cultural needs; on the other hand, *Tawa* and *Djètoko* are cowpea varieties that most

Table 11. Cowpea varieties related to ritual practices by 40 farmers in Diho and Dani.

	Dani		Diho	
Ritual acts	No. of farmers[1]	Varietal group or varieties	No. of farmers[1]	Varietal group or varieties
Funerals	22	White varieties, *Djètoko, Moussa, Tawa, Atama*	5	White varieties, *Tawa*
Twins	5	*Atama*	10	White varieties, *Mata*
Baptism, naming	2	White varieties	5	White varieties, *Djetoko, Tawa*
Fâ	2	White varieties	-	
Tohossou	2	*Atama, Moussa*	-	
Vodoun	2	White varieties		
Wedding	1	White varieties	1	White varieties
Ogoun	1	*Moussa*	-	
Offertory to the King	1	White varieties	-	
Tchango	-		2	*Mata*
Abikoun	-		2	*Mata*
The Thunder	-		1	White varieties
Easter	-		1	White varieties
Reunion	-		1	*Djètoko*

[1] Some farmers mentioned more than one ritual and others mentioned no rituals at all.

farmers chose to use for supplying commercial requirements (Table 12). In Dani, however, there was a significant link between social and market demands, meaning that the same varieties respond both to socio-cultural and economic needs.

Varietal grouping

As shown earlier in this chapter, the dominant cultural colour preference of farmers in the Guinea-Sudan zone of Benin is for white varieties. In addition to colour preference, the current strategic choice of farmers is based on two agro-physiological types: early-maturing and late-maturing varieties (Table 13). These varieties are the ones satisfying consumption needs and local market preferences, guaranteeing both income and food security for farmers' households. In general, both men and women grew more early varieties than late ones. However, women tended to produce more late-maturing varieties than men. From Table 13, it appeared that for farmers who produced two varieties of the two maturity types, the ratio (proportion of farmers producing early-maturing to farmers producing late-maturing varieties) was 23:7 for

Table 12. Frequency distribution of the socio-cultural and economic demands expressed by farmers to use different cowpea varieties in Diho and in Dani.

	Dani (40)		Diho (40)	
Cowpea varieties	Socio-cultural demand	Economic demand	Socio-cultural demand	Economic demand
Moussa	34	25	15	9
Mata	26	19	24	12
Atama	22	18	15	9
Tawa	24	18	18	13
Djètoko	29	10	15	10
Red varieties	6	4	-	-
Niger	-	16	-	10
Malanville	-	16	-	10
Ewa Nigeria	-	17	-	10
Kpodjiguèguè	-	1	-	1
Atacora / Olikpokpodoudou	-	16	-	9
Egni-awo	-	2	-	-

men and 8:4 for women; for farmers who grew three varieties, the ratio was 7:2 for men and 2:1 for women. For economic reasons, men are more and more oriented towards early-maturing varieties, in order to have two cowpea harvests per year. These results suggest that women have a greater positive impact than men have on maintaining the current diversity of the two dominant agro-physiological types of cowpea varieties in the area of study.

Also Table 14 shows that there were more early varieties grown than late-maturing ones. This was true within each socially distinguishable group. In general, it appeared that on average less than one late-maturing variety was grown by the different social categories of farmers, distinguished based on sex, religion, ethnicity, origin, age, and household size. Some socio-cultural factors appeared to influence the choice of cowpea varieties (Table 14). The mean number of late-maturing varieties grown by female farmers (0.7) was slightly higher than the number grown by male farmers (0.6). *Indigenes* (who are mainly farmers of the *Tchabè* ethnic community) appeared to grow the fewest early-maturing varieties of all the social groups considered. Conversely, they tended to grow more late-maturing varieties than migrants. Farmers of a traditional (animist) belief tended to grow more early-maturing varieties than farmers claiming modern religion beliefs. The t-statistic revealed significant differences between the choices made by farmers for the two categories of varieties. Table 14 also

Table 13. Number of varieties of cowpea grown by male or female farmers (n=91) for two different categories of varieties: early maturing and late maturing ones.

	Early-maturing group			Late-maturing group			All varieties		
No. of varieties grown	Male (n=65)	Female (n=26)	Total (n=91)	Male (n=65)	Female (n=26)	Total (n=91)	Male (n=65)	Female (n=26)	Total (n=91)
0	3	1	4	36	14	51			
1	37	18	55	26	9	35	21	9	30
2	23	8	31	7	4	11	30	12	42
3	7	2	9	2	1	3	14	4	19
4	1		1				4	2	7
5							1	1	2
6							1		1
Total (%)	71	29	100	71	29	100	71	29	100

Table 14. Mean number of early- or late-maturing cowpea varieties grown as affected by some socio-cultural characteristics of farmers (n=91).

Farmers' socio-cultural characteristics	Levels	No. of Farmers	Early maturing		Late maturing		t-statistic[1]
			Mean	S.D.	Mean	S.D.	
Sex	Male	65	1.5	0.79	0.6	0.77	6.24***
	Female	26	1.4	0.70	0.7	0.87	2.98***
	F-Statistic[2]		**F=0.48**		**F=0.20**		
Religion	Traditional	16	1.8	0.77	0.3	0.44	6.70***
	Modern	75	1.4	0.76	0.8	0.84	5.02***
	F-Statistic		**F=2.60***		**F=5.58****		
Origin	Native	33	1.2	0.61	0.8	0.88	1.78*
	Migrant	58	1.7	0.78	0.6	0.75	7.50***
	F-Statistic		**F=10.03*****		**F=1.77**		
Ethnicity	*Idatcha*	32	1.7	0.81	0.8	0.82	4.44***
	Tchabè	33	1.2	0.61	0.8	0.88	1.78*
	Others	26	1.6	0.76	0.3	0.54	6.91***
	F-Statistic		**F=5.26*****		**F=3.95****		
Age (year)	< 31	20	1.4	0.88	0.6	0.75	3.08***
	31–50	57	1.5	0.76	0.8	0.80	4.80***
	> 50	14	1.8	0.65	0.4	0.84	4.28***
	F-Statistic		**F=0.20**		**F=1.61**		
Household size	1 to 5	44	1.5	0.70	0.5	0.66	7.04***
	> 5	47	1.4	0.82	0.8	0.90	3.35***
	F-Statistic		**F=0.77**		**F=2.94***		
All categories together		91	1.5	0.77	0.7	0.80	6.90***

Games-Howell multiple comparisons with ethnicity[2]

Varietal group	(I) Ethnicity	(J) Ethnicity	Mean Difference (I-J)	S.E.
Early-maturing group	*Idatcha*	*Tchabè*	0.57***	0.180
		Others	0.14	0.207
	Tchabè	*Idatcha*	–0.57***	0.180
		Others	–0.43**	0.183
	Others	*Idatcha*	–0.14	0.207
		Tchabè	0.43**	0.183
Late-maturing group	*Idatcha*	*Tchabè*	–0.01	0.211
		Others	0.50**	0.181
	Tchabè	*Idatcha*	0.01	0.211
		Others	0.51**	0.188
	Others	*Idatcha*	–0.50**	0.181
		Tchabè	–0.51**	0.188

[1] Results using SAS 8e;

[2] Results from SPSS 12.0.1; Level of significance: 1%:***; 5%:**; 10%:*

shows that the number of varieties between the categories of the different socio-cultural factors were present both for early-maturing and late-maturing varieties. Such differences were significant for religion, origin, household size, and ethnicity as indicated by the F-statistic and the Games-Howell test for multiple comparisons.

Summary of findings on cowpea

This study of cowpea has revealed that cowpea is a central element in religious rituals and ceremonies associated with social relations in the Guinea-Sudan zone of Benin. Female farmers showed high predilection for cultivation activities with ritual significance. White types are preferred in the area of study. The diversity of cowpea varieties was related to socio-cultural and market preferences. Cultivated varieties comprised two agro-physiological types: early-maturing and late-maturing varieties. Men showed more tendency towards the early-maturing varieties, allowing them to grow two cowpea crops per year; women farmers revealed a positive preference for maintenance of both two agro-physiological types of cowpea. These varieties offered farmers food security all year round and responded to various consumer food and technological preferences. Results suggest that female cowpea farmers have a positive impact on the maintenance of cowpea varieties.

Discussion

The priority farmers give to food security in households is an important factor in diversity maintenance. Food security provides the frame within which yam and cowpea varieties with low socio-cultural and market values survive. Indeed, it is so important to cope with hunger in this way that these kinds of varieties have come to dominate in terms of area planted and percent of farmers cultivating them. Data on areas cropped and proportion of farmers cultivating each yam and cowpea variety have been reported elsewhere (Zannou *et al*., 2004).

This study also revealed that the larger ethnic communities in the study area – *Tchabè, Idatcha* and *Mahi* – share some socio-cultural rituals, including funeral rites, ceremonies for twins, and offerings to *Tohossou*. Yam and cowpea feature in all these rituals (Table 15). The yams are mainly the poundable varieties, such as *Laboko* and *Ala-N'kodjéwé*. The featured cowpea varieties, such as *Atama*, *Moussa*, and *Tawa*, are white. The food provided during these rituals can either be a specific preparation based on one or other specific crop variety, or a combination of the two. These varieties, which have high technological requirements, are also highly demanded by the market, and are also noted as food security crops. They can thus be considered multi-purpose varieties, even if they are harder to grow than some other varieties.

This study goes beyond the general assumption that crop varietal diversity

Table 15. Some rituals involving both yam and cowpea varieties in local communities (n=40 from each village).

	Cowpea (Dani and Diho)		Yam (Yagbo and Kpakpaza)	
Rituals	Farmers	Varieties	Farmers	Varieties
Funerals	27	White varieties, *Tawa Atama, Moussa*	41	Pounded, *Laboko, Ala-N'kodjéwé, Effourou*
Twins	15	White varieties, *Atama*	6	Pounded, *Laboko, Ala-N'kodjéwé*
Vodoun	2	White and red varieties	9	Pounded, *Laboko, Ala-N'kodjéwé, Tévi, Gangni*
Fâ	2	White varieties	5	Pounded, *Laboko, Ala-N'kodjéwé, Tévi*
Tohossou	2	White varieties, *Atama*	4	Pounded, *Laboko*

management is mainly a matter of introducing new varieties, and specifically analyses factors that contribute to or affect the maintenance and use of crop varieties by farmers. The use farmers make of yam and cowpea varietal diversity is not solely an expression of an individual preference set, but the outcome of a community-specific intersection of economic and cultural factors. Collective factors are as important as rational choices expressed through market forces. Here, we state that the maintenance of a specific crop variety in the farming system depends (at least in part) on the socio-cultural values assigned to that variety by local communities. The strength of this factor derives from the 'social fact' that farmers believe they belong to a specific ethnic community (or religious congregation) and recognize and express social membership through rituals activities that draw the members of the community together. It is in this framework of collective values that a diversity of yam and cowpea varieties is drawn upon farmers to communicate with and thank various divinities in each community.

Agbo (1995) and Millar (1999) make similar points about the importance of divinities for local communities. It is through these rituals that ancestors continue to play a role in the life of the living; their souls remain associated with the terrain and they are thus available as intermediaries between the divinities and the living (Millar, 1999); the spiritual, cultural and the natural worlds are interlinked in local agricultural thinking (Agbo, 1995). People believe that their planting materials were given to them by their ancestors, who also taught them how to survive. Continued survival depends on continuing to pay close attention to the ancestors. For most farmers in central Benin, crop variety choice cannot, therefore, be solely a matter of technical efficiency. In the communities of the southeast of Guanajuato in Mexico, the cultural significance of food and culinary practices explained how farmers allocate their maize area, and as a consequence, the number of maize landraces that they grew on their farms (Smale *et al*., 2001). Taking the case of cassava diversity among Makushi Amerindians of Guyana in South America, Elias *et al*. (2000) showed various socio-cultural factors exercised selective pressure and food preparation, cultural knowledge and social processes all played a role in bringing cassava varietal and genetic diversity into existence. In the Southern Peruvian Sierra, Zimmerer (1991) argued that off-farm labour is negatively correlated with the maintenance of crop diversity because cultivating diverse types of maize and potatoes is highly labour intensive and entails high opportunity costs.

But maintenance of varieties is not solely a matter of widely-accepted socio-cultural values. Besides the socio-cultural context, the market demand strengthens the use and maintenance of crop varieties in local farming systems. But even here cultural aspects may be surprisingly important. This is an important observation, since it suggests (for this area at least) that there will be a positive link between levels of ethnic diversity and levels of crop varietal diversity. Thrupp (2000) argued that the numerous practices used for enhancing agricultural biodiversity are tied to the rich cultural diversity and local knowledge supporting the livelihood of agricultural communities. Along the same lines, Pretty and Smith (2004) suggested that social learning creates positive biodiversity outcomes and social capital for biodiversity improvements.

This study adds the finding that socio-cultural factors and market demand are inter-linked, not independent, dimensions. Put simply, where tradition lives (as in central Benin) tradition sells. But it also contributes to stability of local production systems. Di Falco and Perrings (2003) found that crop genetic diversity is positively related to mean income and negatively related to the variance of income. The result on the variance of income confirms that greater genetic diversity makes a system more resilient, e.g., to rainfall and temperature fluctuations.

This chapter also adds an important finding on gender. Female farmers had a greater positive effect on the maintenance of diversity of both yam and cowpea than male farmers, as the former valued food security, long storage and technological and culinary traits more than the latter. As shown by Pionetti (2005), women in semi-arid India have the most stakes in increasing crop diversity as they see a direct relationship between diversity and food security, and have the responsibility for preparing meals. They cultivated varieties of different duration to minimize the risk of harvest failure, to meet multiple needs, and to ensure household food security.

The implication of this study for sustainable use and conservation of genetic resources is that farmers bring a variety of motivations to variety choice and management, and that this helps maintain a wider range of material than utilitarian

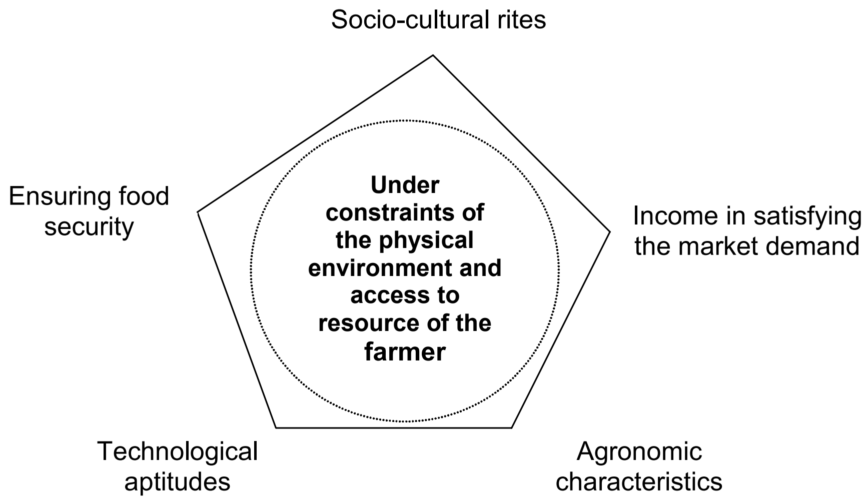

Figure 3. Functions of yam and cowpea varieties in local communities.

selection alone. The maintenance of crop varieties in farming systems or the adoption of crop varieties by farmers should take into account all the relevant components (Figure 3): viz. technological characteristics, socio-cultural values, market demand, agronomic characteristics, capacity to cope with the climatic risks, and the capacity to contribute to food security. The study suggests that on-farm management of genetic resources is in important respects driven by social factors. Any strategy for on-farm diversity management should develop an integrated framework for evaluating social factors alongside biological factors.

CHAPTER 5

The value of yam and cowpea diversity in the Guinea-Sudan transition zone of Benin: Market evidence

A. Zannou, P.C. Struik and P. Richards

Abstract

In this chapter, traders' and consumers' preferences for different yam and cowpea varieties are analysed. For both crops, prices vary by variety, showing that the market values distinct crop traits differently.

For yam, the use for which each variety is appreciated is the most important factor determining the selling price. Market place decision-making with regard to the importance of intrinsic qualitative attributes (such as taste, plasticity, swelling, smelling, flesh colour, maturity, absence of knobs and rot) was analysed using the pair-wise comparison technique. The study showed that the main quality criteria for poundable varieties are plasticity, absence of knobs, taste, and swelling (i.e., the ability to increase its volume while being pounded). The quality of the paste depends on the quality of the 'cossettes' (dried slices). 'Cossette' quality criteria included possibility for long storage, absence of blackening during drying, absence of fibres inside the tuber, strong swelling of the paste, and high eating quality of the paste and the wassa-wassa also called 'African couscous', a kind of granular flour prepared from yam.

The variety preferences of cowpea traders were motivated by seed purity, grain status, skin colour, absence of physical impurities, resistance to bruchids, quality after storage, and grain size. In addition to the physical aspect, cowpea traders' preferences for varieties also reflect profit margins to be gained from particular varieties. Consumers' preferences differ mainly according to grain colour and reflect cultural assumptions. For cowpea consumers the study confirmed strong preferences in most communities from central part of Benin for white cowpea varieties. These preferences were found both among men and women. While red cowpea seeds were somewhat acceptable to some consumers, most remained reluctant to purchase black ones. A number of other attributes are also considered by consumers: swelling (during cooking), taste, softness, skin and eye colour, cooking time, and scent. Taste, absence of bruchids and swelling are the most highly ranked cowpea attributes for both men and women when considering boiled cowpea.

These market data for yam and cowpea confirm that successful varietal technology development on food crops ought to include reference to consumer preferences, including cultural preferences. Each yam and cowpea variety has a distinctive trait that the market values at a specific price. These varietal price differentials are present throughout the year.

Keywords: Market preferences, traders, consumers, yam, cowpea, price, quality criteria, farmer varieties.

Introduction

Developing well-adapted technologies to satisfy consumers' preferences is a challenge for crop scientists in developing countries. Various actors in the crop varietal technology development chain need to know about consumer preferences: "breeders need to know what characteristics consumers want"; "IPM specialists need an estimate of the level of grain damage acceptable to consumers" (Coulibaly and Löwenberg-De Boer, 2002); "knowledge of the distribution of preferences allows researchers to analyse the distribution of welfare effects from a policy change" (Bajari and Benkard, 2001). Knowledge on consumer preferences is then essential to develop new varieties. Adoption of new varieties is often limited because improved varieties do not possess the traits valued by producers and consumers (Pingali *et al*., 2001).

Markets are central crossroads where actors reveal preferences, and where agricultural products, such as the yam and cowpea studied in this thesis, are put to the real consumer test. The market can value multiple traits or attributes. Farmers often assess varieties of yam and cowpea according to their market value. Market values reflect traits such as taste, cooking time, skin colour or roughness, and ease of removal of skin before or after soaking, etc. (Zannou *et al*., 2004). Attributes are found to varying degrees in different yam and cowpea varieties. The characteristics of one or a few varieties cannot meet all needs of farmers and consumers over time. A single variety, or small set of varieties, cannot, therefore, give complete satisfaction to consumers and other agents in the chain (including traders and farmers). Considering that actors' preferences are central in the use and management of different crop varieties, the aim of the present study is to consider how diversity of yam and cowpea in the central part of Benin is valued in the market. The objectives are (1) to assess buyers' (traders' and consumers') preferences, (2) to assess characteristics of yam and cowpea varieties as perceived by traders and consumers, and (3) to assess how traders and consumers make choices about what to make available on the market.

Research methodology

Data collection

An initial diagnostic research phase brought out some of the diversity of yam and cowpea found in local markets (Zannou *et al*., 2004). In the later research phase of the study a more complete data set on varietal diversity, prices for each yam and cowpea variety, and quantities of yam and cowpea sold on the market of Glazoué each weekly market day throughout a full year (2003) was assembled. Additional monthly price data were collected by the recall method from market traders for years 2000–2002 and 2004. These 5-year price data (2000–2004) allowed some analysis of seasonal price variation.

Market traders and consumers usually know which characteristics of different varieties are involved in price variation. They were therefore asked to list the characteristics they desired in yam and cowpea varieties when selling or buying. To address the question for which varietal characteristics traders accept from farmers to buy varieties at different prices questionnaires were addressed to traders in which they listed the varietal characteristics they considered important. A total of 74 yam and 77 cowpea market traders were interviewed. The data collected comprised information on preferred varieties, preferred variety characteristics, consumption quality traits and the ranking of such traits, trader profiles, and strategies for purchasing and selling.

Consumer preferences are expressed in relation to several factors and variety attributes (price, taste, etc.). Individuals with their individual preferences rank such factors or attributes differently. To analyse consumer preferences, a questionnaire was used to interview 160 female and male consumers of cowpea and 160 female and male consumers of yam from the urban zone around the markets of Glazoué and Savè. Consumers were asked to state their preferences. Data collected covered interviewee profiles, variety traits important in consumer choice, and physical features of varieties, such as processing and cooking characteristics, taste, storage capability, prices, etc.

A Likert scale technique and pair-wise comparison methods were developed to analyse the different attributes involved in preferences for consumption traits. Likert scales are categorical ordinal scales used in social sciences to measure attitude. A Likert scale measures the extent to which a person agrees or disagrees with a question (or statement). Subjects were asked to express agreement or disagreement on a five-point scale. Each degree of agreement was given a numerical value from one to five. For example, the scale can be 1 = strongly disagree, 2 = disagree, 3 = not sure or undecided, 4 = agree, and 5 = strongly agree. The results provided ordinal level indications of preferences.

Data analysis

Graphic analysis was made on diversity of yam and cowpea varieties, including the price differences between them. Considering the price variation on a given market day for different yam and cowpea varieties, data analysis takes into account each of the characteristic of the product for which traders and consumers concede different prices in selling or buying. Ranking of preference scores combined assessments of several factors given different weightings by individuals. For the analysis of actors' preferences, Kruskal-Wallis and Wilcoxon-Mann-Whitney tests were used (Hamburg, 1983). These tests were based on the sum of the ranks obtained from pooling the ratings of the different attributes under evaluation. Considering a base variable for each trait, the marginal price values for each factor considered were analysed. Marginal prices indicate how much value a buyer places on another unit of a given characteristic, given the set of initial characteristics.

Results and analysis

Yam traders' valuing yam varieties

Interactions between farmers and traders and socio-economic profiles

On the Glazoué market, yam traders organize themselves in groups of re-sellers. These re-sellers are the intermediaries between farmers and the consumers or other traders willing to buy yam from the market. Each group develops capacities to maintain its client base in the market. Usually, each group comprises several traders moving to the producers to buy yam in the fields. When these traders are not able to reach a yam producer, the latter is obliged to transport the product directly to the market. There are penalties for traders who flout market rules. Members of each trading group agree to mobilize joint funds for their activities. About a dozen such groups exist for the yam market of Glazoué.

There are several categories of market actors: farmers, collectors, wholesalers, farmers-wholesalers, semi-wholesalers and retailers. Agricultural activities, trade and processing are the main activities of agents active in the commercialization of yam on Glazoué and Savè markets. Trading is considered a main activity for most of them (about 58% of the men interviewed and about 70% of the women). The main destinations for yam from the market are Cotonou, Porto-Novo and Bohicon. Secondary destinations are Abomey, Glazoué and the Republic of Gabon.

Various motivations underline the choice of commercialization of yam by traders: profitability, experience, self-consumption, inheritance, income sources, and food security. Purchase takes place on the market or at field borders after the harvest. The main reasons why the actors are motivated to participate in yam trading are profitability and an activity inherited from parents. Most of them found yam trading profitable relative to other activities, or a useful means to increase their income (59% of men and 49% of women). Others (45% men and 30% women) were motivated to this activity by inheritance of skill, knowledge and capital from their parents (Table 1). The income from yam trade represents an important part of the traders' income. When yam trade is undertaken the income from it dominates the income from all other trading activities. There is little variation in length of experience by gender – on average, 11 years for men and 10 years for women (Table 1).

Table 1. Traders' activities, reasons for traders to be involved in selling yam, experience and part of income generated by selling yam.

	Men				
	Reasons for yam trading			Experience	
	Inheritance	Profitability	Others[1]	< 10 years	≥ 10 years
Part of trade out of the total income (10-point grade)					
1 to 4	19	3	13	23	10
5 to 7	19	13	10	27	17
8 to 10	6	0	16	10	13
Total (%)	*45*	*16*	*39*	*60*	*40*
Part of trade from yam out the total income (10-point grade)					
1 to 4	13	6	16	20	13
5 to 7	26	10	19	37	20
8 to 10	6	0	3	3	7
Total (%)	*45*	*16*	*39*	*60*	*40*

	Women					
	Reasons for yam trading				Experience	
	In-heritance	To have a job	Profi-tability	Others[1]	< 10 years	≥ 10 years
Part of trade out of the total income (10-point grade)						
1 to 4	5	2	2	0	5	5
5 to 7	20	12	19	16	40	28
8 to 10	5	7	5	7	16	7
Total (%)	*30*	*21*	*26*	*23*	*60*	*40*
Part of trade from yam out the total income (10-point grade)						
1 to 4	7	5	3	3	12	7
5 to 7	23	16	21	19	49	30
8 to 10	0	0	3	0	0	2
Total (%)	*30*	*21*	*27*	*22*	*60*	*40*

[1] Low income, on advice from a friend, personal initiation.

Table 2. Importance in financial profitability for yam varieties for traders assessed on a grade of 10 points.

	Grade in financial profitability				
Yam varieties	"1-2"	"3-4"	"5-6"	"7-8"	"9-10"
Laboko[1]	1	1	0	33	21
Kabilatonan	1	0	3	0	0
Gnidou	9	3	13	1	1
Ala N'Kodjewe	2	3	14	15	1
Gangni	1	4	6	1	4
Manfobo	0	0	2	1	0
Effourou	0	0	1	1	0
Adigbili	0	1	0	0	0
Klatchi	0	4	2	5	0
Gnanlabo	0	1	4	3	0
Anago/Moroko	1	4	11	13	2
Aga	10	4	4	2	0
Mondji	0	0	1	0	0
Kokoro	1	4	17	12	1

[1] The number for each variety is the absolute frequency of traders mentioning that particular variety (n =74 traders).

Market actors' preferences for yam varieties

Traders revealed that different yam varieties sold on local markets provided them different levels of profitability (Table 2). The variety Laboko was the most profitable for most persons involved in yam commercialization. On the other hand, the varieties Gnidou and Florido/Aga were considered least profitable by most traders, although Florido is widely cultivated and occupies a large surface area. In any period of the year, Laboko is highly requested by consumers both in towns and in rural area for its high quality pounded yam. It appears that market desirability and profitability for traders is not the same thing as desirability for subsistence. Laboko is very profitable at the market, whereas Florido plays a crucial role in subsistence (see also Chapter 5).

Diversity of yam varieties and corresponding market prices

There is fluctuation in the number of varieties brought to the market over the year (Figure 1). This variation is often determined by the seasonal activities of farmers and by the periods when farmers are in high need of income. The number of yam varieties

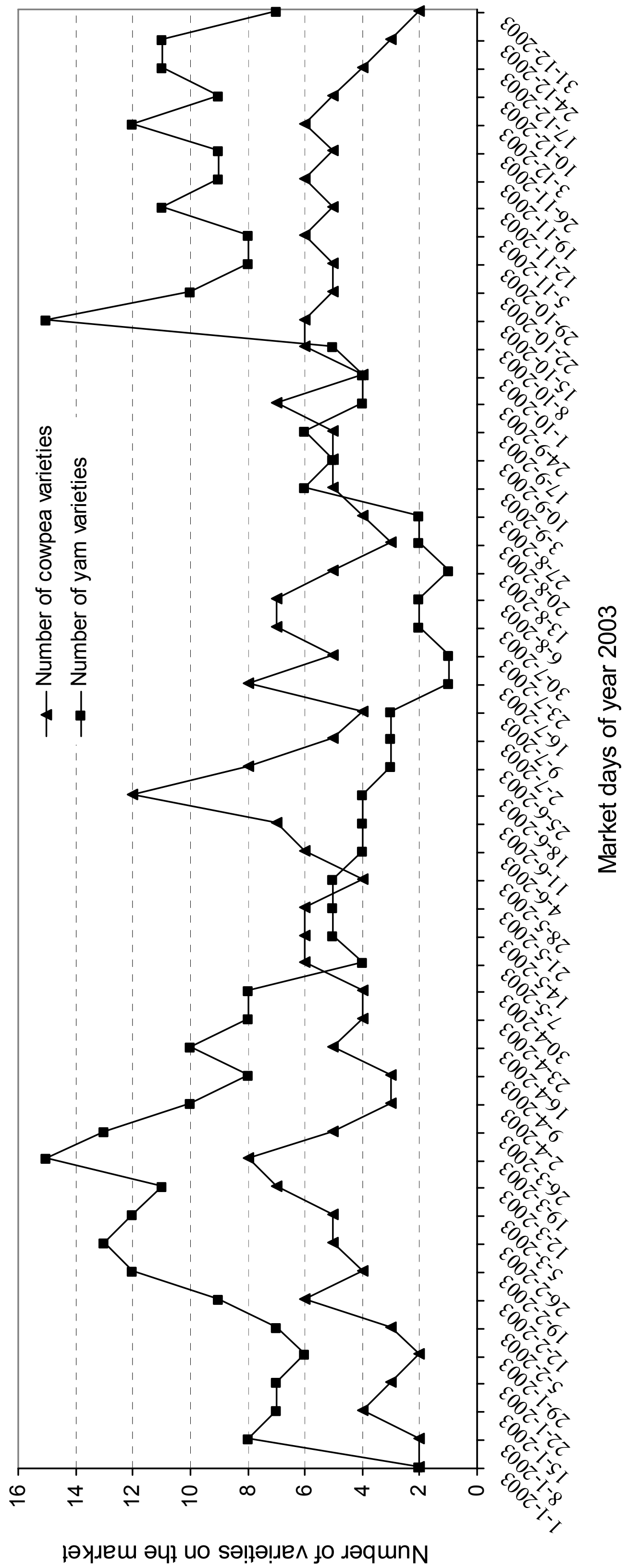

Figure 1. Diversity of yam and cowpea varieties on sale on the market of Glazoué.

on sale mostly averaged between 6 and 8 at the beginning of January 2003. This number increased to 15 varieties towards the end March, a period when farmers expressed high needs for income to support new agricultural activities at the beginning of the rainy season. May is often considered ‘starvation month’ locally. From May to July, the number declined to one or two varieties, mostly the *D. alata* variety Florido, during the food shortage period. From August to September, the first harvest of the early-maturing varieties is sold on the market. October to December are marked by the harvest of early- and late-maturing varieties, a period in which farmers are in need of income to install a new yam crop, and to satisfy other needs. In this period there was an increase of yam diversity on the market. Figure 2 shows the monthly seasonal fluctuations of yam varieties sold on the market of Glazoué over the period 2000–2004, as estimated from trader recall data. In general terms it shows that although differentials between the different varieties fluctuate (reflecting supply variations consequent upon different seasonal production regimes) there are relatively few crossover points. The relative order of price differentials is quite well maintained overall (Laboko, for example, is always the top variety) across the data set. This relatively well-maintained ‘layering’ of prices is here interpreted as evidence that price differentials are significantly linked to quality variations (i.e., that they reflect more than seasonal variations in the relative abundance of supply of different yam varieties). In other words, the quality differences between yam varieties are reflected in market values. As a caveat the reader is reminded that the data set is based only on trader recall for four out of five years, but even conservatively interpreted, the price data show a distinct varietal layering in trader’s perceptions and memory. Absolute price variation is larger for the more expensive varieties than for the cheaper ones.

Over the five years of availability of D. cayenensis / D. rotundata varieties on the market, the mean monthly average price of Laboko varied between 149 CFA/kg in September to 200 CFA/kg in May and June (Table 3). Laboko is a reference point, since it makes the best pounded yam, the most preferred food type. Anago sold for more than 100 CFA/kg, except in September, October and December. The average price of Ala-N’kodjewe and Dodo was more than 100 CFA/kg during the ‘starvation’ period. For other early-maturing pounded yam varieties, the mean price was less than 100 (Gangni, Mafobo, Djilaadja, Kabilatonan, Gnidou, Agatou). These varieties are mainly harvested during the period of declining prices, August-September. The late-maturing type, Gnanlabo, is the one for which price is the highest, varying between 114 and 169 CFA/kg. The prices of other late-maturing varieties (Klatchi, Kokoro) are lower than the one for Gnanlabo. Among late-maturing varieties, Gnanlabo and Klatchi are varieties for pounded yam, while Kokoro is mainly designated for making paste in dry season to cover food needs in the ‘starvation’ period. The average price of

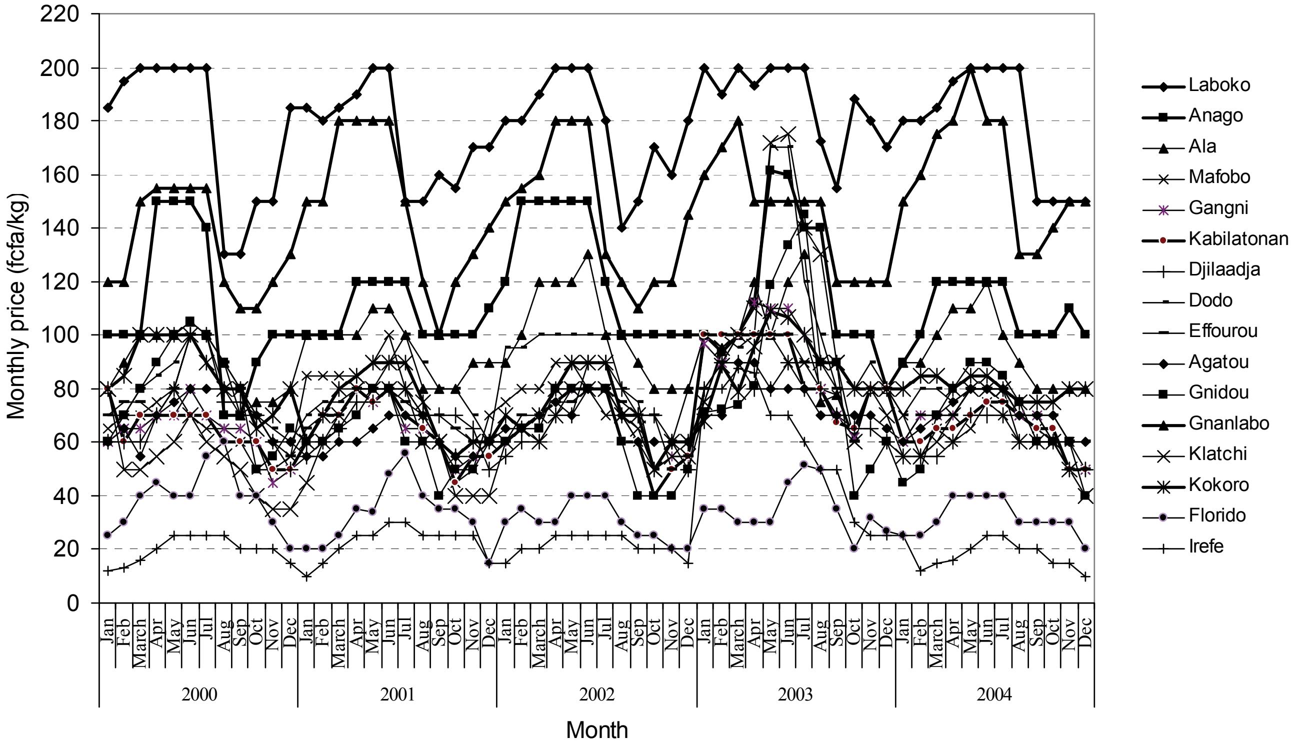

Figure 2. Yam price variations on the market on Glazoué over the period 2000–2004.

D. alata variety Florido and *D. dumetorum* variety Irefe is lower than 50 CFA/kg.

Given the top price paid for Laboko, this has been chosen as a key variety for comparisons. Figure 3 reveals that in January of each year the average price difference between Laboko and the *D. alata* variety Florido or *D. dumetorum* variety Iréfé is 160 CFA/kg. This difference is maintained until June, but decreases to 120 CFA/kg in August and September. The lowest price differential is found between Laboko and Gnanlabo. The average monthly price difference for Gnanlabo varied between 20 and 40 CFA/kg over the 5-year period. The differential is mainly lowest during the hungry period May-June. Between these two extremes, we meet other varieties, e.g., Anago, Ala, Gangni, where differentials run at 100 CFA/kg in January, February, March, April, May and June. The price differential for other yam varieties (Djilaadja, Dodo, Kabilatonon, Agatou, Gnidou, Mafobo, and Effourou) varied between 100 and 120 CFA/kg from January to July. In August and September, the difference between Laboko and other varieties decreases. These data confirm that more than bulk is involved in determining prices for yams on local markets. Crop scientists need to know that traders and consumers recognize large quality differentials, as revealed by market price data, for different yam varieties. Yam improvement programmes need to recognize the basis for these quality valuations, if they are to assist farmers in Benin to avoid poverty by opening up sustainable niche market opportunities.

Table 3. Average price of yam varieties per month over the period 2000–2004 (CFA/kg).

			Average price per month over the period 2000-2004 (CFA/kg)												
Species	Variety-type	Varieties	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
DCR	Early maturing	Laboko	186	185	192	196	200	200	186	159	149	163	162	171	179
		Anago	102	109	114	130	140	140	128	102	94	98	102	98	113
		Ala	92	95	104	110	108	117	106	87	80	75	81	82	95
		Dodo	81	84	86	88	104	108	100	84	77	70	69	68	85
		Effourou	67	75	77	79	83	88	84	79	74	65	60	60	74
		Mafobo	74	77	80	82	85	83	75	71	65	53	60	63	72
		Gangni	67	72	77	82	83	86	79	70	67	56	57	59	71
		Gnidou	59	64	71	80	94	98	94	75	62	48	51	55	71
		Kabilatonan	72	71	75	78	79	81	75	67	63	55	57	58	69
		Djilaadja	61	65	66	71	75	86	84	73	69	67	60	52	69
		Agatou	62	64	69	74	74	78	78	72	66	65	61	61	69
	Late maturing	Gnanlabo	146	151	169	169	173	169	153	128	114	122	128	137	147
		Kokoro	72	79	83	88	95	94	90	78	75	65	70	72	80
		Klatchi	63	65	68	77	94	97	88	75	65	50	52	48	70
DAL	Late maturing	Florido	27	29	31	36	37	43	49	42	33	30	28	20	34
DDU	Late maturing	Irefe	28	28	32	34	33	35	33	29	27	22	21	16	28

DCR = *D. cayenensis* / *D. rotundata*; DAL = *D. alata*; DDU= *D. dumetorum.*

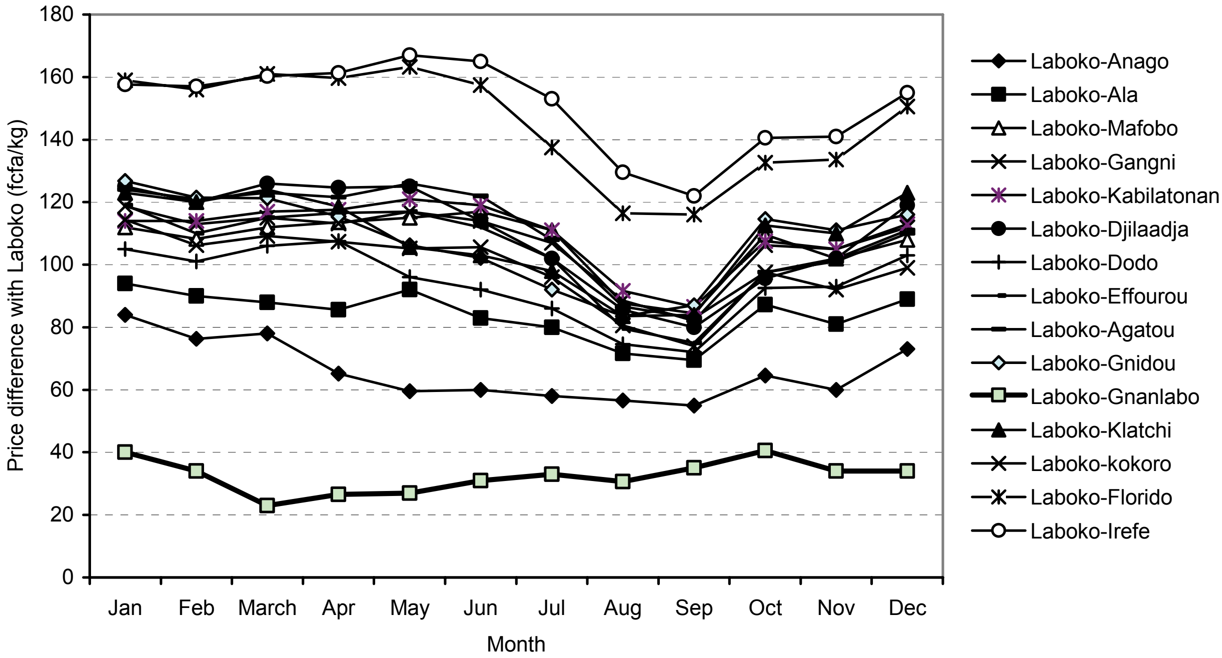

Figure 3. Average monthly price difference between Laboko and others yam varieties sold on the market of Glazoué over 2000–2004.

Market price premium and yam variety differentials

Tables 4–7 provide information on how various groups of men and women and traders and producers assess adaptation of varietal groups to specific consumer uses. Different pounded yam attributes are considered: elasticity, swelling, taste, flesh colour, consistency, smelling and absence of knobs. Different aggregations of attributes in the varieties sold on the market are reflected in the observed price of yam varieties. Tables 4–7 were constructed by posing to informants a base value of 100 CFA/kg for the preferred highest value for each characteristic, and then asking the informants by how much they think the price should be reduced for not having the desired characteristic. Table 4 reveals that when the variety is not elastic for pounded yam, traders or the market will reduce its price to 30 CFA/kg, as is the observed case with the *D. alata* variety Florido, *D. dumetorum* and for some *D. cayenensis / D. rotundata* types, e.g., Kokoro. When the taste is poor, the price drops to the level of 50 CFA/kg. As noted, the taste and the swelling of the variety Gnidou is lowest, and it receives the lowest market price mainly from September to March (Table 3). In general, for Tables 5–7, concerning attributes of paste and wassa-wassa, and boiled and fried yams, consumers apply a reduction of 20–25% over the reference price they are willing to pay for quality when the quality level in question drops to moderate. When the desirable

Table 4. User assessments of discounts for lack of quality (reference price = 100): various yam quality attributes (n=74 traders).

Pounded yam attributes	Level of attribute	Men		Women	
		Mean	SE	Mean	SE[1]
Elasticity	Very high	100	0	100	0
	Moderate	73	3.8	79	3.1
	Slight	50	3.8	51	2.9
	Non-elastic	30	4.7	30	3.3
Swelling	High	100	0	100	0
	Moderate	80	3.5	78	3.3
	Slight	52	5.6	53	6.9
Taste	Very sweet	100	0	100	0
	Moderate	78	2.8	76	2.4
	Poor	53	4.5	42	2.9
	White	100	0	100	0
Flesh colour	Off-white	74	2.9	76	4.0
	Yellow	57	4.6	77	6.9
Level of rot	No rot	100	0	100	0
	10% rotted	73	3.7	84	10.6
	25% rotted	51	4.2	52	3.8
	50% rotted	27	3.4	30	3.9
Consistency	Consistent	100	0	100	0
	Moderate	75	2.7	94	19.8
	Slight	39	3.2	36	2.5
Smelling	Very nice	100	0	100	0
	Moderate	73	2.8	79	4.7
	Disagreeable	41	2.8	43	4.6
Knobs	Absent	100	0	100	0
	Present	61	7.5	57	5.1

[1] SE=Standard error.

quality is classed as poor or not met at all, consumers apply a reduction varying from 40 to 70% over the reference price.

Quality criteria

To provide information on marketing decision making with regard to the importance of the intrinsic qualitative attributes (such as taste, plasticity, swelling, smelling, flesh colour, maturity, absence of knobs and of rot) male and female traders were asked to compare these attributes using the pair-wise comparison method (Table 8). The consistency related to tuber maturity appears in the first rank for men, but plasticity / elasticity is ranked first by women. The smell, absence of rot and flesh colour are considered of lesser significance by both groups. In total, consistency at maturity,

Table 5. User assessments of discounts for lack of quality (reference price = 100): paste and wassa-wassa attributes (n=74 traders).

Paste and wassa-wassa attributes	Level of attribute	Men Mean	Men SE[1]	Women Mean	Women SE[1]
Storage duration	Very long	100	0	100	0
	Moderate	77	6.4	88	6.1
	Short	54	8.1	64	8.7
Burnishing during drying	White	100	0	100	0
	Grey	77	5.6	75	6.0
	Dark	57	10.1	44	3.6
Presence of fibre	Absent	100	0	100	0
	Moderate	72	4.6	69	3.5
	Very high	48	7.2	39	4.6
Paste swelling	High	100	0	100	0
	Moderate	81	4.4	82	3.2
	Slight	53	6.7	56	6.0
Paste quality	Very sweet	100	0	100	0
	Moderate	75	3.7	75	3.1
	Poor	40	4.8	38	3.5
Wassa-wassa	Very sweet	100	0	100	0
	Moderate	65	4.5	69	4.0
	Poor	49	4.4	50	3.2

[1] SE=Standard error.

Table 6. User assessments of discounts for lack of quality (reference price = 100): boiled yam attributes (n=74 traders).

Boiled yam attributes	Level of attribute	Men Mean	Men SE[1]	Women Mean	Women SE[1]
Friability	Very friable	100	0	100	0
	Moderate	70	2.8	75	2.3
	Hard	37	2.4	44	2.9
Smell	Nice	100	0	100	0
	Moderate	68	3.0	76	2.4
	Not nice	36	3.1	41	2.7
Taste	Sweet	100	0	100	0
	Moderate	74	3.0	5	2.3
	Poor	44	3.3	40	2.3

[1] SE=Standard error.

Table 7. User assessments of discounts for lack of quality (reference price = 100): fried yam attributes (n=74 traders).

Fried yam attributes	Level of attribute	Men Mean	Men SE[1]	Women Mean	Women SE[1]
Friability	Very friable	100	0	100	0
	Moderate	75	2.6	75	2.1
	Hard	40	3.3	40	2.4
Taste	Sweet	100	0	100	0
	Moderate	77	2.9	78	2.1
	Poor	45	3.2	43	2.6

[1] SE=Standard error.

swelling, plasticity, taste and absence of knobs are the main traits considered. The Kruskal-Wallis test confirms that traders confer significantly different weights to these yam variety attributes by gender (Table 8). It is not clear how to interpret this gender difference – it is possible women traders do more direct retailing to housewives and are thus more directly attuned to consumer's preparation (as opposed to consumption) requirements.

Yam consumers' preferences

Socio-cultural profiles of the yam consumers

Consumers from different ethnic affiliation have been involved in this consumer study. The socio-cultural background of these consumers is Mahi, Idatcha, Tchabè and Fon. For men, the percentages of the ethnic groups interviewed are Mahi (27.5%), Idatcha 20%, Tchabè/Nago (40%), Fon (10%) and Goun (2.5%). For the women, they are Mahi (30%), Idatcha (17.5%), Tchabè/Nago (32.5%), Fon (17.5%) and Goun (2.5%). Yam is the basic food of the consumers interviewed in the central part of Benin. Various products and dishes are made from yam: pounded yam, fried yam, boiled yam, and 'cossettes'. From the 'cossettes', Té-libo (paste) and wassa-wassa ('African couscous') are prepared. Pounded yam is the most frequently eaten dish of the consumers interviewed. This is a reminder that yam is basic food for consumers in the central part of Benin.

Quality criteria revealed by yam consumers

The plasticity, the absence of knobs, the taste, and the swelling (ability to increase in volume while being pounded) are the main attributes for poundable varieties (Table 9).

Table 8. Scoring and ranking poundable, paste and wassa-wassa, fried and boiled yam attributes for traders (n=74 traders).

	Men (n=31)		Women (n=43)	
Poundable yam attributes	Score	Ranking	Score	Ranking
Consistency	159	1	211	2
Swelling	148	2	193	4
Plasticity	138	3	221	1
Taste	135	4	159	5
Absence of knob	129	5	205	3
Flesh colour	108	6	108	7
Absence of rot	108	7	152	6
Smelling	71	8	99	8
Kruskal-Wallis test				
Chi-Square:	33.106		69.452	
Probability:	<0.0001		<0.0001	
Paste and wassa-wassa	Score	Ranking	Score	Ranking
Quality of the wassa-wassa	127	1	176	1
Swelling	124	2	83	5
Quality of the paste	117	3	146	4
Storability	73	4	150	3
Burnishing during drying	62	5	57	6
Presence of fibre	58	6	164	2
Kruskal-Wallis test				
Chi-Square:	58.849		91.591	
Probability:	<0.0001		<0.0001	
Fried yam	Score	Ranking	Score	Ranking
Taste	60	1	59	2
Friability	43	2	55	3
Smell	37	3	81	1
Kruskal-Wallis test				
Chi-Square:	13.611		14.139	
Probability:	0.0011		0.0009	
Boiled yam	Score	Ranking	Score	Ranking
Taste	59	1	85	1
Friability	51	2	63	2
Smelling	31	3	47	3
Kruskal-Wallis test				
Chi-Square:	20.660		26.673	
Probability:	<0.0001		<0.0001	

The Kruskal-Wallis test is significant and shows that yam consumers confer different weights to attributes. The quality of the paste depends on the quality of the 'cossettes'. The 'cossette' quality criteria to assess for each variety are the duration of storage time, degree of blackening during drying, the presence of fibres inside the tuber, the swelling of the dough, the quality of Té-libo, and the quality of the wassa-wassa (Table 10).

Table 9. Scoring and ranking of quality criteria related to pounded yam by yam consumers.

Attributes	Men (n=80)	Ranking	Women (n=80)	Ranking	Men & women (n=160)	Ranking
Plasticity	445	1	447	1	890	1
Absence of knobs	413	2	371	3	783	2
Taste	384	3	379	2	763	3
Absence of rot	363	4	319	6	680	4
Maturity/consistency	329	5	320	5	649	6
Swelling	304	6	346	4	651	5
Smelling	167	7	164	8	349	8
Flesh colour	158	8	219	7	378	7
Kruskal-Wallis test						
Chi-Square:	189.542		137.073		314.889	
Probability:	<0.0001		<0.0001		<0.0001	

Table 10. Scoring and ranking of paste and wassa-wassa attributes of yam by yam consumers.

Paste attributes	Men (n=80)	Ranking	Women (n=80)	Ranking
Storage duration	184	5	220	4
Burnishing during drying	253	4	157	5
Presence of fibre	117	6	129	6
Swelling	302	3	302	2
Quality of paste	351	1	335	1
Quality of wassa-wassa	336	2	300	3
Kruskal-Wallis test				
Chi-Square:	219.516		154.073	
Probability:	<0.0001		<0.0001	

Table 11. Consumer price assessments of yam varieties by valuing its pounded-yam attributes based on some market prices (CFA/kg of each variety considered).

Attributes	Laboko[1]		Gangni		Gnanlabo		Gnidou		Effourou		Moroko	
	M	W	M	W	M	W	M	W	M	W	M	W
Plasticity	45	44	16	14	32	50	10	12	17	12	15	20
Swelling	23	20	10	10	25	20	9	9	10	10	12	12
Taste	22	25	11	14	25	23	9	9	10	11	14	11
Colour	17	18	11	4	18	17	10	10	12	11	11	10
Absence of rot	23	21	15	11	32	25	13	13	15	14	13	14
Degree of maturity /consistency	25	24	14	14	23	23	11	10	10	16	13	15
Smelling	19	18	11	11	23	20	10	7	12	14	9	8
Absence of knobs	20	24	9	7	16	16	10	11	11	10	10	10
Overall average	194	194	97	85	194	194	82	81	97	98	97	100

[1] Reference price for the group Laboko and Gnanlabo = 200 CFA/kg. For the other varieties, the reference was 100 CFA/kg; M = men; W = women.

Useful traits in yam varieties and revealed by consumer price assessments

Table 11 presents the mean values given to the different consumer criteria based on the real market prices they used to pay for yam varieties bought to produce pounded yam. Note that the overall average provides the overall price for a high quality product. Laboko and Gnanlabo received the highest price assessments with regard to plasticity and taste. These results express quantitatively the widespread perception of farmers that these are the best yams in terms of plasticity and taste. Table 12 presents market values given to the attributes recognized by consumers in yams used for paste and wassa-wassa. Kokoro is the most preferred variety in this group. It has a higher value for all attributes than Florido. More and more, the *D. alata* variety Florido/Aga/Alougan is used in the ‘starvation’ period for paste. The storage duration is considered the most important attribute. Table 13 shows price assessments for attributes recognized by consumers in yam varieties used for boiled and fried yam. The diversity of varieties is large for this type of use. Note that there are large gender differences with regard to the assessments of these attributes in some varieties. Especially the values men give to the different attributes of Laboko are much lower than in the case of women. Yam consumers freely indicated which yam varieties they preferred most or least. Table 14 presents the absolute frequency of consumers who have indicated one or another particular variety. The varieties Laboko and Kokoro were preferred by most consumers (both men and women) involved in this study. On the other hand, the varieties Gnidou and Florido/Aga/Alougan are among the least preferred.

Table 12. Consumer assessments of yam varieties by valuing paste attributes by gender based on real market prices.

Paste attributes	Kokoro[1]		Florido[1]	
	Men	Women	Men	Women
Storage duration	21	19	8	7
Burnishing during drying	12	10	5	7
Presence of fibre	10	12	5	6
Swelling	16	15	8	8
Quality of paste	15	15	8	9
Quality of wassa-wassa	20	19	10	8
Overall sum	94	90	44	45

[1] The reference considered: 90 CFA/kg for Kokoro; 40 CFA/kg for Florido.

Table 13. Consumer assessments of yam varieties by valuing taste, friability and scent by gender based on market prices that consumers used to pay for those varieties.

Attributes	Laboko		Aga		Moroko		Gnidou		Ala		Gangni		Effourou	
	M	W	M	W	M	W	M	W	M	W	M	W	M	W
Taste	11	38	7	19	16	29	8	18	31	29	21	27	13	11
Friability	7	34	8	13	16	33	24	25	24	33	14	17	12	11
Scent	8	28	25	9	18	22	31	13	18	16	13	19	23	42
Overall sum	26	100	40	41	50	84	63	56	73	78	48	63	48	64

M = men; W = women.

Cowpea traders valuing cowpea varieties

Interactions between farmers and traders and socio-economic profiles

The cowpea market is essentially a women's market (96% of actors). The different categories are retailers, semi-wholesalers, and collectors. The trade in cowpea represents the main activity of 77% of the women sampled. The main destinations of the cowpea from the market of Glazoué are Cotonou, Porto-Novo, Glazoué, Bohicon and Abomey. Parakou and Malanville are secondary destinations. Several strategies are developed by sellers and purchasers for arriving at selling prices; these include word of mouth information exchange with semi-wholesalers, agents fixing prices when variety is taken into account and variation of price from seller to seller depending on the state of the grain (Table 15).

Table 14. Consumers' preferences for some yam varieties (n=80 men; 80 women). The figures are the absolute number of consumers indicating the preference.

Species	Yam varieties	Men (n=80)		Women (n=80)	
		More preferred	Less preferred	More Preferred	Less preferred
D. cayenensis - D. rotundata					
	Laboko	30	1	33	0
	Kokoro	12	4	8	0
	Gangni	10	1	6	0
	Ala	8	5	8	0
	Moroko/Anago	3	1	7	0
	Gnanlabo	3	0	3	2
	Mafobo	2	0	0	0
	Klatchi	1	0	2	0
	Dodo	1	0	1	0
	Gnidou/Iridoun	0	12	1	18
	Adigbili	0	0	0	0
D. alata	Florido / Aga	3	17	1	13
D. dumetorum	Lefe/Essourou	2	6	3	4

Cowpea traders' preferences

Cowpea traders preferences towards a variety are motivated by the purity of the variety, the purchase price, grain status (i.e., non-attacked), skin colour, neatness (no mixing with varieties of different colours, well-formed grain), ability of resistance to bruchids, quality after storage, grain size and periods of availability (Table 16).

Respondent cowpea traders freely indicated the cowpea varieties they aimed to buy from farmers. Table 17 provides the list of those varieties. Each cowpea trader then ranked the profitability of these varieties. Some respondents bought up to seven different farmer-named varieties. From its top ranking, it appeared that the variety Djetoko was the single most profitable variety (17 traders placing this in the first rank). Djetoko was followed by Tawa, Aiglo, Atchawekoun, and Mahounan. Mata, Kaki, Togo, and Tawa dominated the second ranked group.

Diversity of cowpea varieties and corresponding market prices

The variation in the number of cowpea varieties follows a pattern equivalent to that described for yam, with two varieties on the market in January and 8 by the end of

Table 15. Experience and part of income generated by cowpea commercialization.

Men and women	Selling reasons					Experience	
	Inheri-tance	Profit-ability	Advice	Personal engagement	Others[1]	< 10 years	≥ 10 years
Contribution of trade to total income (10-point)							
1–4	3	4	1	3	7	11	7
5–7	21	9	5	11	7	29	23
8–10	14	5	8	3	0	15	16
Total (%)	*38*	*18*	*14*	*16*	*13*	*55*	*45*
Part of trade from cowpea out the total income (10-point)							
1–4	12	9	3	5	4	19	15
5–7	24	9	9	8	7	31	27
8–10	3	0	3	3	1	5	4
Total (%)	*39*	*19*	*15*	*16*	*12*	*55*	*45*

[1] To have a job, low income

Table 16. Motivations for trading one cowpea variety or another.

Motivations	Likert score (n=77)	Ranking
Purity of the variety	654	1
Purchasing price	610	2
Grain status	606	3
Skin colour	548	4
Neatness	538	5
Resistance to bruchids	498	6
Quality after storage	477	7
Grain size	451	8
Period of availability	450	9
Eye colour	428	10
Grain weight	426	11
Smoothness	417	12
Storability	411	13
Kruskal-Wallis test		
Chi-Square:	86.749	
Probability:	<0.0001	

Table 17. Profitability ranking of cowpea varieties.

	Profitability ranking (number of traders)						
Variety	1st	2nd	3rd	4th	5th	6th	7th
Djetoko	17	1	4	1	2	1	1
Tawa	11	5	1	3	3		
Kaki		7	7	3	2	3	
Mata/Agbodjouba	5	8	2	4			
Mahounan	6	3	1	1	2	3	
Togo	2	6	2	1			
Atchawékoun	6	2	2	1			
Wankoun	2	1	2	9	1		
Kplobè	1		3	3			
Egni-awo					1		
Kpodjiguègué	1		6	2	2		
Codjovi	1	4	6		1	1	
Aiglo	9	1					
Boto	1	3	5	1	1		
Total	62	41	41	29	15	8	1

March (Figure 1). In April-May, there is then a decrease. In June, the new harvest of the early-maturing varieties arrives on the market, explaining the subsequent recorded increase in number. From September to early December, the number of varieties fluctuates between 5 and 7 per market day.

Figure 4 shows the seasonal variation in prices of cowpea varieties. The data once again suggest some degree of layering of price differentials, though perhaps not so clearly as in the case of yam, but nevertheless providing some indication that varietal issues operate independently of seasonal fluctuations in supply of the different varieties. The same caveat as noted above should be observed – that these data are mainly based on trader recalls, so are perhaps only to be interpreted as an indication of how traders perceive market fluctuations. Figure 4 shows that the prices follow a regular seasonal pattern over the five years (2000–2004). Over the period Djetoko attracts the highest average price (Table 18). Its price varied between 137 CFA in November and 247 CFA in August. November is the month when the late-maturing varieties (such as Djetoko) are harvested, and are therefore abundant (and cheap). Aiglo / Atchawekoun, Egniawo are the late-maturing varieties with a similar seasonal pattern. The price of Aiglo / Atchawekoun varied between 129 CFA/kg in November

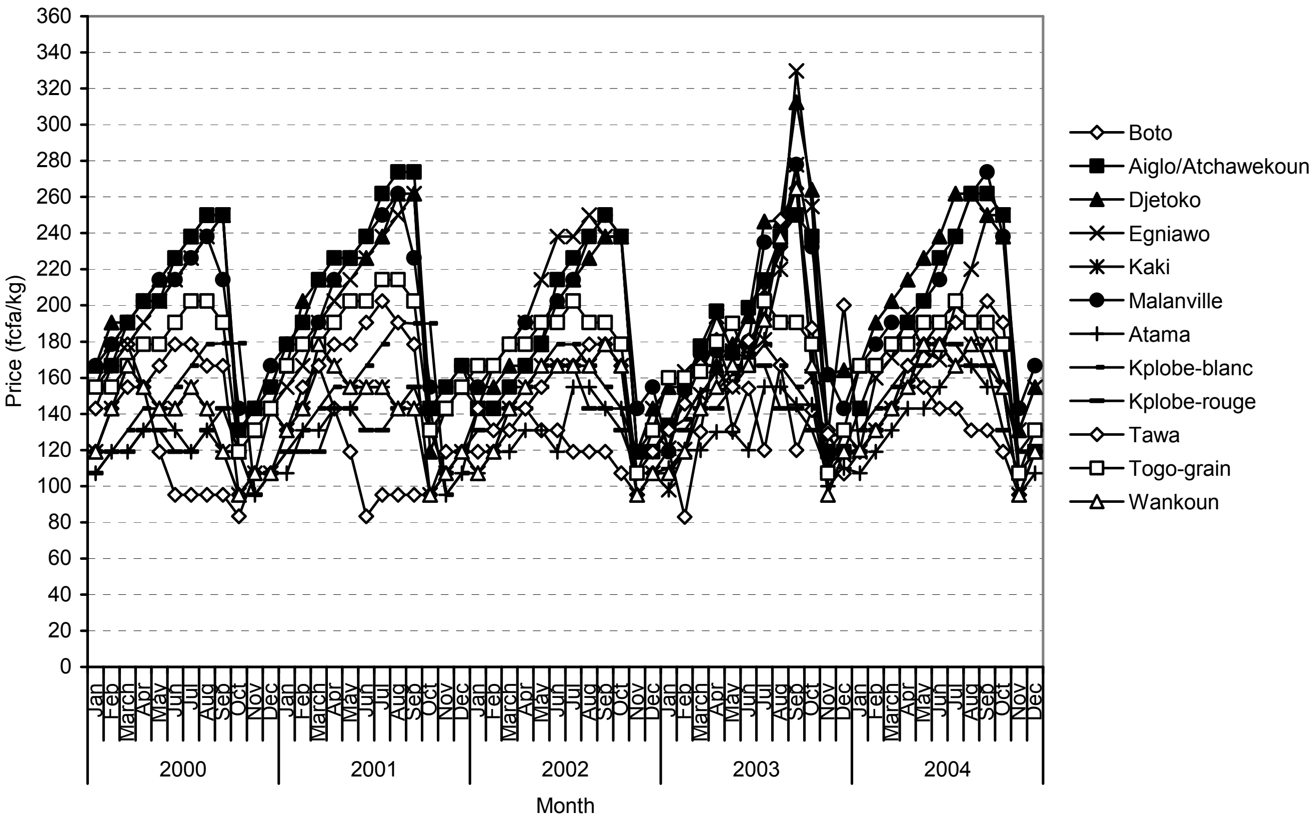

Figure 4. Monthly cowpea price variations on the market on Glazoué over the period 2000–2004.

and 257 CFA/kg in September. Egniawo varied between 133 CFA/kg and 266 CFA/kg over the same period. Among the early-maturing varieties, Malanville Togo-grain, Tawa and Kplobe blanc received the highest price over the period. The lowest average price was observed for Boto.

As Djetoko has been revealed as one of the preferred varieties, it has been taken as the variety of reference for price comparison with other cowpea varieties. Figure 5 shows the price difference between Djetoko and other varieties tracked over the period 2000-2004. The data show that from January to April each year average price differentials between Djetoko and Atama, Wankoun, Boto, Kplobe rouge, Kplobe blanc, and Tawa range between 35 and 60 CFA/kg. Between May and September, the price differential widens. Two factors explain the increase in differential. In June–July, early-maturing varieties are brought to the market. The early-maturing varieties become cheap, while the price for the favoured (and late maturing) Djetoko remains strong (a combination, probably, of the fact that it is favoured but also relatively scarce in the period running up to its main harvest in November). This interpretation is

Table 18. Average price of cowpea varieties per month over the period 2000–2004 (CFA/kg).

Varietie	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Djetoko	162	178	188	193	205	217	240	249	263	196	137	152	198
Aiglo/ Atchawekoun	151	165	183	196	197	221	236	252	257	200	129	136	193
Egniawo	139	167	178	194	196	204	222	237	266	201	133	145	190
Atama	108	122	124	136	138	136	150	150	141	141	96	108	129
Malanville	157	171	184	194	201	210	233	247	248	201	149	160	196
Tawa	129	141	155	165	167	179	186	195	198	147	114	133	159
Kaki	115	131	157	159	160	163	165	170	180	135	103	114	146
Kplobe-blanc	129	135	147	155	161	172	179	179	169	162	109	121	151
Kplobe-rouge	121	126	133	143	150	153	153	145	150	129	105	117	135
Boto	126	129	150	158	131	121	114	121	112	109	107	119	125
Togo-grain	163	166	174	181	190	188	204	197	192	157	119	138	173
Wankoun	117	131	155	157	162	162	167	174	177	136	100	114	146

confirmed by the fact that the price differential between Djetoko and other late-maturing varieties such as Egniawo and Atchawékoun is not so marked, and remains within the same range of variation (0–15 CFA/kg) across the year.

Market price premium and variety differential characteristics

Trader price assessment is discounted progressively from white to black skin. Other differential prices for various attribute levels are displayed in Table 19, constructed using the same price index approach as described for yam above. Different combinations of attribute levels affect assessments of prices of cowpea varieties. For skin colour, with a reference price of 100 CFA/kg for the white type, traders claim they will averagely pay 72 CFA/kg for brown, 53 for red and 35 for black cowpeas. For the eye colour, taking black as the reference, traders are willing to pay the almost the same price as for the white eye type. For the taste, the price will be discounted to 45 CFA/kg for a variety considered (relatively) tasteless. Trader price assessments showed sensitivity to high presence of bruchid holes; they estimate an average reduction of price to 26 CFA/kg where more than 70% of grains are attacked by bruchids.

Quality criteria revealed by cowpea traders

The quality criteria on which cowpea traders rely when negotiating price are taste, purity of variety, grain colour, grain size, eye colour, storage duration, quality of the grain after storage, grain weight, skin roughness and absence of bruchids. The attribute

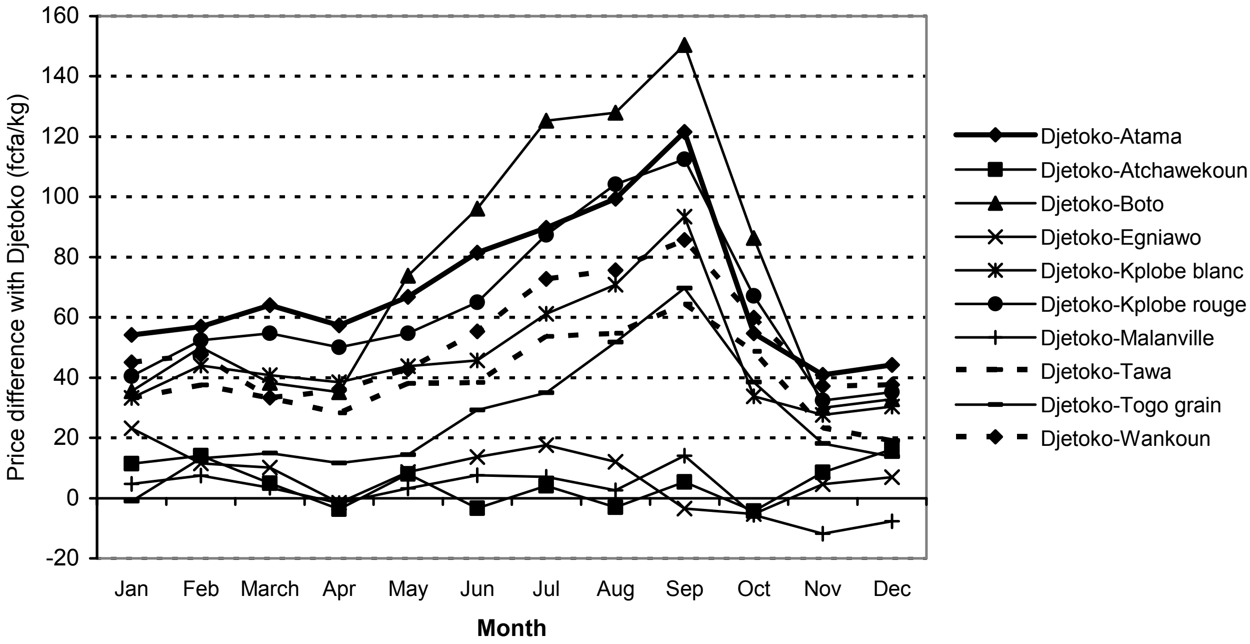

Figure 5. Price difference between Djetoko and other cowpea varieties.

'quality after storage' has different meanings for different actors: a consumer would appreciate cooking time, swelling and aroma; but a producer who wants to buy planting seed from the market would mainly consider seed quality (rate of germination). Adopting once again the pair-wise comparison technique, these attributes were submitted to the assessment of the 77 cowpea traders interviewed. Table 20 presents the results of this evaluation. Grain quality after storage recorded the highest score and occupies the first rank. Taste, storage duration, grain purity, skin colour occupy the second, third, fourth and fifth ranks respectively. As with region, so with culture, consumer preferences vary according to grain colour and other attributes.

Table 21 brings out information on differential rankings based on grain and eye colour attributes. Idatcha and Mahi have opposite assessments of eye colour to Fon and Tchabè, for example.

Cowpea consumers' preferences

Socio-cultural profiles of the cowpea consumers

The socio-cultural profiles of the communities involved are Mahi, Idatcha, Tchabè, Fon and Goun. For men, the percentage of the ethnic group interviewed is Mahi (24%), Idatcha (20%), Tchabè/Nago (5%). For women, the communities represented are Mahi (28%), Fon (28%), Idatcha (23%), Tchabè/Nago (31%), and Goun (2%). Cowpea is a basic food for all consumers interviewed in the central region of Benin.

Table 19. Price assessments relative to best variety for that quality (=100).

Attributes	Attribute levels	Mean (CFA)	Standard error
Skin colour	White	100	0
	Brown	72	2.0
	Red	53	2.0
	Black	35	2.4
Eye colour	Black	100	0
	Grey	83	35
	Brown	69	3.1
	White	96	19.6
Taste	Very sweet	100	0
	Sweet	78	1.5
	Tasteless	45	2.2
Grain size	Big	100	0
	Moderate	75	1.5
	Small	52	2.1
Grain weight	Very heavy	100	0
	Moderate	77	1.8
	Light	45	2.1
Grain purity	Homogeneous	100	0
	25% of another colour	69	2.3
	50% of another colour	44	2.2
Skin roughness	Very rough	100	0
	Smooth	117	22.6
Presence of bruchid holes	Absent	100	0
	1 - 3 grains holed (/10)	75	1.7
	4 - 6 grains holed (/10)	54	2.6
	7 - 10 grains holed (/10)	26	2.2
Storage duration	Very long	100	0
	Moderate	78	2.9
	Short	46	5.1
Quality after storage	Good	78	6.5
	Moderate	83	1.9
	Poor	57	10.3

Table 20. Cowpea grain attributes.

Grain attributes	Pair-wise score (n=77)	Ranking
Grain quality after storage	603	1
Taste	515	2
Storage duration	484	3
Grain purity	445	4
Skin colour	416	5
Grain weight	394	6
Grain size	354	7
Eye colour	254	8
Skin's roughness	199	9
Absence of bruchids	191	10
Kruskal-Wallis test		
Chi-Square:	266.217	
Probability:	<0.0001	

Table 21. Cowpea eye and skin colours assessed by traders from different ethnic communities.

	Score for Idatcha (n=13)	Rank	Score for Mahi (n=29)	Rank	Score for Tchabè (n=18)	Rank	Score for Fon (n=15)	Rank	Score for Bariba & Adja (n=2)	Rank	*Overall Score*	*Rank*
Eye colours												
White eye	29	1	63	1	29	2	18	3	4	1	*143*	*1*
Brown eye	20	2	40	3	13	4	15	4	1	4	*89*	*4*
Grey eye	25	3	43	2	20	3	21	2	3	3	*112*	*2*
Black eye	4	4	28	4	46	1	24	1	4	1	*106*	*3*
Total	*78*		*174*		*108*		*78*		*12*		*450*	
Skin colours												
White skin	26	1	72	1	47	1	37	1	3	2	*185*	*1*
Brown skin	25	2	53	2	27	2	18	3	5	1	*128*	*2*
Red skin	19	3	34	3	21	3	20	2	2	3	*96*	*3*
Black skin	8	4	15	4	13	4	3	4	2	3	*41*	*4*
Total	*78*		*174*		*108*		*78*		*12*		*450*	

Quality criteria revealed by cowpea consumers

Table 22 confirms the high preference of most communities in central Benin for white cowpea varieties. For both men and women, the white colour remains the highest preference. Brown takes second place after white. While some consumers accept red, most remain reluctant about black types.

Although cowpea eye colour is important as part of variety technology evaluation, the difference in weights conferred to the eye colours by consumers is not significant (Table 23). This apparent indifference towards eye colour reflects food types consumers make from the grains.

When cowpea grains are boiled to be served as local food called 'abobo', a number of attributes are considered by consumers: the swelling, absence of bruchids showing that grains have been stored in good condition or that the variety is resistant to bruchids, or the importance in number of grains holed if attacked by storage bruchids, the taste, softness, skin and eye colour, cooking time, and aroma. These attributes have been submitted to consumer evaluation to reveal preferences. The taste, the absence of bruchids and the swelling are the main cowpea attributes highly ranked by men and women for boiled cowpea. This result indicates consumers are very sensitive to the presence of bruchids in cowpea (Table 24). Taste ranking brings out the fact that consumers prefer sweeter varieties. The aggregated scores for both men and women reveals softness and grain colour to be important criteria considered by traders.

Discussion

This study analysed price variations for yam and cowpea varieties sold on Glazoué market and their variation over a 5-year period, 2000–2004. Some varieties are highly preferred by both traders and consumers, thus often yielding traders better profits, as they are easily sold on the market. This is the case with many early harvested yam varieties, such as the *D. cayenensi / D. rotundata* varieties Laboko, Anago/Moroko, and Ala-N'kodjéwé. The prices of the other early-maturing varieties decreased at harvesting time when there is an abundant flow of yam on the market. The price of the late-maturing variety Gnanlabo is almost as high as for Laboko. Both are favoured for pounded yam, the most preferred dish. Within the late-maturing varieties of the *D. cayenensis – D. rotundata* group the price of Kokoro was relatively the lowest. Kokoro is mainly used by consumers for paste. The *D. alata* Florido and the *D. dumetorun* Iréfé/Essourou are the yam varieties with the lowest prices over the year. Although the price of Florido makes it one of the least valuable yam varieties in the region, one cannot underestimate its wider value since it contributes importantly to maintenance of domestic food security in the period when other varieties become very scarce on the market. Its contribution to household subsistence means that other

Table 22. Skin attributes of cowpea ranked by consumers.

Skin attributes	Men (n=80)	Ranking	Women (n=80)	Ranking	Men & women (n=160)	Ranking
White	210	1	232	1	441	1
Brown	178	2	173	2	331	2
Red	138	3	136	3	273	3
Black	116	4	101	4	217	4
Kruskal-Wallis test						
Chi-Square:	53.117		93.754		144.041	
Probability:	<0.0001		<0.0001		<0.0001	

Table 23. Scoring and ranking of cowpea eye attributes as assessed by cowpea consumers.

Eye attributes	Men (n=80)	Ranking	Women (n=80)	Ranking	Men & women (n=160)	Ranking
Grey	176	1	174	1	350	1
White	161	2	160	3	321	3
Black	158	3	168	2	325	2
Brown	147	4	140	4	286	4
Kruskal-Wallis test						
Chi-Square:	4.332		6.660		10.331	
Probability:	0.227		0.0835		0.0159	

Table 24. Scoring and ranking of boiled cowpea attributes as assessed by consumers.

Boiled (‘abobo’) attributes	Men (n=80)	Ranking	Women (n=80)	Ranking	Men & women (n=160)	Ranking
Swelling	479	1	400	3	877	2
Absence of bruchids	472	2	430	2	860	3
Taste	431	3	511	1	982	1
Softness	393	4	320	7	708	4
Eye colour	321	5	327	6	646	7
Number grain holed	296	6	236	9	533	8
Grain colour	293	7	386	4	682	5
Cooking time	292	8	369	5	664	6
Smelling	268	9	266	8	533	8
Kruskal-Wallis test						
Chi-Square:	105.577		106.716		182.110	
Probability:	<0.0001		<0.0001		<0.0001	

varieties can be released for sale, so in a sense it props up the market. Florido is used both as fried and boiled yam, and is transformed by some consumers to make paste. As is the case in this study in Benin, a study from Ivory Coast by Doumbia *et al*. (2004) shows that Florido underpins farmer food security and contributes to farmer cash incomes because it can be sold on the market at the time when the production of most yam varieties is less abundant. Different quality traits are valued in different varieties. In a study on the colour and taste of Amala, a paste made from yam chip flour, Mestres *et al.* (2004) discovered that Florido gave the sweetest amala. Using a hedonic method, they suggested that the ideal product was obtained from a Kokoro-type, evaluating attributes based on colour, sweetness, bitterness, acid taste, fermented taste, and roasted taste. Likewise, Egesi *et al.* (2003) show that mealiness, colour and taste, for boiled yam, and consistency, colour and stickiness, for pounded yam, are crucial in determining consumer acceptance.

The present study also analysed different cowpea varieties sold on the market over the five years 2000–2004 in terms of price assessments. Some cowpeas attain highest prices all year round. This is mainly the case with the late-maturing varieties Djetoko, Egniawo or Atchawékoun. Djetoko is the variety traders find most profitable. Different grain qualities – e.g., taste and grain colour – are valued by the market in cowpea varieties. This study also showed the impact of cultural preference on the varieties sold on the market. In a study on cowpea in West Africa, Coulibaly and Löwenberg-De Boer (2002) show that marketing and consumer preferences are key research areas that help explain the adoption and wide diffusion of improved cowpea technologies among small farmers. Their study showed that consumers in Ghana and Cameroon are equally sensitive to cowpea damaged by insects. Cowpea grain size, colour of eye, and the number of insect holes are important factors explaining cowpea price variability. Mainly, the grain colour and eye are important when the intended use requires decortication. The study brings out clearly the issue of cultural preference, in showing that while in Ghana consumers are willing to pay a premium of between 109 Cedi/kg and 226 Cedi/kg for black-eyed cowpea, consumers in Cameroon, in contrast, discount up to 14 CFA/kg for black-eyed cowpea. For Sénégal, Faye (2005) shows that market consumers are willing to pay a premium of 15 CFA/kg for red colour, but discount the price by 25 CFA/kg for black skin compared to the white skin colour (the reference on a local market named MPal); but in Bamley – another locality in Sénégal – consumers were willing to pay a premium for black speckled skin.

Market research on yam and cowpea highlights and confirms the fact that successful variety improvement in crop research requires good knowledge of local preferences. It comes out from the present study on yam and cowpea diversity that consumer preferences are the driving forces determining the kinds of varieties brought to market.

Each yam and cowpea variety has distinctive traits, and prices reflect with some accuracy consumer concerns despite seasonal variations across the year in aggregate supply.

CHAPTER 6

Morphological, agronomic, and molecular characterization of yam (*Dioscorea* spp.) varieties in Benin*

Abstract

Yam (*Dioscorea* spp.) is an important food and cash crop in the Guinea-Sudan zone of Benin. Increasing yam yield by improved crop husbandry or by improving varieties is instrumental to achieve poverty alleviation and to ensure food security. However, little information exists on the agronomic and genetic potentials of farmer varieties. Based on field and laboratory experiments developed through a joint learning exercise between farmers and the principle researcher on cultivated yam varieties in Benin, this study addresses the following questions: What are the morphological, agronomic and genetic differences in existing cultivated yam varieties? Why do farmers use certain tuber parts as planting material? What are the factors that can influence the post-harvest dormancy and increase the emergence of varieties in farmers' conditions?

This study analysed the morphological characteristics of 71 farmer-named varieties of *D. cayenensis / D. rotundata* and 26 *D. alata* collected through the Guinea-Sudan transition zone of Benin. Over two years, the agronomic potentials of 27 of the *D. cayenensis / D. rotundata* and 17 of the *D. alata* varieties were assessed. The genetic diversity of about 70 cultivars of *Dioscorea cayenensis / Dioscorea rotundata* (Guinea yam) and about 20 cultivars of *Dioscorea alata* (water yam) was analysed using random amplified polymorphic DNA (RAPD). Within the *D. cayenensis / D. rotundata* and the *D. alata* varieties, the study revealed a large genetic variation in yield potential. Planting material from different tuber parts (proximal, medial, distal) showed significant differences in number of plants emerged and time of emergence, but the effects depended on the variety. This result confirms the value of farmer's variety-specific handling of seed tubers. Farmers also manage the dormancy of the seed tubers. Our results show that there are genetic differences in depth of dormancy and that farmers deal with these differences by applying specific post-harvest storage strategies and practices. One strategy is to bury seed tubers in the dry season in order to induce a rapid breaking of dormancy. The high soil temperatures during the dry season contribute to early dormancy breaking.

The amplified bands of the molecular analysis revealed high polymorphism. These polymorphic DNA fragments were used to construct dendrograms, clustering all accessions into 18 groups: 12 for *D. cayenensis / D. rotundata* and six for *D. alata*. The analysis of molecular variance revealed highly significant variation among species, among groups within species, and among varieties within groups (F_{ST}=0.473; P<0.0001). The dendrograms showed that the genetic diversity changed along a spatial gradient. In general, it was possible to clearly distinguish varieties from the north-east and north-west of the Guinea-Sudan zone on the one hand and yams from the centre of the country on the other.

The current study suggests that the Guinea-Sudan zone of Benin represents a very large gene-pool of yam varieties. Yam farmers in Benin, with their continuous commitment to domestication of material from the wild, clearly play a significant role in the enrichment and the maintenance of the genetic diversity of yam cultivars. Their participation in the research, and perception of the benefits of such participation, suggest new ways of designing research projects to enhance impact.

Key words: Co-research, genetic diversity, *Dioscorea cayenensis / D. rotundata, D. alata,* yam dormancy, seed tuber management, farmers, gene-pool, RAPD, G×E interaction, impact assessment, human and social capitals, sustainable livelihood.

* Part of this chapter is submitted for publication.

Introduction

Yam belongs to the genus *Dioscorea* of the family Dioscoreaceae. The genus contains some 600 species with more than 10 species cultivated for food and for pharmaceutical use (Coursey, 1976a; Ake Assi, 1998). Six species are important staples: white yam (*D. rotundata*), water yam (*D. alata*), yellow yam (*D. cayenensis*), trifoliate yam (*D. dumetorum*), aerial yam (*D. bulbifera*) and Chinese yam (*D. esculenta*) (Ng and Ng 1994). Different species were brought into cultivation independently in three regions of the world: West Africa (*D. rotundata*, *D. cayenensis* and *D. dumetorum*), South East Asia (*D. alata* and *D. esculenta*), and Tropical America (*D. trifida*).

Yam represents an important component of West African agriculture and contributes to the food security for large parts of the populations of West-Africa, particularly in Benin. In addition to its economic and nutritional values, yam also plays a significant role in the cultural life of rural communities in Benin (Chapters 3 and 4). Little information exists on agronomic, physiological, morphological, and genetic characteristics useful to farmers. Doing research with farmers, and working on the agronomical and physiological constraints to develop adaptive technology for farmers, emphasized the need to really understand the genetic diversity of crop traits (Zannou *et al*., 2004). Recent studies have also shown the necessity to put more emphasis on farm management of genetic resources (Zoundjihékpon *et al*., 1997; Pardey *et al*., 1999; Jarvis *et al*., 2000). Different and complementary markers are useful both to appreciate the traits and evaluate the different performances of yam cultivars. Phenotypic performance reflects the joint influence of non-genetic and genetic factors (Brennan and Byth, 1979). The genotype by environment interaction is a phenomenon in which the relative performance of genotypes varies with environmental conditions and is attributed to the dependence of expression of underlying genes or quantitative trait loci on environments (Yin *et al*., 2004).

A characterization only based on morphological or agronomic traits hides important genetic information. Apart from morphological traits (Dansi *et al*., 1998, 1999), isozymic techniques (Dansi *et al*., 2000a; Mignouna *et al*., 2002; Mignouna and Dansi, 2003) and flow cytometry (Dansi *et al*., 2000b), molecular techniques provide opportunities to obtain high amplification of genetic traits for the development of genetic maps, variety identification and for the analysis of important morphological and agronomic traits (Fatokun *et al*., 1997; Dansi *et al*., 2000c; Tostain *et al*., 2002; Tostain *et al*., 2003; Dumont *et al*., 2005). Molecular markers showing a high level of polymorphism on plant materials include micro-satellites (Sonnante *et al*., 1994; Akkaya *et al*., 1995), RAPDs (Williams *et al*., 1990; Williams *et al*., 1993; Dansi *et al*., 2000c), and AFLP (Vos *et al*., 1995; Tostain *et al*., 2002; Tostain *et al*., 2003; Kiambi *et al*., 2005). RAPD (Random Amplified Polymorphic DNA) markers have been shown to be useful in assessing intra-specific or inter-specific genetic variability in many crop plant species (Liu and Fumier, 1993; Haley *et al*., 1994; Katsiotis *et al*., 2003; Ravi *et al*., 2003).

Our diagnostic study (Zannou *et al*., 2004) has shown that not only the management of genetic resources as such is relevant, but that proper seed tuber management of yam is also essential, and that this management is variety-specific. There are two elements that need to be addressed: the variety specific management of seed tuber dormancy and sprouting and the variety specific ways of cutting the seed tubers to save on seed tuber costs or to enhance the seed tuber productivity.

The growth cycle of yam tubers includes a period of dormancy of the seed tubers. At the breaking of dormancy, the tuber produces sprouts and a new cycle of vegetative growth begins. The length of this dormancy period constitutes the major agro-physiological constraint to successful yam seed system management. The temperature is the main physical factor influencing the length of yam dormancy (Degras, 1986). The mechanism of dormancy breaking in tropical yam species is not well documented (Wickham *et al*., 1984b). Breaking or shortening dormancy in yam is a priority for yam breeders (Asiedu *et al*., 1998), but the physiological and genetic control of dormancy is not well understood (Passam, 1982; Suttle, 1996; Ayankanmi *et al*., 2005). In fact, farmer-managed varieties differ in the length of post-harvest dormancy. These differences in dormancy are probably due to genetic differences. Farmers are concerned about a long dormancy. With early varieties, they usually do a first harvest for consumption and selling and leave the plant on stand to produce new tubers, which are then used as seed tubers for the next crop. The first harvest needs to be as early as possible to provide food after a hunger period, whereas the formation of the tubers for the second harvest needs to be fitted in the rest of the rain season (August–October) to avoid drought during the production of the second wave of tubers. Moreover, early harvest of the seed tubers is crucial to have enough time to obtain the right physiological condition for use as planting material for the subsequent crop. When the seed tubers are in the right physiological stage when planted they will produce a subsequent crop with early tuber formation. For the late-maturing varieties both the ware and seed tubers are harvested at the same time, and only when the tubers have reached marketable sizes.

Yam growers in Benin practise cutting of seed tubers and use specific parts of the seed tubers as planting material. The reasons behind this may be associated with the sprouting capacity of the eyes present in the different sections of the seed tubers, but there is little research to prove this assumption to be true. Therefore, another seed tuber issue needs to be addressed: Why do farmers in Benin use particular seed tuber parts as planting material and why are their practices of cutting the seed tubers different for different varieties? The hypothesis here is that farmers are aware of the specific anatomy of the seed tubers from different varieties, know the physiological behaviour of varieties in response to cutting the seed tubers (such as breaking of dormancy, or breaking of apical dominance), and recognize the differences in agronomic performance of seed tuber pieces of specific varieties.

We explored with farmers ways to shorten the duration of the post-harvest dormancy of the seed tubers and to advance their sprouting to advance the first harvests of yams thus advancing food availability for farmers during the period of food shortage. We also explored possibilities of using different parts of tubers as planting materials and the basic understanding that govern seed practices in yam diversity management in Benin, thus seeking, with farmers, to know how to optimize the performance of the planting material.

As working and doing research with farmers for better technology development is a core principle of the Convergence of Sciences approach (Zannou *et al*., 2004) this research aimed at characterizing the different varieties of yam in Benin using different morphological, agronomic, physiological and molecular marker techniques, identifying under local farming conditions the main manageable factors affecting post-harvest dormancy, and analysing the ways seed tubers of the various varieties are cut for optimal use. We also performed a sustainable livelihood analysis according to the methods of Bartlett (2004) and Mancini (2006).

Materials and methods

Plant material

Tubers of 71 cultivars of the *D. cayenensis / D. rotundata* complex and 26 cultivars of *D. alata* were collected from farmers throughout the transitional Guinea-Sudan zone of Benin and were subsequently planted to analyse their morphoplogical characteristics (Table 1). Over two years, the agronomic potential and seed tuber behaviour of 27 of the *D. cayenensis / D. rotundata* and 17 of the *D. alata* varieties were assessed. The genetic diversity of about 70 cultivars of *D. cayenensis / D. rotundata (*Guinea yam*)* and about 20 cultivars of *D. alata* (water yam) was analysed using random amplified polymorphic DNA (RAPD). Samples of young fresh leaves of each of these cultivars were taken for DNA extraction.

Morphological analysis: qualitative plant and tuber characteristics

Data were collected and analysed on three different groups of variables. These groups comprised eight tuber flesh characteristics, eight characteristics relating to the external morphology of the tubers, and eight leaf or stem characteristics. The eight variables of

Table 1. List of yam cultivars used for RAPD analysis and origins of collection in the transitional Guinea-Sudan zone of Benin. C=centre; NE= north-east; NW= north-west.

Code	Species' and varieties' names	Village	Region	Code	Varieties	Village	Region
	D. cayenensis / D. rotundata						
1	Adigbili	Yagbo	C	54	Kaagourou	Sontou	NE
3	Aguida	Kaboua	C	55	Kokorogbarou	Ouroumonsi	NE
4	Ahimon	Yagbo	C	57	Moroko	Kpébié	NE
5	Ala N'kodjéwé	Yagbo	C	58	Morokorou	Kpébié	NE
6	Alakitcha	Ouoghi	C	59	Oroubessi	Sirarou	NE
7	Anago	Yagbo	C	60	Sika	Sakagbansi	NE
8	Assibo	Ouoghi	C	61	Singo	Sonnoumon	NE
10	Bodi	Aklampa	C	62	Wabè	Alfakpara	NE
11	Dègbo	Assanté	C	63	Wobo	Sakagbansi	NE
12	Djilaadja	Okounfo	C	64	Yakassougo	Suya/Sandiro	NE
13	Dodo	Ouèdèmè	C	65	Yontémé	Marégourou	NE
14	Effourou	Yagbo	C	39	Alassoura	Alédjo-Kpatago	NW
15	Efour	Ouoghi	C	66	Assana	Ouassa	NW
16	Enanwaï	Okounfo	C	67	Bakanon	Alfakpara	NW
17	Gangni	Ouèdèmè	C	68	Héléba	Foubéa	NW
18	Gnanlabo	Kpataba	C	69	Itolo	Foubéa	NW
19	Gnidou	Yagbo	C	70	Koutounou	Alfakpara	NW
20	Gogan	Assanté	C	71	Kpagnina	Alédjo-Kpatago	NW
21	Idoun	Pira	C	72	Kpakara	Foubéa	NW
22	Ilèkè	Kaboua	C	73	Lorie	Alédjo-Kpatago	NW
23	Kabilatonan	Yagbo	C	74	Noudoss	Ouassa	NW
24	Kanatonan	Assanté	C	75	Noukpam	Foubéa	NW
26	Kokoro	Yagbo	C	76	Papetè	Foubéa	NW
27	Kokoro Djougou	Ouoghi	C	77	Younouan	Alédjo-Kpatago	NW
28	Kokouman	Kaboua	C				
29	Kpakala	Ouoghi	C		***D. alata***		
30	Kpakra	Ouoghi	C	2	APK Florido	Ouoghi	C
31	Laboko	Ouèdèmè	C	4	Djekin	Aklampa	C
32	Laboko Parakou	Ouèdèmè	C	6	Florido	Yagbo	C
33	Mafobo	Kpakpaza	C	8	Kèègbè	Kaboua	C
35	Mondji	Ouoghi	C	9	Kpakata	Kaboua	C
36	Ofègui	Kaboua	C	12	Louelougan	Yagbo	C
37	Okoguin	Kaboua	C	13	Ogbo	Koko	C
38	Adani	Ginagourou	NE	14	Ogbo otcho adjana	Akpassi	C
40	Angogo	Sonoumon	NE	22	Sonouko	Yagbo	C
42	Baniwouré Bakarou	Suya	NE	24	Tchoko la vipère	Kaboua	C
43	Baniwouré Yantékpéron	Suya	NE	25	Tifiou	Okounfo	C
44	Boniyakpa	Marégourou	NE	15	Sankou arisso	Kpébié	NE
45	Danwaré	Biro	NE	16	Sankou Gankou	Sonri	NE
46	Dibiri	Sontou	NE	17	Sankou Garkou	Sandiro	NE
47	Dourokonou	Suya	NE	18	Sankou Kergba	Sontou	NE
48	Doudouwourou	Sontou	NE	19	Sankou souan	Ouroumonsi	NE
50	Youbakatanou	Sirarou	NE	20	Sankou Wa	Marégourou	NE
51	Gbarao	Sakabansi	NE	21	Sankourou	Ouénou	NE
52	Gonni	Ouénou	NE	11	Kpatagnan Pénin	Ouassa	NW
53	Ibérégbesse	Marégourou	NE	26	Toufou	Foubéa	NW

tuber flesh characteristics were hardness, skin colour, flesh colour, uniformity of the colour at the central section of the tuber, oxidation time, oxidation colour, flesh texture, and skin thickness. The variables relating to the tuber's external morphology were tuber shape, forking, forking position, spine presence on tuber, spine abundance of rootlets, small excrescences on tuber, presence on tuber of wrinkles, presence on tuber of cracks, abundance of rootlets, relations between tubers from the same plant. The eight traits of the leaf and stem were presence of wings, wing colour, presence of spines, coloured base of the spine, leaf shape, leaf colour, stem colour, and petiole colour. These observations are in line with indicators used by farmers and with yam descriptors (IPGRI/IITA 1997).

Agronomic analysis

Agronomic evaluation of yam varieties: Genotype by environment interaction
Yield data (kg/heap) were collected during 2003 and 2004 on the agronomic performance of three yam species. The data set included 27 *D. cayenensis / D. rotundata* and 17 *D. alata* varieties.

Management of the dormancy of yam planting material
The length of the post-harvest dormancy (and thus the earliness of sprouting) is mainly affected by variety and temperature during storage of the planting material. Therefore, the effects of storage conditions, storage duration and variety were studied. Twenty yam varieties (16 *D. cayenensis / D. rotundata* and four *D. alata* varieties) were selected for this experiment. The 16 *D. cayenensis / D. rotundata* varieties included 12 early-maturing ones (Kabilètonan, Laboko, Ala, Mafobo, Ofègui, Anago, Mondji, Effourou, Gangni, Djiladja, Ahimon, Gnidou) and four late-maturing ones (Kokoro, Alakitcha, Gnanlabo, Klatchi). The *D. alata* varieties were *Florido, Louélougan, Hounvè,* and *Sounouko.* Tubers were stored under two storage conditions (under a tree and in a hole) and for two storage periods (3 weeks and 6 weeks). The average temperature in the hole was 31.7 °C and under the tree it was 28.3 °C during the test period. Data recorded included the number of sprouted seed tubers at several dates. The first records were taken after 3 weeks. At that time, the seed-tuber samples of each variety were divided into two parts. One part was planted that same day with the farmers; the second part was maintained in storage for another 3 weeks, after which the second recording was taken and the remaining seed tubers were planted. Days after planting to emergence and fresh tuber yield (kg/heap) were assessed.

Use of different tuber parts as planting material

Traditional practice on planting material is based on using different parts of the tuber, very often the entire tuber from the second harvest for early maturing vareties and the proximal, middle, and distal part for late maturing varieties of *D. cayenensis* / *D. rotundata* / *D. alata* at first (and only) harvest. Seed-tubers from four different farmer-varieties (Laboko, Gangni, Alakitcha, and Gnanlabo) were selected, based on information given by farmers on those varieties. For the early-maturing varieties (Laboko and Gangni) there were four treatments: apical parts, middle parts, distal parts, and non-cut seed tubers, always using seed tubers from the second harvest. For the late-maturing varieties (Alakitcha and Gnanlabo) three treatments were applied: apical parts, middle parts, and distal parts of seed tubers taken from the only harvest that occurred. There were four repetitions of five heaps per variety for each treatment, resulting in 20 heaps per treatment per variety. See also Table 2.

Molecular analysis

DNA isolation

The collected fresh leaves were frozen in liquid nitrogen. Leaves were ground with a mortar and pestle. DNA was isolated according to the Cethyltrimetylammonium bromide (CTAB) protocol described by Rogers and Bendich (1985) with slight modifications as described below. Up to 200 mg of ground leaf tissue was transferred

Table 2. Farmers' seed practices and knowledge.

	Farmers' seed practices and knowledge
Laboko	Laboko is an early-maturing variety. Often farmers do not use a sectioned tuber as it quickly rots. By experience, farmers do not plant the distal part of Laboko because it never or rarely sprouts. The vigour of a non-fractioned tuber is higher than the one from which the distal part has been removed.
Gangni	Gangni is an early-maturing variety for which the second harvest is often used for seed. Farmers have the opinion that the tuber of Gangni can be sectioned in case the proximal part is used for planting, but the distal part sprouts very slowly.
Alakitcha	Alakitcha is a late-maturing variety. Only its proximal part is used as planting material by farmers.
Gnanlabo	Gnanlabo is a late-maturing variety. Farmers mentioned that any part of Gnanlabo can sprout if they prepare the tuber properly before planting. However, farmers often use an entire tuber as tubers from Gnanlabo are not very big.

to 2 ml eppendorf tubes, mixed with 500 µl of 2 × CTAB extraction buffer and incubated in a 65 °C water bath with frequent agitation by hand for 90 min. The tubes were removed from the water bath and allowed to cool at room temperature before 500 µl of phenol was added and mixed thoroughly. The mixture was centrifuged at 12000 rpm for 10 min and the upper supernatant phase collected in a new tube. A second extraction was performed with 500 µl of mixture v/v phenol/chloroform isoamyl alcohol (24:1). After centrifugation, the supernatant was treated with RNase and the last extraction was performed with chloroform isoamyl alcohol. The upper phase was transferred into a new tube and DNA was precipitated with equal volumes of 2–propanol and Na-acetate. The DNA pellet was washed with 70% ethanol dried for 5 min in a heating bloc at 60 °C. The resulting DNA pellet was dissolved in 100 µl of distilled and sterilized water (Sigma). DNA quality was tested, using 1.5% agarose gel electrophoresis, and its concentration was determined with a UV spectrophotometer. Part of the DNA was then diluted to 25 ng/µl for PCR amplification.

PCR amplification

PCR reactions were performed in 25 µl volume in a mixture containing 1.7 mM $MgCl_2$, 1 × PCR buffer (50 mM KCl, 10 mM Tris-HCl pH 9.0), 0.1 mM of each dNTPs, 0.1 µM of random decamer primer, 50 ng of DNA and 1 unit of Taq DNA polymerase. The PCR amplification process was conducted in either T3 Thermocycler Biometra or Eppendorf Mastercycler. For each amplification process, an initial heat denaturation of DNA at 94 °C for 3 min was followed by 45 cycles consisting of 1 min at 94 °C, 1 min at 36 °C, and 2 min at 72 °C. A final incubation for 10 min at 72 °C was performed and the amplification products analysed on 2% agarose gel in Tris-borate buffer at 150 volts for 1 h. The agarose gel was stained in ethidium bromide, visualized under UV and photographed using a digital camera (Canon ISUS 3030). The ladder from SIGMA was used as standard molecular weight size marker.

The 12 primers used in this research were obtained from Invitrogen Life Technologies (Table 3). These primers were identified by Dansi *et al.* (2000c) as the best for genetic diversity characterization of yam.

Preliminary PCR amplification trials were performed on four cultivars arbitrarily selected in order to standardize the DNA amplification conditions for yam. These cultivars included two of *D. cayenensis / D. rotundata* species (Gangni and Laboko) and two of the *D. alata* species (Djekin and Sankou kergba). Different concentrations of $MgCl_2$, DNA, dNTPs, and Taq DNA polymerase were tested to obtain the most reproducible and reliable DNA amplification profiles. Optimal conditions which revealed clear and reproducible amplification fragments were used in the study as earlier described.

Table 3. List and sequence of the 10-base nucleotide primers used for the RAPD analysis.

Selected Primers		Not Selected Primers	
Primer code	Nucleotide sequence	Primer code	Nucleotide sequence
OPW-2	5'-ACCCCGCCAA-3'	OPW-1	5'-CTCAGTGTCC-3'
OPW-5	5'-GGCGGATAAG-3'	OPW-12	5'-TGGGCAGAAG-3'
OPW-6	5'-AGGCCCGATG-3'	OPW-14	5'-CTGCTGAGCA-3'
OPW-8	5'-GACTGCCTCT-3'	OPW-15	5'-ACACCGGAAC-3'
OPW-16	5'-CAGCCTACCA-3'	OPW-17	5'-GTCCTGGGTT-3'
OPQ-4	5'-AGTGCGCTGA-3'	OPW-18	5'-TTCAGGGCAC-3'

Selection of the most informative primers

PCR amplification was performed on 14 yam accessions (12 accessions of the *D. cayenensis / D. rotundata* complex and two of *D. alata*). The 12 primers were used individually in order to select the primers that showed most important polymorphic amplification fragments. Six out of 12 primers (OPW-2, OPW-5, OPW-6, OPW-8, OPW-16, and OPQ-4) revealed important polymorphic bands on the 14 yam cultivars screened and these were then selected for the whole study.

Farmer yam knowledge from the perspective of human and social capital

Human capacity is sometimes described in terms of capital (wealth foregone as investment). Five kinds of capital are considered by social scientists: social, human, financial, physical, and natural capitals (Bourdieu, 1988; Scoones, 1998; FAO, 1999; Pretty, 1998, 2001; Pretty and Ward, 2001; Bartlett, 2004; Mancini, 2006). For this study, two capitals have been evaluated: human and social capitals. Human capital is the total capacity in individuals, based on their stock of knowledge and skills (Pretty, 2001). Social capital yields a flow of mutual benefits from investment in collective action, and this flow of benefits is often seen as a means to explain the subsequent cohesiveness of human groups. Social capital consists of assets such as norms, values and attitudes that predispose people to cooperate, relations of trust, reciprocity and obligations, and common rules and sanctions mutually-agreed and handed-down (Pretty, 2001). In Benin, the whole methodology of the impact assessment of Convergence of Sciences research was designed by the PhD researchers, but the field survey of this impact assessment was conducted by two external independent researchers.

In this study, we are interested in human and social capital as a way of characterizing the knowledge-based capacity of farming groups in Benin to capitalize on yam planting materials and yam genetic resources. This impact assessment was conducted on 17 farmers (11 men and 6 women) of the learning group of Yagbo. The concrete value of the impact was assessed, based on the difference in farmers' appreciation of the two capitals realised in two periods, before (year 2003) and after (year 2005, i.e., the time of impact assessment) of the co-experimentation in the framework of the Convergence of Sciences intervention. The information on the baseline year 2003 was gathered by the recall technique.

The impact assessment involved several research phases and covered the period April–October 2005. In April 2005, a literature review was made on the history of the participatory research and technology development in Benin. In May-June 2005, an explanatory research phase of the impact of co-researching on farmers' livelihoods was made. During this explanatory phase, data were collected on the 17 farmers and mainly on the socio-cultural and economic characteristics of the farmers, their various motivations of being members of the co-researching on yams, and their relations with other farmers, non-members of the learning group in the village. In July–October 2005, the in-depth research impact assessment was realized in two steps.

As a first step in understanding how farmers form human and social capital around yams, we asked respondents to evaluate the most important assets in their capital stock. Human capital on yam diversity characterization comprised knowledge concerning new varieties, rapid sprouting, seed multiplication, storing for long duration, and yield increase. In respect of social capital the valued assets were social cohesion of different ethnic groups, information sharing between researcher and farmer, farmer to farmer interaction, taking into account of farmer decisions during the research process, tontine (rotational savings club) memberships among members of farmer learning group, and improved gender relations through yam experimentation.

In a second step, respondents rated the stocks of assets identified for each capital for the baseline year 2003 (starting year) and impact year 2005 (end of co-research activity by the Farmer Learning Group), based on a 0–5 scale, with the zero value referring to no stocks and the maximum indicating the full satisfaction in that capital stock to each farmer. The final assessment has been realized on 15 farmers (9 men and 6 women), two of the farmers of the learning group being absent during this final assessment.

Data analysis: Morphological data analysis

Qualitative tuber, leaf and stem morphology characteristics

The variables of the three qualitative tuber, leaf and stem characters were encoded into 2 to 7 classes. Frequency distributions were performed for these qualitative tuber, leaf and plant morphology variables. The frequency distributions were used to calculate the Shannon-Weaver diversity index (*H*') for each character (Grenier *et al*., 2004):

$$H' = -\sum_{i=1}^{n} p_i \ln(p_i)$$

where, n is the number of phenotypic classes, p_i the frequency of the observation in the i^{th} class. Because of its additive property, the indices of all characteristics were pooled over the characteristics and the global phenotypic diversity was estimated by the mean index value using the SAS 8e program. In this chapter, data were analysed on 70 *D. cayenensis / D. rotundata* and 26 *D. alata* farmer varieties, all of which were different according to morphological criteria.

Data analysis: Agronomic data analysis

Genotype by environment interaction

An integrated full interaction analysis of variance was carried out. Such an analysis describes the phenotypic responses and allows for differential environmental sensitivity between genotypes based on the regression on the mean model of differences in environmental sensitivity (Finlay and Wilkinson, 1963; Van Eeuwijk *et al*., 2005). The philosophy of this model is that in the absence of explicit physical or meteorological characterizations of an environment, a good approximation of the general biological quality of the environment is given by the average phenotypic performance across the genotypes (Van Eeuwijk *et al*., 2005). The phenotypic responses of individual genotypes are then regressed on the average performance, and the genotype by environment interaction expresses itself by differences in the slopes between the genotypes. This regression on mean model can be written as follows:

$$\mu_{ij} = u + G_i + E_j + \beta_i E_j$$

where, the genotype by environment interaction is modelled as differential genotypic sensitivity and represented by the parameters β_i to environmental characterization E_j, with the average sensitivity being zero.

In this study, the Generalized Linear Model of Analysis of Variance (GLM ANOVA) under SAS was performed to analyse the variation of yield components in response to change in year effects. The GLM ANOVA is appropriate especially for unbalanced data, where there are unequal numbers of observations for the different combinations of class variables specified in the model structure. With this ANOVA, the yield was analysed. The following effects were considered for each variety-type (early or late maturing) and each species:

- Genotype (farmer-named variety)
- Year (2003–2004)
- Genotype × Year

The data set for the genotype by environment interaction analysis included 27 *D. cayenensis / D. rotundata* and 17 *D. alata* varieties. These data were analysed using a general linear model for the pooled analysis of variance across years using the SAS program. The Student-Newman-Keuls (SNK) multiple range means comparison test was used to separate genotypes with different yield performance.

Genetic expression variability

The Expected Mean Squares (EMS) for the genotypic variance components (Becker, 1984; Comstock, 1996; Hebert *et al*., 1998; Li *et al*., 1998) are:

EMS (Genotypes): $\sigma_e^2 + r\sigma_{G*Y}^2 + 2r\sigma_G^2$

EMS (Genotypes × Year): $\sigma_e^2 + r\sigma_{G*Y}^2$

EMS (error): σ_e^2

where, *r* is the number of replications. From the Mean Square calculated and the EMS (Genotypes), the genetic variance, the genetic coefficient of variance (GCV), the Genotype × Year variance component and the environmental variance were estimated. The Student-Newman-Keuls (SNK) multiple range means comparison test was used to separate genotypes with different yield performance.

Molecular data analysis

After electrophoresis separation, amplified DNA fragments detected in each cultivar were scored for presence (1) or absence (0) of a particular DNA fragment at a particular position. A data matrix was then prepared for different analyses.

To assess genetic diversity, a pair-wise similarity matrix was generated using the Nei – Li similarity index ($S=2N_{AB}/(N_A+N_B)$; Nei and Li, 1979), where N_{AB} is the number of RAPD fragments shared by two genotypes or cultivars (A and B); N_A and N_B are the total number of RAPD fragments analysed in each genotype (Levi *et al*., 2001).

A dendrogram was then constructed based on the similarity matrix data using the UPGMA (Unweighted Pair-Group Method using Arithmetic Averages) cluster analysis of NTSYSpc-2.02j (Numeral Taxonomy and Statistical Analysis; Rohlf, 1998).

The genetic variation between cultivars was investigated by an Analysis of Molecular Variance (AMOVA) (Excoffier *et al*., 1992). The total molecular variance (σ_T^2) was partitioned into a variance component due to differences among species (σ_{CT}^2), a variance component due to differences among groups within species (σ_{SC}^2), and to differences among cultivars within groups within species (σ_{ST}^2).

In a natural selection system, the allele fluctuation which occurs within groups of individuals tends to create or increase the genetic differentiation among groups by increasing homozygosity and decreasing heterozygosity (Conner and Hartl, 2004). It is the same pattern produced by inbreeding within groups. As reported by Conner and Hartl (2004), the geneticist Sewal Wright used this similarity between the fluctuation frequency within groups and inbreeding to create the F Statistic, which provides an integrated view of genetic variation at three levels: within groups, among groups, and the total variation. As differentiation increases, so does the variance in allele frequency among groups, so the fixation index increases (Conner and Hartl, 2004). It is called fixation index because it increases as more groups become fixed for one allele (or close to fixation with the frequency tending to 0 or 1). To analyse the genetic structure, the fixation index is a measure that is more and more used (Weir and Cockerham, 1984; Excoffier *et al.*, 1992; Weir, 1996; Excoffier, 2000; Schneider *et al.*, 2000; Rousset, 2001; Dugoujon *et al.*, 2004; Kiambi *et al.*, 2005; Excoffier *et al.*, 2006). This index, also called Wright's (1969) fixation index, was calculated for polymorphic loci and notated F_{ST}. F_{ST} is considered as the standardized variance of allele frequencies among cultivars (Excoffier, 2001).

The AMOVA was performed based on a pair-wise squared Euclidean distance matrix using Arlequin ver. 3.01 software (Excoffier *et al.*, 2006). The different patterns of gene-pool differentiation are presented using the bi-plot of the multivariate analysis component of the statistical package GenStat 8.11 (2005).

Data analysis: Human and social capital analysis

The above analysis allows us to assess levels of genetic diversity in yam materials under farmer usage. Human and social capital analysis is used here as way of trying to assess how farmers value their own knowledge of yam varieties, and whether, when they add to stocks of knowledge, they see this as investment in themselves and/or investment in group knowledge and capacity. Spider diagrams were made as a simple way of visualizing the two capitals, in farmers' own evaluations. Based on the scale 0–5, the zero value (no stock) was at the centre of the diagram and the value 5 at the extreme of each of the axes. The extreme of each axis corresponds to respondents' full satisfaction regarding the capital stock in his/her possession. The spider diagram was used to visualize change perceived over time. Median values of capitals were calculated and compared for baseline and the impact year. In effect we were trying to measure whether farmers thought they had added significantly to their knowledge stocks concerning yam by taking part in joint experimental activities with a researcher. Significant differences were determined using the Wilcoxon Matched-Pairs Signed-Ranks, a non-parametric test (alternative to the Student t test for ordinal data) applied to two-sample designs involving repeated measures, matched, or before and after measures (Van der Waerden, 1969; Mancini, 2006).

Results

Morphological diversity of yam

Dioscorea cayenensis / D. rotundata was characterized as wingless. While some varieties were spineless, others were marked with few or dense spines. On young plants 30 days after emergence, the abundance of spines varied from one variety to another. Some varieties had a few spines at the first internodes, but the rest of the stems (main and secondary ones) were spineless (Degbo). Some varieties were characterized by robust stem and dense spines (Alakitcha, Ahimon, Adigbili, Gnidou, Parakou Tevi); the stems of others were thin but had dense spines (Anago, Aguida, Efour, Assibo). The size of spines also varied: short (Moroko) or prickled (Ofegui) spines. Very small leaves and numerous stems (14–24 stems as for Kaagourou) were observed. On adult plants, there was variation in leaf shape, stem and leaf colour (Table 4a). Various tuber shapes and forking tendencies were observed (Table 4b). The tuber flesh of different varieties presented different colours, texture, oxidation colour, oxidation time, and ability to irritate (Table 4c).

Dioscorea alata varieties were all characterized by spineless and winged stems, pentagonal or quadrangular at the basis of the stem, but changing to triangular towards the top. On young plants (30 days after emergence), the leaf shape was variable: oval, long and lanceolate, or funnel-shaped. Various leaf colours, ranging from slight green, green, to red-purple, were observed. Some varieties also showed red-purple petioles. The petiole was red-purple mainly at the insertion point of the leaf on the stem. The number of stems emerging from the planted materials varied from 1 to 10, depending on the variety. On adult plants there was a high variation in stem shape and leaf shape, but also in tuber shape as reflected by presence and position of forking. There were also differences in abundance of presence of rootlets on tubers, and the colours of the skin or flesh of the tubers and of the petiole or vein of the leaves (Tables 4a, 4b, 4c). On average for the characteristics considered, the mean Shannon-Weaver index was 0.86 for the external morphology of the tuber, 0.55 for tuber flesh characteristics, and 1.13 for stem and leaf morphology.

Agronomic evaluation of yam varieties

Genotypic variability

Table 5 presents the mean yield (kg/heap) per variety and shows the variation of the yield from one year to another. The mean yield varied from 0.83 to 3.12 kg/heap in 2003 and from 0.95 to 4.73 kg/heap in 2004 for the early-maturing varieties of the D. *cayenensis / D. rotundata* complex. The pooled mean over 2003 and 2004 varied

Table 4a. Frequency distribution and Shannon-Weaver diversity index (H') for yam stem and leaf morphology.

		D. cayenensis / D. rotundata								*D. alata*					
Variables	Modalities	C	index	NE	index	NW	index	Total	index	C	index	N	index	Total	index
Stem colour	1= light green	0.65		0.64		0.58		0.63		0.54		0.46		0.50	
	2= green	0.05		0.04		0.08		0.06		0.33		0.27		0.31	
	3= dark green	0.11		0.14		0.08		0.11		0.07		0.27		0.15	
	4= purple	0.06		0.09		0.09		0.06							
	5= reddish-purple	0.13	1.11	0.09	1.12	0.17	1.24	0.14	1.15	0.07	1.07		1.06	0.04	1.12
Wing colour	1= light green									0.13				0.08	
	2= green									0.13		0.10		0.12	
	3= dark green														
	4= purple									0.14		0.10		0.12	
	5= reddish-purple									0.60	1.11	0.80	0.64	0.68	0.97
Presence of coloured spot at spine base	0= absent	0.73		0.91		0.92		0.82		1		1		1	
	1= purple	0.08						0.04							
	2=reddish-purple	0.19	0.75	0.09	0.30	0.08	0.28	0.14	0.57						
Presence of spines (Spines)	0= absent	0.08		0.05		0.33		0.06		1		1		1	
	1= very sparse	0.38		0.45		0.42		0.39							
	2=abundant	0.41		0.36		0.17		0.39							
	3=very abundant	0.14	1.21	0.14	1.15	0.08	1.23	0.16	1.20						
Leaf colour	1= light green	0.51		0.45		0.67		0.52		0.33		0.09		0.23	
	2= green	0.30		0.18		0.08		0.23		0.27		0.09		0.19	
	3= dark green	0.19		0.37		0.25		0.25		0.27		0.73		0.46	
	4= purple														
	5= reddish-purple		1.02		1.04		0.82		1.02	0.13	1.34	0.09	0.88	0.12	1.27
Vein colour	1= light green	0.95		0.86		0.92		0.91		0.33		0.73		0.50	
	2= green	0.05		0.14				0.07		0.47		0.18		0.35	
	3= dark green					0.08		0.02							
	4= reddish-purple		0.20		0.40		0.28		0.35	0.20	1.04	0.09	0.76	0.15	1.01
Petiole colour (Petiole)	1= light green	0.67		0.69		0.50		0.65		0.26		0.64		0.43	
	2= green	0.14		0.18		0.25		0.17		0.40		0.18		0.31	
	3= dark green	0.05		0.09		0.08		0.07		0.07		0.18		0.12	
	4= purple	0.14		0.04		0.17		0.11		0.13				0.08	
	5= reddish-purple		0.97		0.91		1.20		1.01	0.14	1.44		0.90	0.04	1.31
Leaf shape	1= small	0.22		0.04				0.13							
	2= medium	0.16		0.27		0.25		0.21				0.18		0.08	
	3= large	0.22		0.41		0.33		0.29		0.67		0.64		0.65	
	4= cordate long	0.19				0.25		0.14		0.07				0.04	
	5= funnel-shape	0.13		0.14		0.08		0.13		0.07		0.09		0.08	
	6= ovate	0.08	1.74	0.14	1.40	0.08	1.46	0.10	1.72	0.20	0.96	0.09	1.03	0.15	1.10

Table 4b. Frequency distribution and Shannon-Weaver diversity index (H') for yam tuber's external morphology.

		D. cayenensis / D. rotundata								*D. alata*					
Variables	Modalities	C	index	NE	index	NW	index	Total	index	C	index	N	index	Total	index
Tuber shape	1= oval	0.19													
	2= oval-oblong	0.28		0.31		0.40		0.15		0.08		0		0.04	
	3= cylindrical	0.38		0.56		0.60		0.26		0.46		0.55		0.50	
	4= flattened	0.03		0.07				0.45		0.23		0.18		0.21	
	5= irregular	0.12		0.06				0.10		0.08		0.18		0.12	
	6= snake-shaped		1.40		1.04		0.67	0.04	1.35	0.15	1.38	0.09	1.16	0.13	1.32
Digitations / forking	0= no forking	0.03		0.12		0.60		0.11		0.23		0.18		0.21	
	1= slightly forked	0.41		0.38		0.20		0.38		0.23				0.13	
	2= forked	0.12		0.31		0.20		0.19		0.23				0.12	
	3= highly forked	0.44	1.09	0.19	1.30		0.95	0.32	1.29	0.31	1.38	0.82	0.47	0.54	1.18
Digitation position	0= no forking	0.25		0.13		0.60		0.24		0.23		0.18		0.21	
	1= third-top	0.22		0.56		0.20		0.32		0.15		0.27		0.21	
	2= middle	0.13		0.31				0.08		0.08		0.09		0.08	
	3= third-bottom	0.38				0.20		0.34		0.38		0.36		0.38	
	4= 1+2; 2+3; 1+2+3	0.03	1.42		0.95		0.95	0.02	1.35	0.16	1.49	0.09	1.46	0.12	1.48
Relationship of tubers	1= separate and distant	0.41		0.31		0.40		0.38		0.54		0.36		0.46	
	2= separate but close together	0.25		0.25		0.40		0.26		0.31		0.27		0.29	
	3= fused at neck	0.28		0.44		0.20		0.32		0.15		0.36		0.25	
	4= 1, 2, 3	0.06	1.24		1.07		1.05	0.04	1.21		0.98		1.09		1.06
Roolet abundance	0= absent	0.03		0.06				0.04							
	1= few	0.69		0.63		0.80		0.68		0.31		0.45		0.37	
	2= abundant	0.19		0.13		0.20		0.17		0.31		0.09		0.21	
	3= very abundant	0.09	0.89	0.19	1.04		0.5	0.11	0.94	0.38	1.09	0.46	0.93	0.42	1.06
Roolet position on tuber	0= absent	0.06		0.06				0.06							
	1= basal	0.09		0.13				0.09		0.08		0.09		0.04	
	2= middle									0.08				0.04	
	3= proximal	0.66		0.56		1		0.66		0.08				0.04	
	4= combination of 1, 2, and 3	0.18	0.97	0.25	1.11			0.19	0.98	0.76	0.81	0.91	0.30	0.88	0.50
Wrinkles on tuber	0= absent	0.28		0.38		0.20		0.30		0.92		0.73		0.83	
	1= few	0.47		0.50		0.60		0.49				0.27		0.13	
	2= abundant	0.16		0.13		0.20		0.13							
	3= very abundant	0.09	1.22	0	0.98		0.95	0.08	1.18	0.08	0.28		0.58	0.04	0.55
Bulbe on tuber	0= absent	0.44		0.38		0.60		0.43		0.85		0.82		0.83	
	1= present	0.56	0.69	0.62	0.66	0.40	0.67	0.57	0.68	0.15	0.42	0.18	0.47	0.17	0.46
Spine on tuber	0= absent	0.65		0.63		0.60		0.63		0.85		0.91		0.87	
	1= present	0.35	0.65	0.37	0.66	0.40	0.67	0.37	0.66	0.15	0.42	0.09	0.3	0.13	0.39
Bulbe on tuber	0= absent	0.47		0.50		0.60		0.49		0.69		0.64		0.67	
	1= present	0.53	0.69	0.50	0.69	0.40	0.67	0.51	0.69	0.31	0.62	0.36	0.65	0.33	0.63

Table 4c. Frequency distribution and Shannon-Weaver diversity index (H') for yam tuber flesh characteristics.

		D. cayenensis / D. rotundata								*D. alata*					
Variables	Modalities	C	index	NE	index	NW	index	Total	index	C	index	N	index	Total	index
Tuber hardness	1= difficult	0.31		0.19		0.25		0.26		0.09				0.06	
	2= easy	0.66		0.71		0.75		0.69		0.91		1		0.94	
	3= moderate	0.03	0.74	0.10	0.79		0.56	0.05	0.76		0.30				0.23
Tuber's skin colour	1= white	0.82		0.90		0.83		0.85		0.45		0.43		0.44	
	2= yellow	0.13						0.06				0.14		0.06	
	3= cream	0.06		0.05				0.02							
	4= white with purple			0.05				0.02		0.18		0.43		0.28	
	5= white with red spot		0.60		0.39	0.17	0.46	0.06	0.63	0.36	1.04		1.00	0.23	1.22
Flesh colour	1= whitish	0.44		0.95		0.83		0.86		0.46		0.86		0.61	
	2= yellow	0.13						0.06				0.14		0.06	
	3= orange	0.38													
	4= cream	0.06		0.05						0.09				0.06	
	5= white with purple							0.02		0.09				0.06	
	6= white with red spot		1.16		0.20	0.17	0.46	0.06	0.55	0.36	1.16		0.40	0.21	1.14
Flesh colour's uniformity	1= uniform	0.72		0.57		1		0.72		0.27		1		0.83	
	0= non uniformity	0.28	0.59	0.43	0.68			0.28	0.59	0.73	0.58			0.17	0.46
Flesh texture	1= smooth	0.47		0.52		0.50		0.49		0.91		1		0.94	
	2= grainy	0.25		0.43		0.50		0.35		0.09				0.06	
	3= very grainy	0.28	1.06	0.05	0.85		0.69	0.16	1.01		0.30				0.23
Flesh oxidation colour	0= no oxidation	0.09		0.24		0.08		0.13		0.91		0.86		0.89	
	1= grey	0.03						0.02				0.14			
	2= orange	0.16						0.07							
	3= purple	0.59		0.57		0.75		0.61		0.09				0.11	
	4= yellow	0.06		0.05		0.08		0.06							
	5= reddish-purple	0.03		0.14				0.07							
	6= ivory	0.03	1.31		1.18	0.08	0.82	0.04	1.39		0.30		0.40		0.35
Oxydation time	0= absence of oxidation									0.91		0.86		0.88	
	1 min	0.44		0.33		0.42		0.40							
	1–2 min							0.14							
	2 min	0.19		0.10		0.08						0.14		0.06	
	3 min	0.38	1.04	0.57	0.92	0.50	0.91	0.46	1.00	0.09	0.30		0.40	0.06	0.45
Tuber irritation	0 = absent	0.03						0.02							
	1 = little	0.53		0.33		0.50		0.46		0.82		1.00		0.89	
	2 = medium	0.31		0.53		0.50		0.41		0.18					
	3 = high	0.13	1.07	0.14	0.98		0.69	0.11	1.04		0.47			0.11	0.35

Table 5. Mean yield (kg/heap) of 27 *D. cayenensis / D. rotundata* and 17 *D. alata* yam varieties over 2003−2004.

Species	Variety type	Variety	2003 Mean	2003 SE	2004 Mean	2004 SE	Pooled mean 2003−2004	Pooled mean SE
D. cayenensis / D. rotundata								
	Early	Anago	1.77	0.27	4.73	0.47	3.30 a	0.38
	Early	Adigbili	3.12	0.33	2.81	0.59	3.04 ab	0.28
	Early	Effourou	1.88	0.23	3.23	0.51	2.71 abc	0.35
	Early	Ahimon	1.78	0.15	3.57	0.72	2.58 abcd	0.36
	Early	Gnidou	1.60	0.11	4.19	0.62	2.44 abcd	0.27
	Early	Kpakra	2.28	0.19	2.18	0.29	2.25 abcde	0.15
	Early	Ala N'kodjewe	1.35	0.23	2.82	0.25	2.13 abcdef	0.22
	Early	Djilaadja	1.01	0.25	2.55	0.35	2.13 abcdef	0.30
	Early	Dodo	3.05	0.51	1.66	0.23	2.12 abcdef	0.27
	Early	Gangni	1.64	0.18	2.94	0.29	2.09 abcdef	0.18
	Early	Laboko	1.92	0.45	1.89	0.40	1.90 bcdef	0.32
	Early	Okoguin	1.55	0.17	2.21	0.45	1.75 bcdef	0.19
	Early	Ofegui	0.96	0.13	2.27	0.21	1.66 cdef	0.17
	Early	Danware	0.85	0.21	1.90	0.22	1.38 def	0.20
	Early	Dibiri	1.10	0.46	1.02	0.08	1.05 ef	0.16
	Early	Affo	0.83	0.23	0.95	0.05	0.89 f	0.11
	Late	Alakitcha	1.60	0.50	3.48	0.43	3.03 a	0.39
	Late	Kokoro	1.02	0.11	3.81	0.79	1.93 b	0.32
	Late	Degbo	2.46	0.30	1.33	0.48	1.89 b	0.34
	Late	Klatchi	1.57	0.13	2.18	0.32	1.80 b	0.15
	Late	Bodi	1.26	0.21	2.03	0.14	1.77 b	0.16
	Late	Dourokonou	1.18	0.25	1.85	0.79	1.42 b	0.32
	Late	Aguida	0.60	0.25	1.53	0.14	1.41 b	0.14
	Late	Gnanlabo	0.58	0.14	1.63	0.23	1.34 b	0.20
	Late	Enanwai	0.98	0.31	1.67	0.24	1.24 b	0.24
	Late	Kokorogbarou	0.92	0.10	1.10	0.16	1.03 b	0.11
	Late	Baniwoure	0.86	0.13	1.15	0.18	0.94 b	0.11
D. alata	Late	Djekin	2.65	0.46	4.65	0.63	4.17 a	0.52
	Late	Sankou Garkou	2.22	0.24	5.26	1.48	3.44 ab	0.68
	Late	Sankou Souan	2.03	0.20	3.73	0.65	3.37 abc	0.54
	Late	Kpakata	3.22	0.44	3.11	0.63	3.15 abcd	0.42
	Late	Keegbe	2.62	0.29	3.67	0.48	3.08 abcd	0.28
	Late	Sankou Kergba	2.22	0.27	3.10	0.54	2.79 bcde	0.37
	Late	Tchoko la Vipere	2.74	0.25	2.51	0.52	2.67 bcde	0.23
	Late	Sankounou	1.96	0.39	2.58	0.33	2.39 bcde	0.26
	Late	Afe	1.01	0.27	3.12	0.32	2.30 bcde	0.33
	Late	Louelougan	1.32	0.09	3.07	0.36	2.15 cde	0.23
	Late	Gobiledo	1.42	0.20	2.24	0.28	2.04 de	0.23
	Late	Egni-Eri	1.14	0.21	2.37	0.32	1.93 de	0.25
	Late	APK Florido	1.55	0.10	2.94	0.74	1.92 de	0.24
	Late	Florido	1.58	0.05	2.88	0.42	1.83 de	0.10
	Late	Hounve	2.20	0.37	1.36	0.16	1.65 e	0.18
	Late	Dangbeko	1.16	0.20	1.78	0.25	1.63 e	0.20
	Late	Sankou Wa	2.04	0.24	1.07	0.14	1.45 e	0.17

Means followed by the same letter or letters are not significantly different at the level of 0.05 using the test of Student Newman Keuls.

Table 6. Estimated parameters for genotypic and environmental variability of 27 *D. cayenensis / D. rotundata* and 17 *D. alata* yam varieties from pooled ANOVA.

Species	Variety type	Source of variation	DF	Mean square	F-statistics
D. cayenensis / D. rotundata					
	Early maturing	Variety	15	8.57	4.99**
		Year	1	60.09	35.04**
		Variety × Year	15	7.78	4.54**
		Model	31	12.13	7.07**
		Error	403	1.71	
		Mean (kg/heap)=2.26			
		R-square=0.35			
	Late maturing	Variety	10	5.94	4.27**
		Year	1	21.98	15.79**
		Variety × Year	10	5.21	3.74**
		Model	21	8.53	6.13**
		Error	207	1.39	
		Mean (kg/heap)=1.70			
		R-square=0.38			
D. alata	Late maturing	Variety	16	9.49	4.68**
		Year	1	79.59	39.23**
		Variety × Year	16	5.84	2.88**
		Model	33	12.56	6.19**
		Error	448	2.03	
		Mean (kg/heap)=2.39			
		R-square=0.31			

Level of significance: ** $P < 0.01$.

between 0.89 and 3.30 kg/heap. On average, the mean yield of the late-maturing varieties of the *D. cayenensis / D. rotundata* complex varied between 0.86 to 2.46 kg/heap in 2003 and between 1.15 and 3.81 kg/heap in 2004. The pooled mean for these late varieties ranged from 0.94 to 3.03 kg/heap.

The *D. alata* varieties were essentially all late maturing. The mean yield of *D. alata* varied from 1.01 to 3.22 kg/heap in 2003 and between 1.07 and 5.26 kg/heap in 2004, with a pooled mean ranging from 1.45 to 4.17 kg/heap over the two years.

Table 6 provides the variance components using the GLM-ANOVA as described in the methodology section. Varieties showed highly significant differences. The year effect was highly significant for variety-type group and species. This year effect was larger than the genotypic effect. The genotype by year interaction effects were also highly significant.

Genetic variability

After removing the year and genotype by year interaction from the total genotypic variation, the genetic variance component remained significant for the two species with large numbers of varieties included in the analysis (Table 7). For the early-maturing varieties of *D. cayenensis / D. rotundata* genotypes, the genetic variance was greater in 2004 than in 2003. For the late-maturing varieties, the environmental variance was greater than the genetic variance both in 2003 and 2004. For the *D. alata* genotypes, the genetic variance was greater in 2003 but lower than the environmental variance in 2004. Over the two years, the environmental variance was greater than the genetic variance for both species groups. There was a large non-genetic component in the phenotypic behaviour of these two species groups of yams. Moreover, the *D. cayenensis/D. rotundata* genotypes responded differently to the year effect compared to *D. alata* genotypes.

Grouping varieties based on the mean yield

The Student-Newman-Keuls (SNK) test was used to separate the different varieties based on the mean yield over the two years (Table 5). Means followed by the same letters are not significantly different at the level of 0.05. That test separates the early-maturing varieties of the *D. cayenensis/D. rotundata* complex into 11 groups, while the late ones were grouped into two groups. The highest yields were obtained by Anago (3.30 kg/heap), Adigbili (3.04 kg/heap) and Alakitcha (3.03 kg/heap) and the lowest by Affo (0.89 kg/heap), Baniwouré (0.94 kg/heap), Kokorogbarou (1.03 kg/heap) and Dibiri (1.05 kg/heap).

Eight groups were distinguished for *D. alata* varieties. Three of the groups composed of individual variety (Djekin, Sankou-garkou, Sankou-souan) showed the highest yields (4.17; 3.44 and 3.37 kg/heap, respectively) (Table 5). The lowest yield was obtained for the group with the varieties Hounvè, Dangbéko and Sankou-wa.

Co-researching specific characteristics and strategies of diversity management

Management of dormancy of planting material of yam

The effects of storage location and storage duration strongly affected the time of sprouting for the early-maturing *D. cayenensis / D. rotundata* varieties (Table 8). Moreover, the analyses of variance revealed that variations in rate of sprouting were different among the 12 early-maturing *D. cayenensis / D. rotundata* varieties involved. For the late-maturing *D. cayenensis / D. rotundata*, both storage location and (especially) storage duration affected sprouting (Table 8). There was no effect of storage location or storage duration for the four *D. alata* varieties.

Table 7. Genetic variability from individual and pooled year analyses.

	D. cayenensis / D. rotundata					*D. cayenensis / D. rotundata*					*D. alata*				
	Early		Early		Early	Late		Late		Late					
	2003	F	2004	F	Pooled	2003	F	2004	F	Pooled	2003	F	2004	F	Pooled
Genotypic variability															
Mean Square (genotype × year)	0		0		7.78	0		0		5.21	0		0		5.84
Mean Square (genotype)	5.83	6.88**	12.07	4.43**	8.57	1.72	4.73**	10.41	4.43**	5.94	4.87	7.10**	14.43	4.30**	9.49
Error	0.85		2.73		1.71	0.36		2.35		1.39	0.69		3.36		2.03
Mean	1.79		2.79		2.26	1.19		2.19		1.70	1.92		2.85		2.38
CV (%)	51.30		59.17		58.20	50.77		70.00		69.17	43.21		64.26		59.69
Genetic expression variability															
Genotype-by-Year variance	/		/		1.92	/		/		1.06	/		/		1.27
Genetic variance	1.29		2.34		0.10	0.26		2.02		0.09	1.05		2.77		0.46
Environmental (error) variance	0.69		3.36		2.03	0.69		3.36		2.03	0.69		3.36		2.03
Phenotypic variance	1.98		5.70		4.05	0.95		5.38		3.18	1.74		6.13		3.76
Genetic Coef. Var. (GCV) (%)	71.79		83.69		4.37	21.64		92.01		5.37	54.43		97.11		19.17

Table 8. Factors that influence (shorten) dormancy or sprouting of yam planting material under farmer conditions using ANOVA.

Species	Variety type	Source of variation	Mean Square	F-Statistics
D. cayenensis / D. rotundata				
	Early maturing (n = 12)	Variety	616.8	3.33**
		Storage method	6486.8	34.99***
		Duration of storage	12160.3	65.59***
		Overall (model)	1861.6	10.04***
	Late maturing (n = 4)	Variety	382.2	1.25 ns
		Storage method	2256.3	7.38*
		Duration of storage	5476.0	17.91**
		Overall (model)	1486.8	4.86*
D. alata	Late maturing (n = 4)	Variety	612.2	0.73 ns
		Storage method	90.3	0.11 ns
		Duration of storage	1936.0	2.30 ns
		Overall (model)	648.8	0.77 ns

* significant at $P < 0.05$; ** significant at $P < 0.01$; *** significant at $P < 0.001$; ns: non-significant.

Table 9. Factorial ANOVA of Days to Emergence from heaps after planting.

Species	Variety type	Source of variation	Mean Square	F-Statistics
D. cayenensis / D. rotundata				
	Early maturing (n=12)	Variety	2946.7	19.54***
		Storage method	13606.7	90.21***
		Duration of storage	63252.9	419.37***
		Storage method × Duration of storage	6936.3	45.99***
		Overall (model)	8280.8	54.90***
	Late maturing (n=4)	Variety	2118.6	14.27***
		Storage method	13154.2	88.58***
		Duration of storage	12411.5	83.58***
		Storage method × Duration of storage	966.3	6.51*
		Overall (model)	5665.4	38.15***
D. alata	Late maturing (n=4)	Variety	221.7	2.03 ns
		Storage method	544.3	4.99*
		Duration of storage	8546.5	78.36***
		Storage method × Duration of storage	144.1	1.32 ns
		Overall (model)	1731.2	15.87***

* significant at $P < 0.05$; *** significant at $P < 0.001$; ns: non-significant.

When these varieties from the different storage and environmental conditions were planted, there were highly significant differences in terms of number of days after planting to emergence (Table 9). In addition to storage method and storage duration effects, the results also showed that the variety effect was highly significant for days to emergence, particularly within the early- and late-maturing variety groups of the *D. cayenensis / D. rotundata* species. The variety effect among *D. alata* varieties was not significant. As shown in Figure 1, the lowest values for days after planting to emergence were observed for all varieties exposed to storage in holes for 6 weeks. Figures 2a, 2b, and 2c reveal the different relationships between the results in terms of days to emergence of the four different modes of storing the planting materials. Figures 2a and 2b showed a positive correlation between 'Holes, 3 weeks' and 'Under tree, 3 weeks', and between 'Holes, 6 weeks' and 'Under tree, 6 weeks', respectively. Figure 2c reveals that the difference between 'Under tree, 6 weeks' and 'Holes, 6 weeks' became progressively reduced when more days were taken to emerge in response to the storage treatment 'Holes, 6 weeks'. This suggests that the effect of temperature sum during storage becomes smaller when the varieties have a longer dormancy.

For yield (kg/heap), there was a large variation within the different types of varieties (early- or late-maturing) or within species (Table 10). Effects of storage method and duration were also significant, as were some of the interactions between storage treatments and variety. Considering each specific storage system, the effect of variety appeared as very important for some varieties showing the highest yield in each system (i.e., Kabilatonan) or showing the lowest yield (i.e., Ofegui) for the early maturing varieties (Table 11). For the late-maturing varieties, the highest yield was obtained from Alakitcha and the lowest from Gnanlabo, while for the *D. alata* varieties, the highest was from Florido and the lowest from Hounvé.

Table 11 also suggests that most of the varieties yielded more when stored in holes or under trees for 3 weeks than when exposed to the same treatments for 6 weeks. The environmental conditions after planting might have been important for this effect.

Our observations suggest that farmer' strategies and practices of managing yam seed tubers differ according to (genotype-specific) dormancies – the main aim appears to be to plant seed tubers in the dry season in order to induce a rapid breaking of dormancy. The main factor contributing to early dormancy breaking is higher temperature of soils.

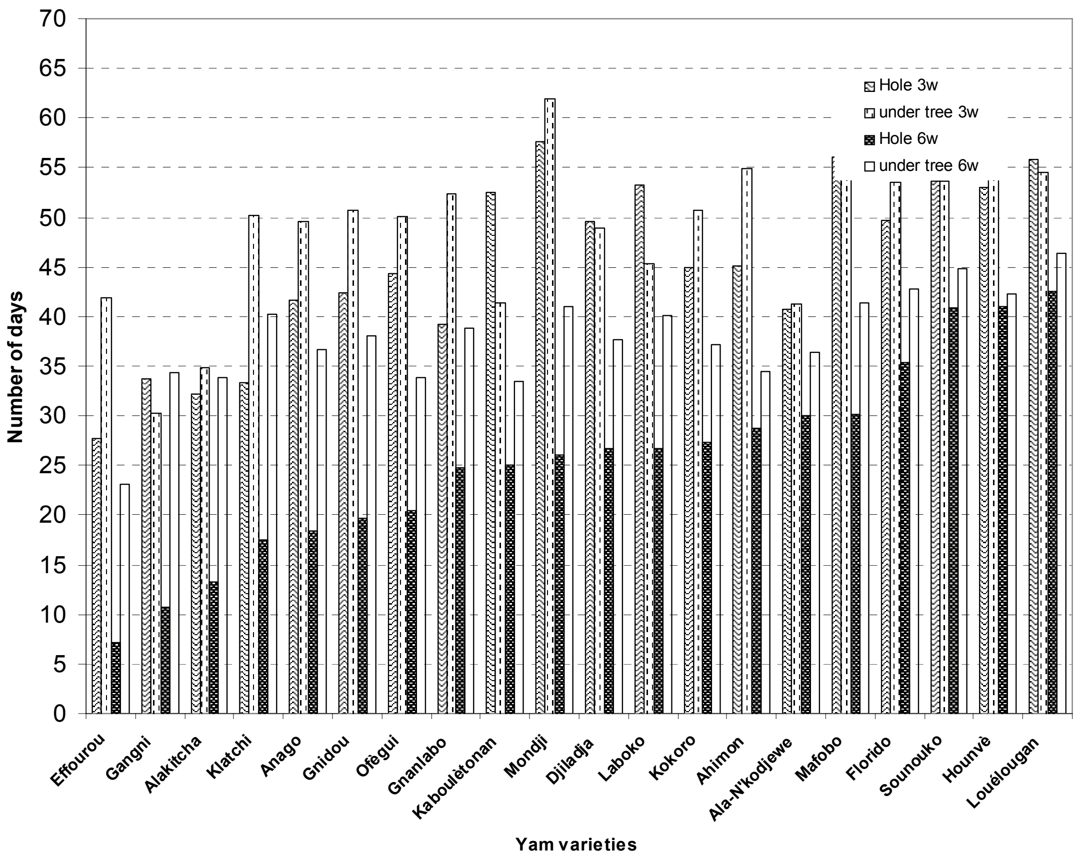

Figure 1. Average number of days from planting to emergence for 20 varieties stored under two different conditions (Holes or under Tree) and for two different periods (3 or 6 weeks).

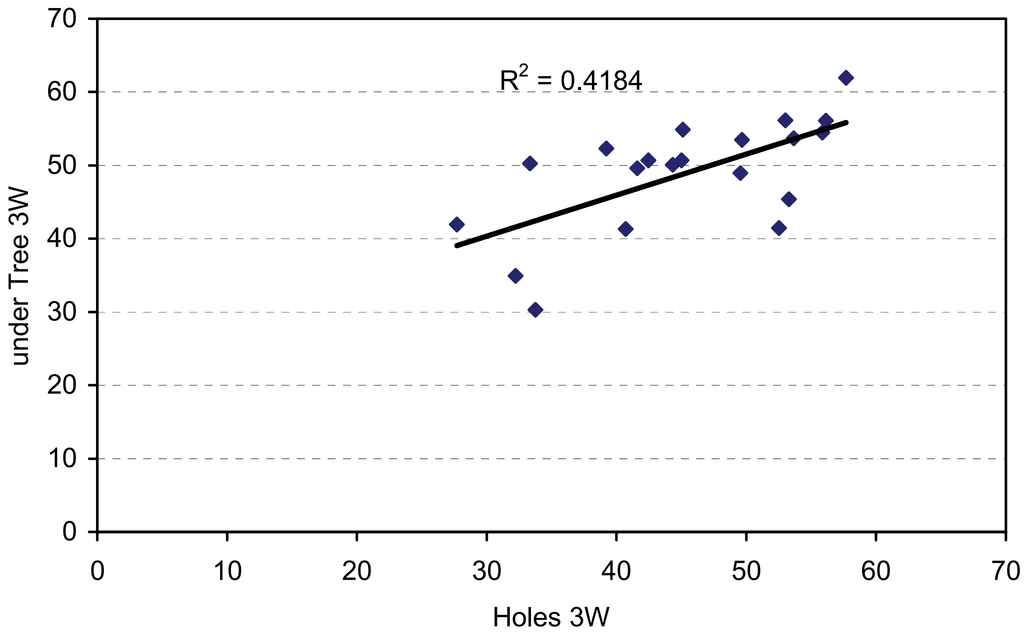

Figure 2a. Relationship between the number of days required to realize emergence for treatment Holes, 3 weeks, and under Tree, 3 weeks.

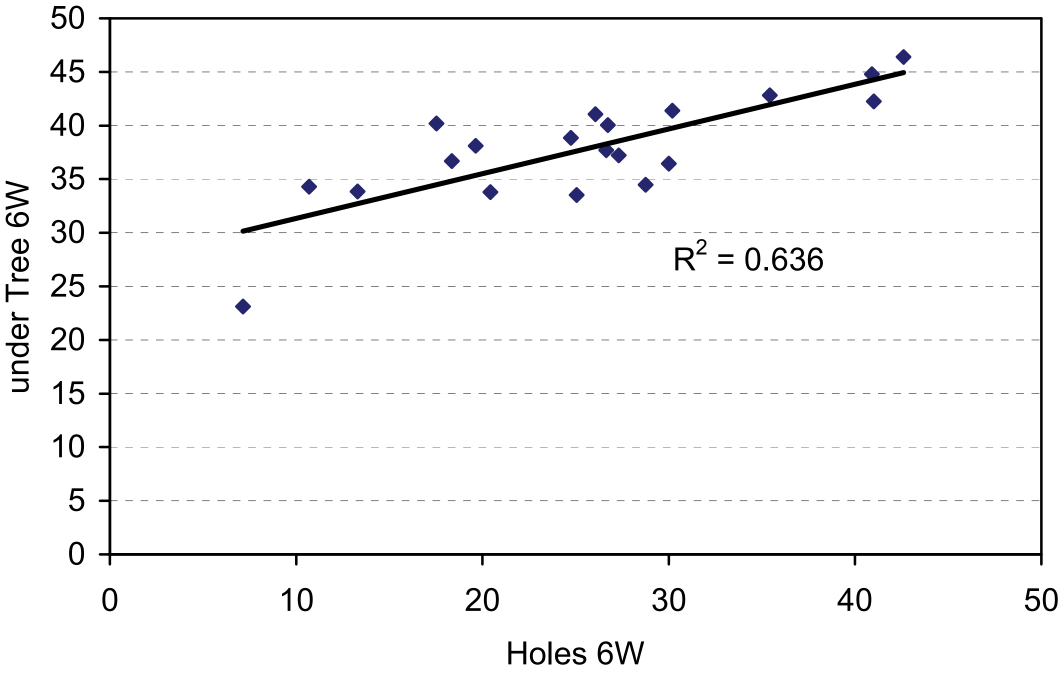

Figure 2b. Relationship between the number of days required to realize emergence for treatment Holes, 6 weeks, and under Tree, 6 weeks.

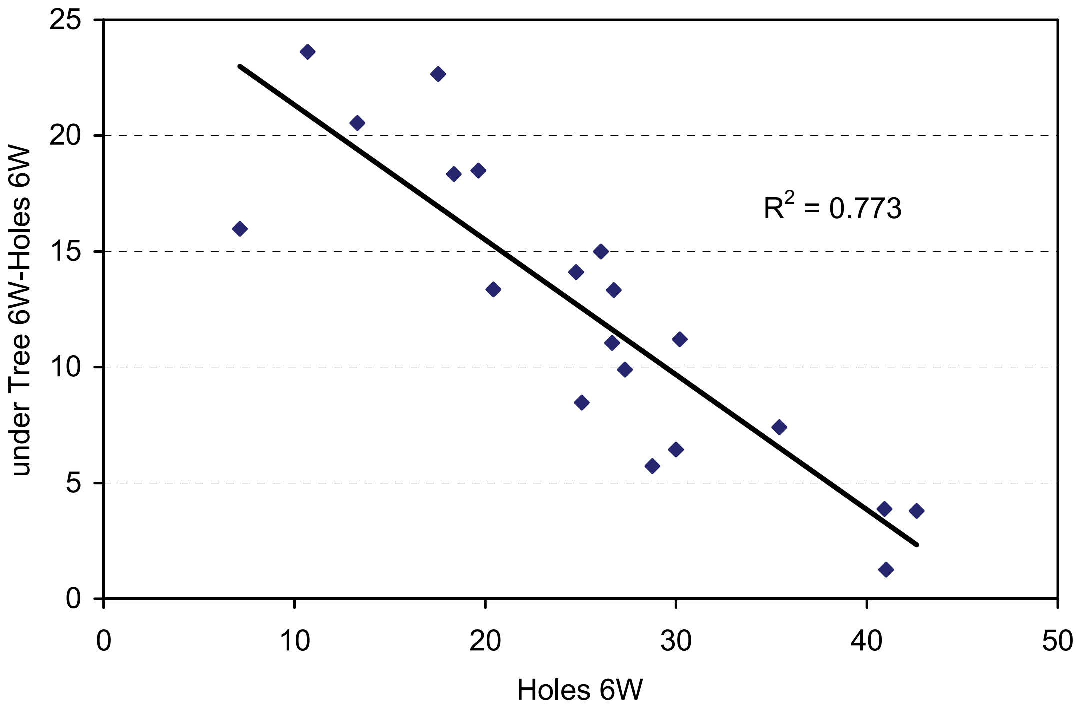

Figure 2c. Relationship between the number of days required to realize emergence for treatment Holes 6 weeks and the difference (under Tree, 6 weeks – Holes, 6 weeks).

Table 10. ANOVA in yield (kg/heap) of 20 varieties for different storage durations and conditions.

	Source of variation	DF	Mean Square	F-Statistics
D. cayenensis / D. rotundata				
Early maturing	Variety	11	63.95	20.99**
(n=12)	Storage method	1	24.24	8.94**
	Duration of storage	1	75.70	24.85**
	Storage method × Duration of storage	1	0.08	0.03
	Variety × Duration of storage	11	6.61	2.17**
	Variety × Storage method	11	5.63	1.85*
	Model	36	26.14	8.58**
	Pooled error	731	3.04	
	(R^2=0.30; Overall mean= 2.83 kg/heap)			
Late maturing	Variety	3	17.56	12.18**
(n=4)	Storage method	1	31.40	21.78**
	Duration of storage	1	58.67	40.70**
	Storage method × Duration of storage	1	10.38	7.20**
	Variety × Duration of storage	3	6.35	4.40**
	Variety × Storage method	3	4.66	3.23*
	Model	12	15.51	10.76**
	Pooled error	243	1.44	
	(R^2=0.35; Overall mean = 1.44 kg/heap)			
D. alata (n=4)	Variety	3	21.19	8.47**
	Storage method	1	117.59	46.98**
	Duration of storage	1	48.39	19.33**
	Storage method × Duration of storage	1	53.74	21.47**
	Variety × Duration of storage	3	9.59	3.83**
	Variety × Storage method	3	18.60	7.43**
	Model	12	30.65	12.25**
	Pooled error	243	2.50	
	R^2=0.38; Overall mean=2.97 kg/heap			

Level of significance: * $P < 0.05$; ** $P < 0.01$.

Utilization of different parts of tuber as planting material

The reasons why farmers use different specific parts of tubers as planting materials depend on the variety in question. Farmers handle the seed tubers of early-maturing and late-maturing varieties differently, because the seed tubers are produced in a different way. In early-maturing varieties, tubers for consumption or sale are harvested first. The plant then produces new tubers which are used as planting tubers for the next cropping season. This is called '*double harvest*'. The first harvest is done at the

Table 11. Mean yields of 20 varieties after different storage conditions and durations before planting.

				Hole-3W		Hole-6W		Tree-3W		Tree-6W	
Species	Earliness	Variety	No.	Mean (kg/heap)	SD	Mean (kg/heap)	SD	Mean (kg/heap)	SD	Mean (kg/heap)	SD
D. cayenensis/	Early	Kabiletonan	16	6.09 a	3.81	5.33 a	3.32	6.29 a	3.38	4.68 a	3.38
D. rotundata		Anago	16	4.06 b	2.33	2.52 b	1.61	4.73 b	1.88	2.08 b	1.04
		Gangni	16	3.53 bc	1.58	2.45 b	0.95	2.94 bcd	1.16	3.11 b	1.36
		Mafobo	16	3.23 bc	2.28	2.95 b	1.30	2.66 cd	1.39	3.25 b	2.09
		Effourou	16	3.08 bc	2.16	2.50 b	1.68	3.23 bcd	2.06	1.75 b	0.85
		Ahimon	16	2.97 bc	1.39	2.33 b	1.49	3.57 bcd	2.88	2.57 b	0.81
		Ala	16	2.81 bc	1.81	1.84 b	0.98	2.82 bcd	1.00	3.14 b	1.75
		Djilaadja	16	2.53 bc	1.45	1.94 b	0.91	2.55 cd	1.42	3.24 b	1.51
		Gnidou	16	1.96 c	0.93	1.33 b	0.77	4.19 bc	2.48	2.74 b	0.80
		Mondji	16	1.87 c	1.09	1.51 b	0.95	2.60 cd	1.51	2.61 b	1.74
		Laboko	16	1.76 c	0.91	1.80 b	1.10	1.97 d	1.67	1.80 b	1.01
		Ofegui	16	1.65 c	0.87	1.27 b	0.63	2.27 cd	0.84	1.55 b	0.88
		Overall mean	192	2.96 bc	2.19	2.31 b	1.77	3.32 bcd	2.23	2.71 b	1.77
	Late	Alakitcha	16	2.81 a	1.44	1.78 a	0.79	3.48 a	1.71	1.86 a	0.74
		Klatchi	16	1.54 b	1.08	1.03 b	0.54	2.18 ab	1.28	1.37 ab	0.69
		Kokoro	16	1.21 b	0.77	0.69 b	0.56	3.81 a	3.14	1.10 b	0.77
		Gnanlabo	16	1.12 b	0.44	0.97 b	0.49	1.63 b	0.92	1.33 ab	0.48
		Overall mean	64	1.67	1.19	1.12	0.71	2.77	2.11	1.41	0.72
D. alata	Late	Sonouko	16	5.94 a	1.86	2.93 a	1.87	1.93 ab	1.35	1.41 b	0.93
		Florido	16	4.38 b	1.96	3.22 a	1.63	2.90 a	1.77	4.08 a	1.74
		Louelougan	16	4.09 b	1.47	2.55 a	1.80	2.99 a	1.48	2.13 b	1.05
		Hounve	16	3.75 b	2.63	2.32 a	1.10	1.26 b	0.50	1.64 b	0.78
		Overall mean	64	4.54	2.15	2.75	1.63	2.27	1.51	2.32	1.57

physiological maturity of the tubers, a stage at which the tuber reaches its maximum development in the soil and can be harvested and processed for food. At this stage, the yam plant is still alive and green and the crop is maintained. The second harvest takes place at the complete senescence of the plant. Tubers at that time are much smaller than the tubers harvested at the first harvest. The decision what proportion of the total field will be used for double harvesting is taken before or at physiological maturity. Crops which are projected to be used for this double harvesting technique will be planted with whole tubers and cutting of their progeny tubers is not done, because of their small size and because of the risk of loss.

Late-maturing varieties, usually called 'single-harvest' varieties, are only harvested once. Examples are the varieties Gnanlabo or Kokoro. One of the characteristics of these late-maturing varieties is that the yield is composed of several tubers differing in size. The large tubers are used for consumption or sale and the small ones are used for planting the next cropping season. A single harvest is undertaken at the complete senescence of the plant. The relatively big seed tubers can be cut, in a way depending on size. There is a desired seed tuber size for planting, as smaller sizes will have lower vigour as planting material.

Sometimes, some early-maturing varieties are grown for a single harvest. In those cases the product is only used for consumption or sale, and no seed tubers are taken from that crop for the next cropping season.

Days after planting until emergence (DAP) for different tuber parts used as planting materials

For three out of the four varieties, there were significant differences in mean value of days after planting to emergence between parts of planting materials used (Table 12). The proximal part and the entire tuber of a second harvest of early-maturing varieties showed the fastest emergence. For Laboko, the proximal part and the entire tuber emerged after 19 and 26 DAP respectively, the medium part sprouted after 40 DAP and the distal part after 47 DAP. For Gangni, the proximal part was the earliest while the distal part was the latest in emergence. For the two late-maturing varieties, Alakitcha and Gnanlabo, the proximal part also emerged earlier than the middle and the distal parts.

The rate of emergence is of economic importance in managing yam planting material by farmers. All tubers planted emerged for both the proximal part and the entire tuber of the 2nd harvest (Figure 3). This result suggests that any of those planting types can be used for planting when available. Within the late-maturing varieties, all planted proximal parts of Gnanlabo emerged. For four varieties, the loss was highest for the distal part: it was of 5% for Gnanlabo, 50% for Laboko, 65% for Gangni, and 85% for

Table 12. Number of days after planting until emergence for tubers from proximal, medium, distal parts and tubers of second harvest.

Variety types	Variety	Parts	n	Mean of DAP until emergence	S.E. of Mean	F
Early maturing	Laboko	Proximal	20	18.7	1.49	42.09***
		Middle	11	39.5	2.37	
		Distal	10	47.3	1.28	
		Entire tuber of 2nd harvest	20	26.2	1.97	
	Gangni	Proximal	20	24.4	2.12	10.87***
		Middle	11	39.3	1.91	
		Distal	7	42.7	2.57	
		Entire tuber of 2nd harvest	20	28.9	2.33	
Late maturing	Alakitcha	Proximal	13	41.5	2.9	0.73
		Middle	6	45.0	2.2	
		Distal	3	47.3	0.9	
	Gnanlabo	Proximal	20	16.1	2.1	29.46***
		Middle	19	35.8	2.5	
		Distal	19	38.3	2.2	

Level of significance: *** $P < 0.01$.

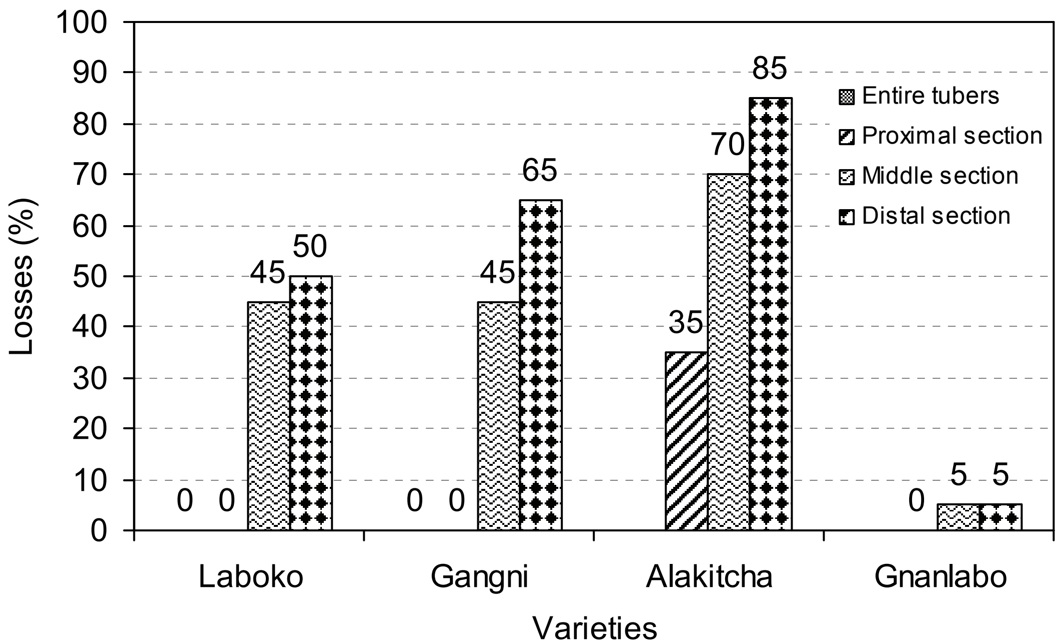

Figure 3. Losses in terms of non-emergence of planted materials submitted to different seed-section practices for four contrasting varieties. Note that the treatment ‘entire tubers’ was not present for the late cultivars Alakitcha and Gnanlabo.

Table 13. One-way analysis of variance of yield performance per variety for each seed type (kg/heap).

Source of	Distal			Middle			Proximal			2^{nd} harvest		
variation	D.F.	MS	F	D.F.	MS	F	D.F.	MS	F	D.F.	MS	F
Variety	3	11.99	15.39***	3	13.08	9.90***	3	16.95	8.19***	1	2.28	1.52
Model	3	11.99		3	13.08		3	16.95		1	2.28	
Error	54	0.78		43	1.32		63	2.07				
R-square	0.46			0.38			0.28			0.05		

Mean tuber yield (kg/heap) per variety and per seed-type

	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Gangni	3.01 a	0.16	3.77 a	0.40	4.08 a	0.43	1.90	0.31
Laboko	0.98 c	0.16	1.40 b	0.15	1.79 b	0.32	2.43	0.30
Alakitcha	2.11 b	0.35	1.79 b	0.34	2.90 b	0.38	-	-
Gnanlabo	1.32 c	0.21	1.95 b	0.21	2.33 b	0.24	-	-
Overall mean	1.93		2.28		2.82		2.19	

Alakitcha. All tubers used from the second harvest as entire tuber and from the proximal sections of Gangni and Laboko, and from the proximal sections of Gnanlabo sprouted.

Be it the distal, middle or proximal part, there was a highly significant difference between yield performance of yam varieties (Table 13). For the distal part, the highest mean yield value was obtained for Gangni (3.01 kg/heap) and the lowest one for Laboko (0.98 kg/heap). Also for the middle and proximal parts, the highest yield was obtained for Gangni and the lowest yield for Laboko. However, when the seed tubers came from the second harvest, Laboko yielded more than Gangni, but the difference was not statistically significant. As such, yam varieties' performance not only depended on the variety or genotype that had been planted, but also on the seed tuber material that was used. Using the Generalized Linear Model of ANOVA on the variety, seed type and interaction variety × seed tuber type, Table 14 reveals that the joint effect of variety and seed type was highly statistically significant in determining the yield obtained by yam farmers in Benin.

Molecular diversity

Specificity of the primers

Figure 4 shows DNA polymorphism detected in the 14 accessions screened using primers OPW-8 and OPW-16. The primer OPW-8 revealed 5 different bands in size range between 400 bp and 1600 bp, while the primer OPW-16 distinguished four different amplified fragments in size range between 200 bp and 1000 bp. From lane 1 to 7, PCR profiles showed polymorphic patterns with different band sizes as revealed by the primer OPW-16: lane 1: 0 band, lane 2: 2, Lane 3:1, Lane 4: 2, Lane 5: 2, lane 6: 4, and lane 7: 2 bands. However, PCR amplification profiles were similar in some of the accessions as revealed by this primer OPW-16 showing two amplified bands in

Table 14. GLM-ANOVA of yield performance depending on the variety and the seed type.

Source of variation	DF	Mean Square	F
Variety	4	23.45	16.92***
Seed type	3	9.29	6.70***
Variety × Seed type	9	5.63	4.06***
Model	16	10.35	7.47***
Pooled error	224	1.39	
R-square	0.35		

Level of significance: *** $P < 0.01$.

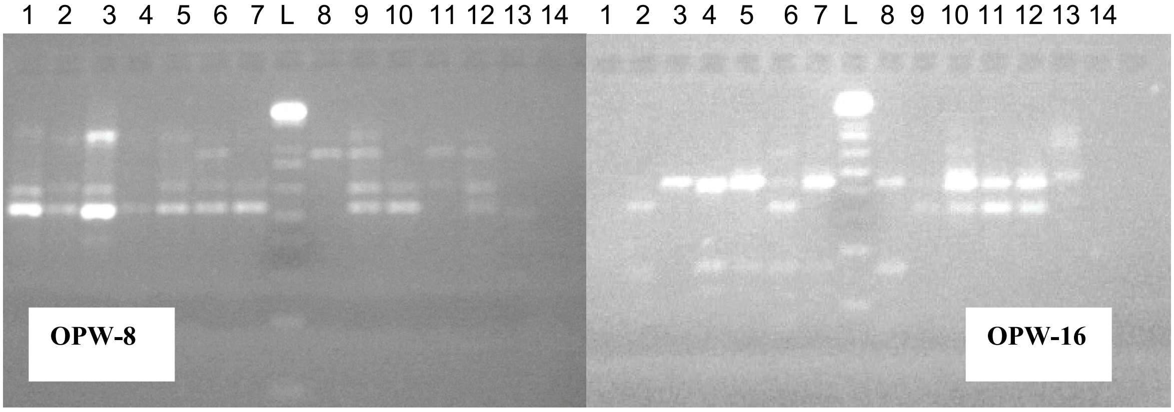

Figure 4. Gel electrophoresis of PCR products. Samples 1 to 12 represent accessions of *D. cayenensis / D. rotundata* (DCR) 1: Ala- N'kodjéwé, 2: Alakitcha, 3: Djilaadja, 4: Efour, 5: Gangni, 6: Laboko, 7: Mafobo, 8: Angogo, 9: Boniyakpa, 10: Dourokonou, 11: Sika, 12: Yakassougo and samples 13 and 14 represent accessions of *D. alata* (DAL), 13: Djekin, 14: Sankou kergba. L: molecular marker (100 bp).

size of 420 and 520 bp in lane 10: Dourokonou, lane 11: Sika, lane 12: Yakassougo. While OPW-16 was unable to distinguish these accessions, the primer OPW-8 distinguished them by detecting polymorphic bands, lane 10 and 11 showed two bands at different size and lane 11 showed three bands. Similarly, the four other primers used in the study also detected DNA polymorphisms. Hence, these six primers were used to characterize genetic diversity of the 90 cultivated germplasm accessions investigated (Table 1).

Genetic diversity and cluster analysis

Important genetic diversity was detected in the yam species investigated in this study. However, the diversity was larger in the *D. cayenensis / D. rotundata* complex compared to the *D. alata* species. Considering the results from all the six primers, a total of 67 amplified DNA bands were generated. The size of the amplified bands ranged from 100 bp to 2000 bp. The number of RAPD marker loci detected was 10 for the primer OPW-16, 11 for the primers OPW-5, OPW-8 and OPQ-4, and 12 for the primers OPW-2 and OPW-6. None of the primers considered individually was able to distinguish all the accessions. However, when other primers were used, accessions which were showing the same DNA fingerprint based on a particular primer could be differentiated from each another.

Also while the following bands 250 bp (OPW-2), 350 bp (OPW-5), 1200 and 1500 bp (OPW6), 150, 250 and 300 (OPW-16), 700 and 1000 (OPQ-4) were present in *D. cayenensis / D. rotundata* species, they were absent in *D. alata* species. Conversely, while the bands 450 (OPW-6) and 200 bp (OPW-8) were present in *D. alata*, they were absent in *D. cayenensis / D. rotundata* species.

Based on the presence or absence of DNA fragments, the estimates of the similarities among cultivars were calculated and used to construct the dendrograms for all cultivars together and separately by species. All cultivars from the yam species were partitioned into 18 groups based on the main class clusters generated at the level of 72% of similarity coefficient (Figures 5 and 6). The cultivars of the *D. cayenensis / D. rotundata* complex composed the groups between 1 and 12, while the 20 cultivars of *D. alata* belonged to the groups between 13 and 18. In the dendrogram of the *D. cayenensis / D. rotundata* complex (Figure 2), the accessions were clustered into 12 groups. The groups 1, 5, 8 and 9 containing 7, 2, 1 and 5 cultivars, respectively, consisted of only accessions collected from the central part of the transitional zone of Benin. There were also groups (7, 10 and 11) containing only germplasm originating from the north-east. The largest group in the dendrogram contained 14 cultivars of which 12 collected from the central Benin and two from the North-East part of this zone.

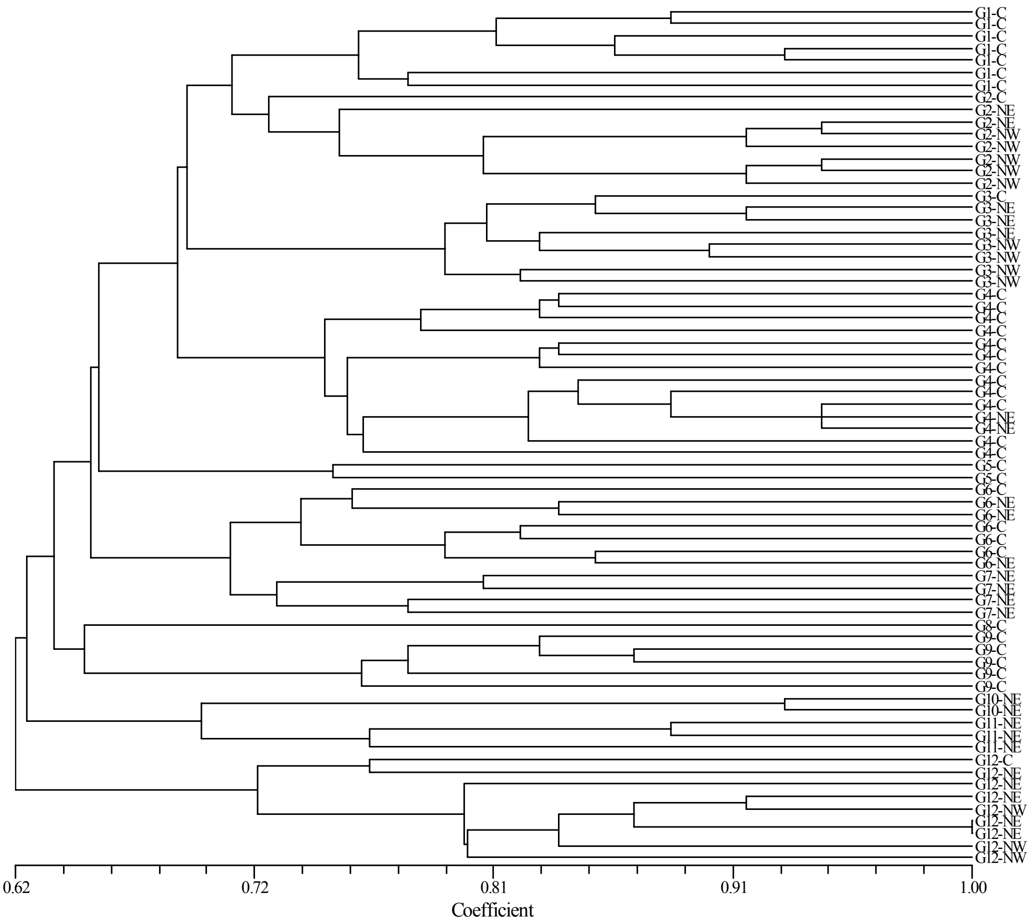

Figure 5. Dendrogram of *D. cayenensis / D. rotundata* accessions based on coefficient of similarity matrix. The codes correspond to the groups and the origin of collections (Table 1).

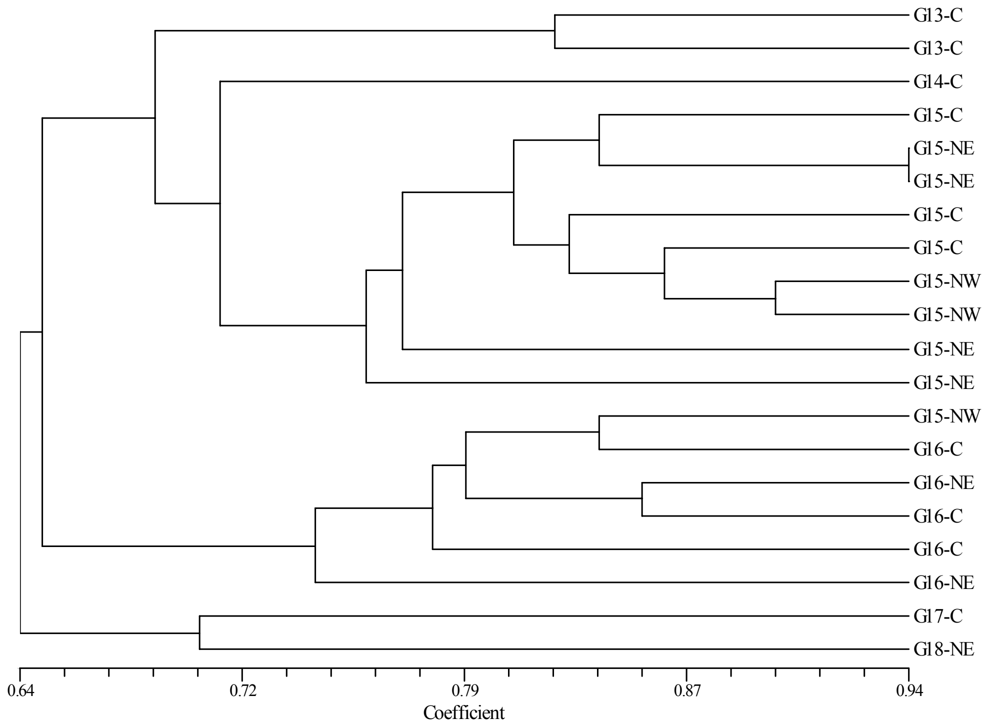

Figure 6. Dendrogram of *D. alata* accessions based on coefficient of similarity matrix. The codes correspond to the groups and the origins of collection (Table 1).

In the dendrogram constructed with *D. alata* cultivars only (Figure 6) the 20 accessions were clustered into six groups. Two groups contained the largest number of cultivars: group 15 consisted of nine accessions, group 16 contained six. Group 13 consisted of two accessions only. Some groups even consisted of only one accession (groups 14, 17, 18).

Frequencies of the amplified bands as revealed by the six primers

The 67 amplified DNA fragments frequency as revealed by the six primers is shown in Figure 7. Most primers showed fragments of high frequencies. However, some of the fragments had very low frequencies. The frequencies of amplified bands 450, 1200, 1500 bp (OPW-6) and 200, 1000, 1200 bp (OPQ-4) were very low, and ranged between 0.00 and 0.10. The frequency of the fragment in size of 200 bp was very low in five different primers (OPW-2, OPW-5, OPW-8, OPW-16, OPQ-4). Some of the amplified bands were revealed by more than two primers and some were specific to a particular primer. None of the amplified bands was simultaneously revealed by the six primers. However, in general, all amplified DNA fragments revealed by the six primers had high frequencies. This result showed that all six primers were reliable in assessing the genetic variation in the yam cultivars analysed.

Molecular genetic differentiation

The components of the molecular variance (AMOVA) are summarized in Table 15. The total molecular variation was partitioned to variation between species, between varietal groups within species and between individuals within varietal groups. AMOVA showed that 12.72% of the molecular variance resulted from the variance among species. Most of the variation (52.68%) was due to the variation among individuals within varietal groups and variation among varietal groups (34.60%).

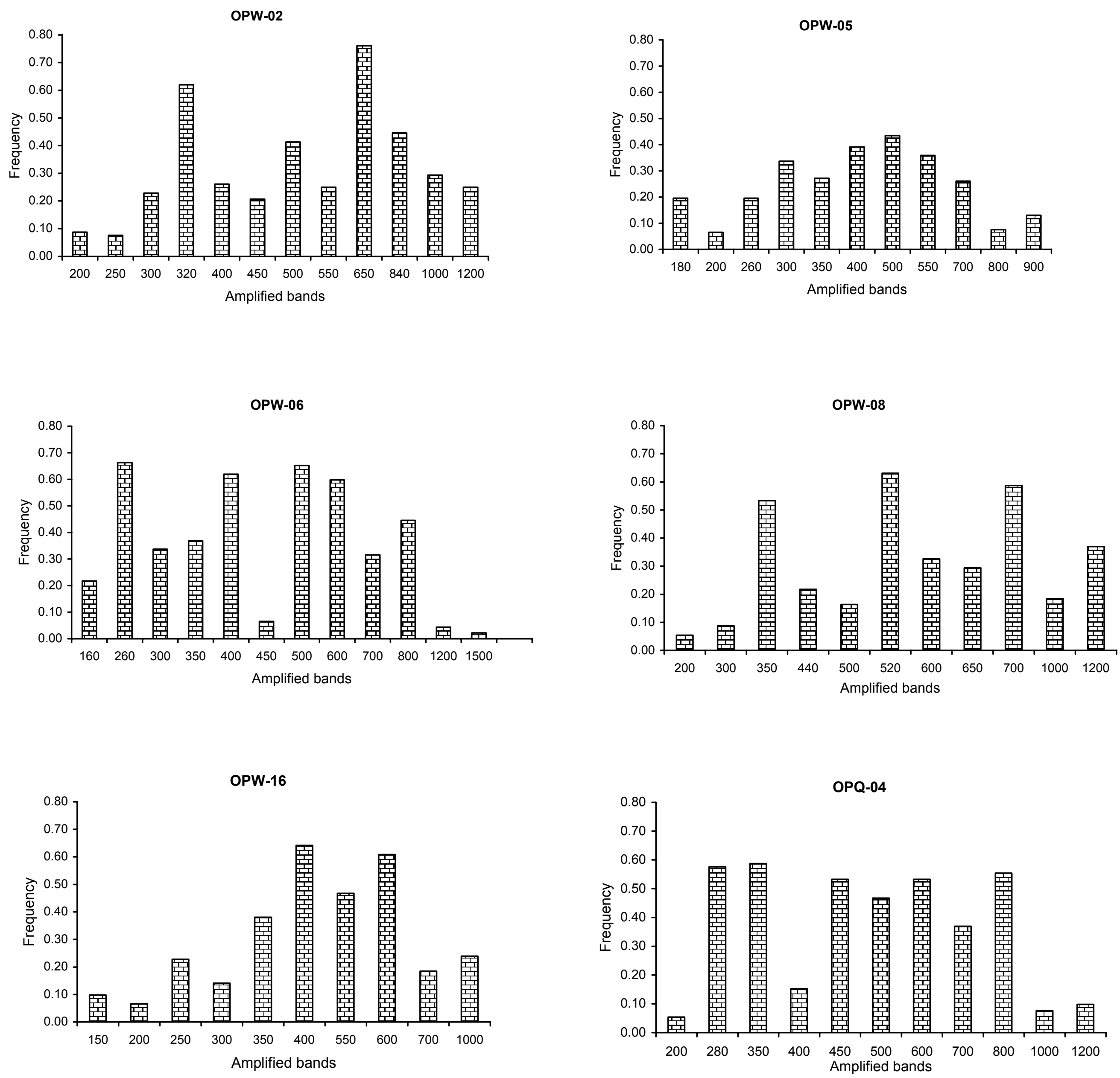

Figure 7. Amplified DNA fragments frequencies as revealed by the six primers.

Table 15. Analysis of molecular variance of *D. cayenensis / D. rotundata and D. alata* cultivars.

Source of variation	Degrees of freedom	Sum of squares	Variance components[1]	Percentage of variance	F-Statistics[2]
Among species	1	91.253	σ_{CT}^2= 1.715	12.72	F_{CT}: 0.127***
Among groups within species	16	467.001	σ_{SC}^2= 4.664	34.60	F_{SC}: 0.396***
Among cultivars within groups	72	511.335	σ_{ST}^2= 7.102	52.68	F_{ST}: 0.473***
Total	89	1069.589	σ_T^2 =13.480		

[1] (σ_T^2)= the total molecular variance is partitioned into a variance component due to differences among species (σ_{CT}^2), a variance component due to differences among groups (σ_{SC}^2), and to differences among cultivars (σ_{ST}^2).

[2] The allele frequency variation index (F-statistics) for the three variance components are F_{CT}, F_{SC}, F_{ST}, respectively.

*** These three F-statistics are highly significant (P < 0.001).

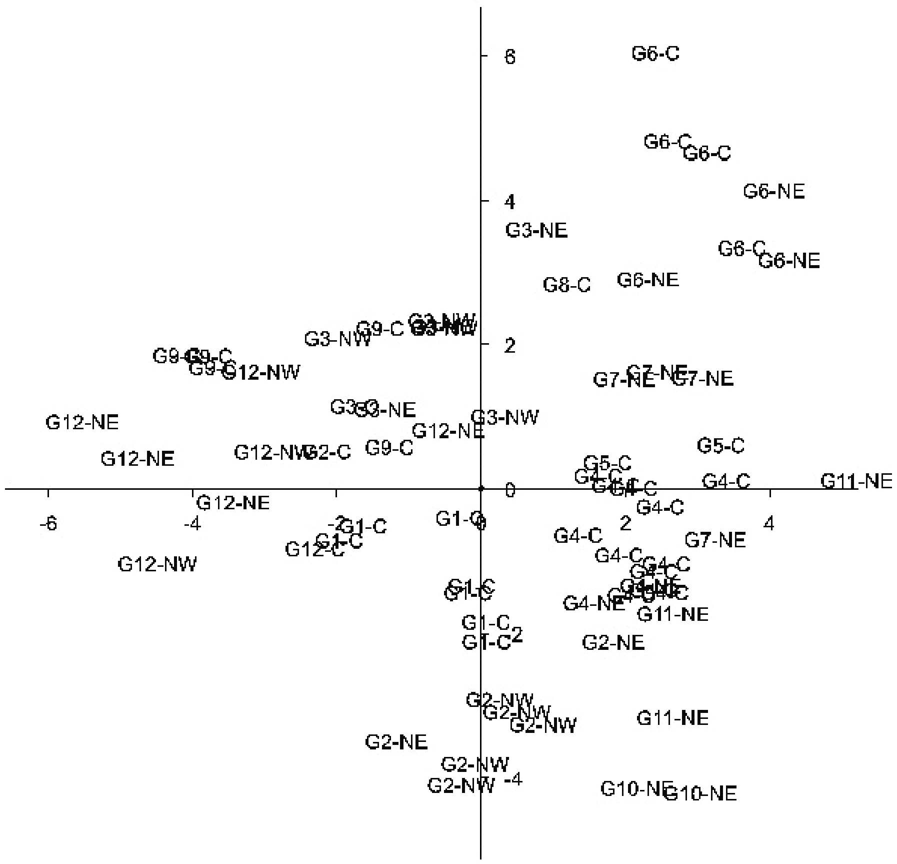

Figure 8. Pattern of gene-pool revealed by the molecular markers on *D. cayenensis / D. rotundata* cultivars.

AMOVA revealed that significant individual and varietal group differences existed. The genetic variability of the cultivars investigated by analysis of molecular variance from different levels (species and group) revealed significant genetic differentiation when considering the F-Statistics' values. The results showed highly significant variation among species with respect to all cultivars (F_{CT}=0.127; P=0.0009), among groups within species (F_{SC}=0.396; P<0.0001), and among cultivars (F_{ST}=0.473; P<0.0001). This genetic differentiation index value (F_{ST}=0.473) indicates a very large genetic differentiation among the cultivars.

Combining the information provided by all molecular markers, most of the varieties from the north-east and north-west of the area investigated appeared to be distinctive from the ones of the centre as shown along the two axes for the *D. cayenensis / D. rotundata* (Figure 8) and for *D. alata* cultivars (Figure 9). It might be possible that this differentiation is due to their ancestry, i.e., *D. abyssinica* – the savannah wild species - as opposed to *D. praehensilis*, the forest zone wild species.

The comparison between the molecular and morphological characterization using the Mantel matrix comparison test revealed an absence of relationship between the molecular and the morphological distances.

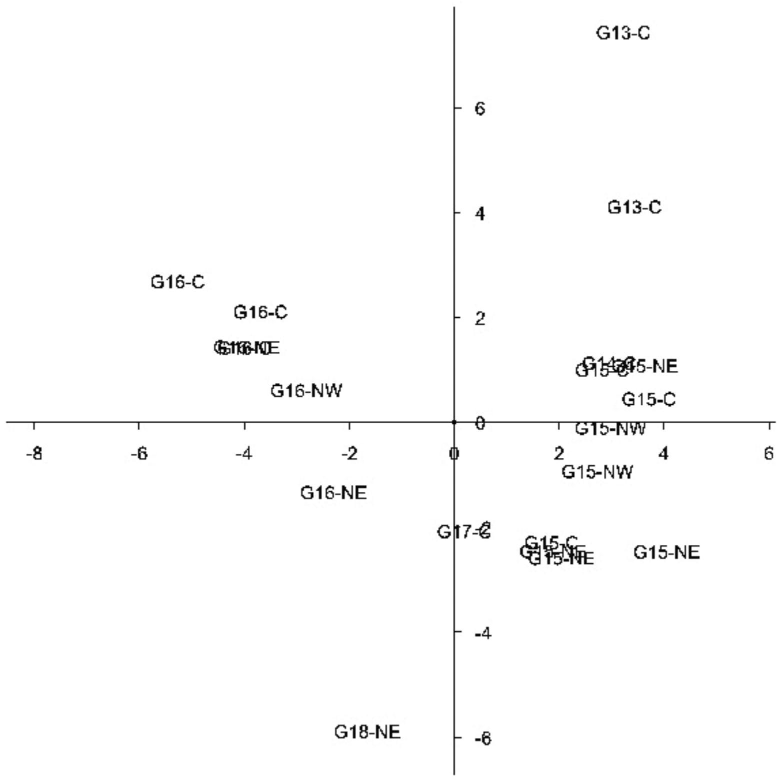

Figure 9. Pattern of gene-pool revealed by the molecular markers on *D. alata* cultivars.

Assessment of human and social capital formation around yams

The collection and initial assessment of yam cultivars discussed above was undertaken in a learning group linking the researcher and farmers. It was considered important to undertake an impact assessment of the co-research, using the human and social capital perspective discussed above. This assessment reveals that farmers had various motivations to work in the Learning Group (Table 16). Most participants joined the group because they desired an increase in their knowledge on the varieties under experimentation in the village. Others were motivated by the idea of belonging to a club, doing research, or by curiosity. The perceived benefits from the interactive process between farmers and researcher were high in relation to new varieties characterized, and in relation to tests concerning rapid sprouting (Figure 10a). The Wilcoxon test showed significant differences in benefits gained from knowledge on different new varieties to the village, rapid sprouting of planting material and seed multiplication from different varieties. It appeared from the impact analysis that farmers had also other expectations concerning increase in the yield of existing varieties and how to increase storage durations to meet consumption needs in the shortage period. The study revealed that knowledge generated, and technologies initiated within the group, were applied on the farmers' own fields, and were progressively diffused among farmers of the village. Seventy six percent of farmers revealed that they had directly adopted the technologies of seed-tubers sprouting gained through co-experimentation. The category of primary adoption is composed of farmers who have already integrated some ideas and technologies generated during the joint experimentation in their own farming practices. The category of secondary adoption is composed of farmers who later began experimenting the ideas or technologies on their farms during the period of experimentation (Table 16). The study threw light on how decisions were made within the group, and the perceptions of individual members concerning learning group activities (Table 16). About 65% of members thought that the decisions were made as a group decision, while 35% thought decisions were in effect made by the group leader. Figure 10b presents the perceived gain by farmers in social capital from this interaction research. The research activity on yam brought together farmers from different ethnic groups in the village. It was also seen as strengthening farmer decision making, and improved gender relations through joint activities on yam in the village.

Discussion

This chapter has analysed in-depth various relevant morphological, agronomic and molecular traits characterizing cultivated yam varieties in the Guinea-Sudan zone of Benin. Among the qualitative morphological characteristics, internal and external

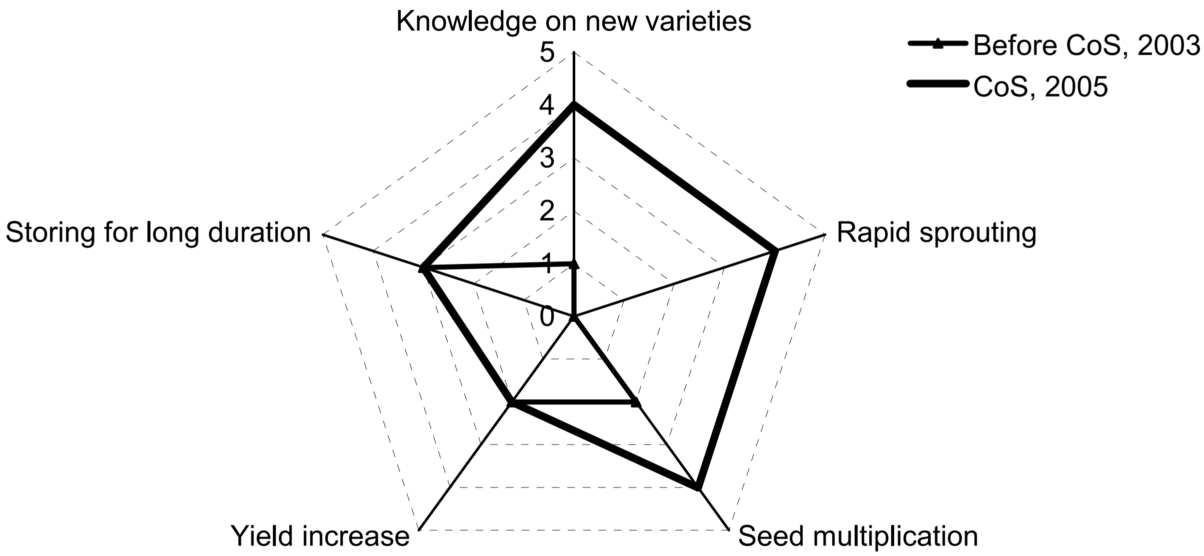

Figure 10a. Human capital formation through co-experimentation on yam (n=15 farmers).

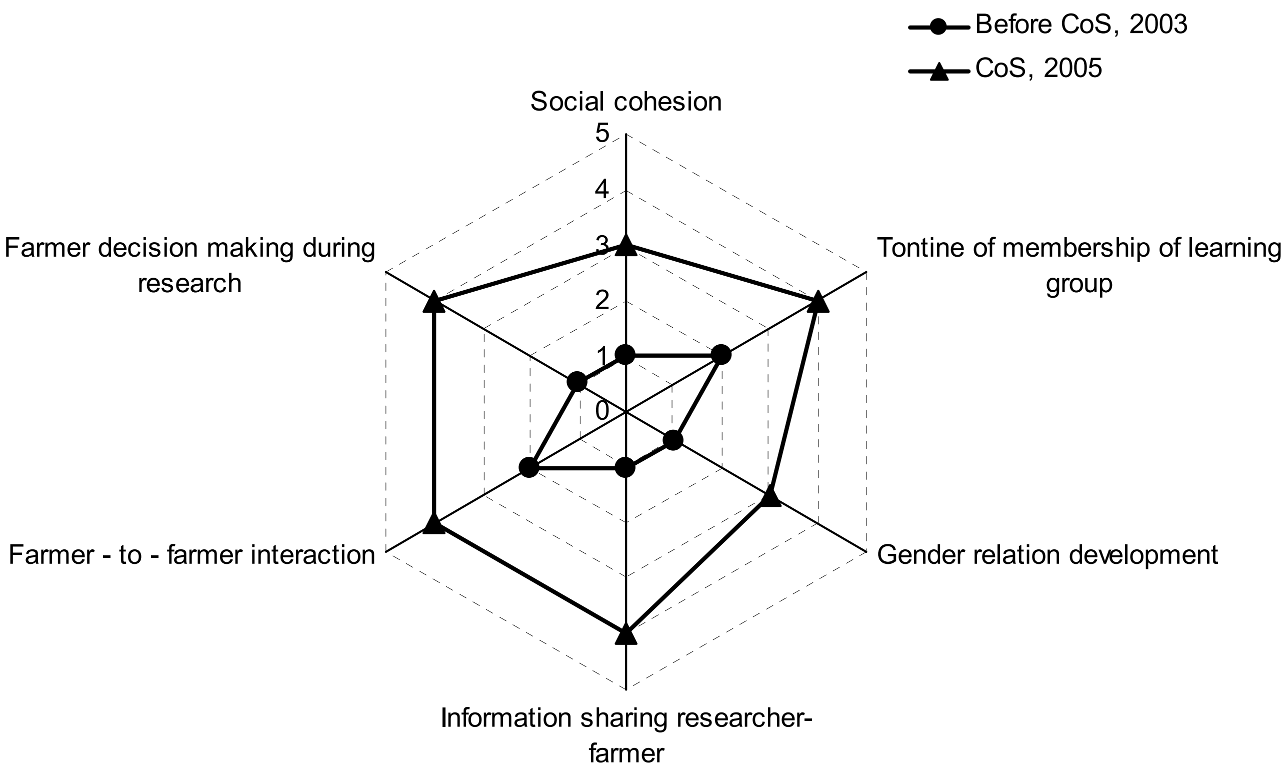

Figure 10b. Social capital formation through co-experimentation on yam (n=15 farmers).

Table 16. Motivations, decision making, and use of co-research results (n=17 farmers).

Motivations, decision making, and use of results	Components	No. of farmers
Motivation in joining the learning Group	Desire of knowledge	6
	Willing to be in association	4
	Doing research	3
	Curiosity	3
	Stimulation	1
	Gain of assets	0
Levels of decision making	Group	11
	Group leaders	6
	Researcher	0
Levels of use of the results from co-researching	Primary adoption	13
	Diffusion	6
	Secondary adoption	1

morphology of the tuber and the stem and leaf characteristics form groups of distinctive traits that allow farmers and consumers to differentiate between varieties and guide farmers and consumers in their choice of planting materials and food choices. Classification systems help to identify the primary responses that exist in a species, which aids plant breeders and agronomists in their choice of the most appropriate germplasm and testing environments (Ehlers and Hall, 1996). The joint experimental approach described is likely to form classifications embodying both breeders and farmers interests.

The earliness, post-harvest dormancy, number of days after planting to emergence, and the yield are important agronomic and physiological characteristics of yam diversity in Benin. In experimenting under real farmer conditions, this study has revealed that the duration of dormancy depends not only on the species but also on the variety, the physical storage conditions and the duration of the storage. Passam (1982) found that the duration of dormancy does not only depend on the plant but is also influenced by physical factors. By testing different storage procedures this study has thrown new light on how this factor can be managed in typical farming conditions.

Double harvesting practices appear to reflect an agro-physiological principle known and respected by farmers concerning early-maturing varieties, and the need to avoid second crop seed tubers at planting time because use of other parts than the whole tuber from the 2nd harvest as planting material usually results in high losses (non-sprouting of the tubers after planting, and consequently high economic loss) and, thus, undermines food insecurity. Experimentation revealed a gradient along the tuber in its potential for sprouting. The proximal part of most varieties has a high sprouting potential, while the distal part has the lowest potential. Experimentation in real farming conditions revealed that the proportion of non-emerged plants after planting was highest and the yield the lowest when the distal part was used as planting material. However, there was some variation among varieties. The results suggest that there could be a complex genetic – physiological property governing the sprouting ability of each fragment of the tuber. Along the tuber, there could a gradient of earliness in sprouting, in the availability of nutrient reserves and in the viability which decreases from the proximal to the distal part (Onwueme, 1974; Passam, 1977; Kossou, 1990).

Work also confirmed that as the environmental conditions change from year to year there is variation in the yield of the same variety. This study has shown that the genotype by environment interaction was highly determinant of yam performance. For important agronomic characteristics, the differential response of a genotype or cultivar for a given trait is an important and essential component of plant breeding programmes dedicated to cultivar development (Campbell and Jones 2005), and is thus also of great importance for farmers. In selecting for better plant types in white and yellow yams information on the quantitative inheritance of important plant characters is needed.

Most of the *D. alata* varieties (65%) yielded more than 2 kg/heap. The most widely cultivated *D. alata* variety Florido (Zannou *et al.*, 2004) did not perform as well as the other *D. alata* varieties. This result suggests that the choice of this variety Florido by many farmers is not related to its high yield performance, but to the quality of the tuber, storability and perhaps other agronomic characteristics.

In the present study, where RAPD analysis was performed to evaluate the genetic diversity in 70 cultivars of the *D. cayenensis / D. rotundata* complex and 20 of *D. alata* collected throughout the transitional Guinea-Sudan zone of Benin, the genetic variation was higher in the *D. cayenensis / D. rotundata* complex, compared to *D. alata*. This result is in agreement with results of Dansi *et al*. (2000c) who reported important diversity in 23 accessions of the *D. cayenensis / D. rotundata* complex using RAPD analysis. This result may suggest that cultivars of the *Dioscorea* species analysed were originally generated by different ancestors of yam in the past.. The fact that according to the present study genetic diversity of wild yams is structured geographically also supports such a conclusion (cf. Tostain *et al*., 2003). All accessions of *D. alata* were separated from those of the *D. cayenensis / D. rotundata* complex.

From the analysis of the molecular variance, the average fixation index value (Wright's F_{ST}=0.473) is above the reference value (0.25) of great differentiation revealed by Wright (1978), Hartl (1987) and Kiambi *et al.* (2005). This value shows that in Benin the yam population displays a very large amount of genetic differentiation.

The value of Wright's F_{ST} (0.473) is higher than the reported average for animal or insect pollinated out-crossing seed plants (Hamrick, 1989) or for out-crossing cultivated seed plants (Hamrick and Godt, 1997) (F_{ST} mean values = 0.187 and 0.234, respectively (Montes-Hernandez and Eguiarte, 2002). The evidence supports a conclusion that farmers' selection and domestication strategies have played, and continue to play, significant roles in the ongoing enlargement of the genetic diversity of the cultivars investigated.

The study showed that the genetic diversity changed along a spatial gradient. In general there was a tendency that most of the varieties from the north-east and north-west of the zone investigated appeared to be distinctive from the ones of the centre according to the dendrograms. However, few varieties were distributed randomly and did not reflect any specific relation to their zone of collection. The dendrogram suggests, in effect, that the Guinea savannah zone of Benin is a very large gene-pool of yam varieties. Yam farmers in Benin – active even today in domestication – may have played a significant role in the enrichment and the maintenance of this genetic diversity.

The large genetic differentiation among yam cultivars suggests that each cultivar is distinctive and owns distinctive traits as confirmed by the level of polymorphism. Additionally, this study shows the presence of important genetic variability among the Benin yam germplasm which can be used to broaden the genetic bases of the crop for better use of its genetic potential.

The impact of this research on farmer livelihoods is as yet unclear. Interactive research was well received, but it was somewhat limited in impact, being based on only three years of joint experimentation. Some impact has already shown up via the brief assessment undertaken of human and social capital. Farmers showed considerable willingness to add to their already impressive knowledge of yam cultivars and cultivation strategies, confirming a possible knowledge deficit on a crop somewhat neglected by the national research system. Farmers quickly formed new expectations concerning systematic development of new yam-oriented technologies. There would be no lack of future demand, it can be concluded, for suitably designed convergent research targeted on local yam varieties, and the better exploitation of the rich local genetic potential of this crop.

CHAPTER 7

Morphological, agronomic and molecular characterization of the cultivated cowpea [*Vigna unguiculata* (L.) Walp.] varieties in Benin*

Abstract

Characterization of genetic diversity among cultivated cowpea [*Vigna unguiculata* (L.) Walp.] varieties is important to optimize the use of available genetic resources by farmers, local communities, researchers and breeders. This study was based on a joint farmer-researcher characterization of 70 different farmer-named cowpea varieties. The cowpea varieties were characterized with farmers using different morphological and agronomic traits. The varieties varied in growth habit (prostrate, erect), and in colours of the leaves, stems, flowers, pods and seeds, and in seed shape and texture. The variation of the qualitative traits of plant and seed morphology was assessed using the Shannon-Weaver diversity index. This index revealed a high global mean morphological diversity among the varieties (*H'*=1.23), ranging from 1.02 for pod pigmentation to 1.61 for seed coat colour. Within regions, this index varied from 0.33 to 1.57, depending on the characteristic.

Farmers used the photoperiodic response of the late varieties to distinguish between early-maturing and late-maturing varieties. By doing so they were able to separate varieties that could only be planted once per year during the second growing season (late maturing) from early-maturing varieties, which could be planted twice per growing season (i.e., first and second season each year). In a 3-year experiment, the variety by environment interactions, as expressed by variety-specific effects of planting date, season, and year on yield and yield components, were highly significant. The reproductive period of the late-maturing varieties appeared to be longer than the one of the early-maturing varieties. These varieties with longer reproductive period showed more pods and more seeds per plant and thus higher yield.

Random amplified polymorphic DNA (RAPD) markers were used to evaluate the genetic diversity in 70 farmer-named cowpea varieties collected throughout Benin. Nine random primers were screened on 24 accessions to assess their ability to reveal polymorphisms in cowpea, and four of them were selected for use in characterizing the total sample. A total of 32 amplified bands were generated by the four primers. The number of loci detected varied from 5 to 11. RAPD profiles were analysed and amplified polymorphic DNA fragments were used to construct a dendrogram, clustering the accessions into nine groups at a similarity index of 71% based on the Unweighted Pair-Group Method using Arithmetic Averages (UPGMA). The genetic diversity among the cowpea cultivars investigated was large and the RAPD proved to be a useful technique to characterize it. Based on the analysis of molecular variance (AMOVA), the fixation index suggests a large differentiation of cowpea cultivars in Benin.

However, a comparison of the different characterizations using the Mantel matrix comparison test indicated that there was no relationship between the molecular, agronomic and morphological distances. More research is needed to analyse the different classification systems and their relationships.

Keywords: Cowpea germplasm, farmers' varieties, agro-morphological diversity, molecular diversity, RAPD, *Vigna unguiculata*, photoperiodism, genotype by environment interaction, yield components.

* Part of this chapter is submitted for publication.

Introduction

Under farming conditions in Benin, cowpea (*Vigna unguiculata*) varieties strongly interact with the environmental production factors, i.e., they show a strong genotype by environment interaction. The genotype by environment interaction is the phenomenon that ranking of genotypes based on their performance varies for different environmental conditions. Genotype by environment interaction is attributed to the fact that the expression of underlying genes or quantitative trait loci depends on the environment where the genotype is grown (Yin *et al*., 2004). This genotype by environment interaction determines the yield potential. Both farmers and breeders manage this interaction, farmers by managing the environment in a variety-specific way, and breeders by selecting varieties for specific environments. In cowpea production areas in Benin successive generations of farmers have selected cowpea varieties that flower at different periods during the growing seasons in response to the prevailing conditions at each location (Wien and Summerfield, 1980). Farmers proved to be aware of the differential response to photoperiod in early and late cowpea varieties (Zannou *et al*., 2004). In such a context, developing new varieties, or developing strategies for improving and maintaining existing varieties, requires a clear understanding of the characteristics and diversity of those varieties with which farmers have long-term experience. Doing research with farmers to analyse relevant agronomic and physiological traits and production constraints of the crop brought out the need to really understand the genetic diversity of the crop (Zannou *et al*., 2004).

Recent taxonomic studies of *Vigna* (Ng and Maréchal, 1985; Pasquet, 1993a, b, 1997, 1999) divided cowpea into ten perennial subspecies and one annual subspecies (ssp. *unguiculata*). These studies split the ssp. *unguiculata* into var. *unguiculata* and var. *spontanea* (Schweinf.) Pasquet (annual wild cowpea) (Pasquet, 1999). The annual culti-group (var. *unguiculata*) is composed of the cultivated cowpea varieties on which this study focused.

Previous studies on cowpea diversity, based on isozyme diversity and proteins alone, have shown very low genetic diversity (Pedalino *et al*., 1990; D'Urzo *et al*., 1990; Vaillancourt *et al*., 1993; Panella *et al*., 1993). With these techniques the cultivar group *sesquidalis* could not be distinguished from the group *unguiculata* (Vaillancourt *et al*., 1993). Molecular markers based on differences in DNA sequences between individuals generally detect more polymorphisms than morphological and protein-based markers and constitute a new generation of genetic markers (Botstein *et al*., 1980; Tanksley *et al*., 1989). DNA markers survey both expressed and silent nucleotide sequences. Alternative molecular markers showing very high levels of polymorphism even among closely related genotypes include markers based on RAPDs (Williams *et al*., 1993; Haley *et al*., 1994; Mignouna *et al*., 1998; Ba *et al*., 2004; Diouf and Hilu, 2005), microsatellites (Sonnante *et al*., 1994; Akkaya *et al*., 1995; Diouf and Hilu, 2005), and AFLPs (Vos *et al*., 1995; Coulibaly *et al*., 2002; Gillaspie Jr *et al*., 2005).

The objective of the present study was to develop a joint characterization of cultivated cowpea germplasm in Benin for the best use of the genetic potential of the crop and for a better use and management of cultivated cowpea varieties, based on agronomic and morphological descriptors as commonly used by farmers and molecular descriptors as used by researchers.

Materials and methods

Plant materials

The plant material used in this study only included cowpea varieties grown by farmers; they all belonged to *Vigna unguiculata* ssp. *unguiculata* var. *unguiculata* (Table 1). A total of 70 farmer-named cowpea varieties were collected from farmers of the transitional Guinea-Sudan zone of Benin and some from the south-east of Benin.

Field experiments

Field experiments were conducted in Dani, Savé district, in the central part of Benin, during three years (2003–2005). Seventy varieties were evaluated for their morphological and agronomic traits through a joint effort between the principle researcher and the farmers. During each farmer cropping season, and for each variety included, data were collected on 40 plants (10 plants × 4 repetitions). An additional experiment conducted at the experimental farm of the Faculty of Agronomy of the University of Abomey-Calavi in the south of Benin in 2003 included 30 varieties. The late-maturing varieties in this set did not flower in the south of Benin.

Joint characterization by farmers and the principle researcher

Data were collected and presented on various physiological, morphological and agronomic characteristics. These characteristics comprised:

- Qualitative plant and seed morphology traits including growth habit, pod pigmentation, flower colour, stem colour, seed shape, eye pattern, seed coat colour, skin texture; and
- Quantitative plant and seed traits: plant height at five different development stages, days to first flower, days to first pod; days to 50% maturity, pod length, number of seeds per pod, number of pods per plant per variety, and number of seeds per plant, and 1000-seed weight.

The characterization, based on the knowledge of farmers and the principle researcher, was carried out within the framework of a local learning group, and took place during different sessions throughout the period of crop growth and after harvest.

Table 1. List of cowpea germplasm accessions and their regions of collection used for RAPD analysis. C: central, NE: north-east, NW: north-west, SE: south-east.

Codes	Cultivar names	Villages	Region	Codes	Cultivar names	Villages	Region
1	Adjaïkoun ancien	Bohicon	C	43	Sowétin	Gbékandji	SE
2	Yawari petit grain	Dani	C	44	Aïglo	Glazoue	C
3	Djohozin (Adjohozin)	Gbékandji	SE	45	Kacripia	Alfakpara	NW
4	Moussa	Dani	C	46	Atchawékoun (Bohicon)	Bohicon	C
5	Kpohoundjo	Dani	C	47	Malanville petit grain	Dani	C
6	Sèwékoun	Glazoué	C	48	Niger	Save	C
8	Tawa petit grain	Dani	C	49	Zerma soui	Marégourou	NE
9	Adjaïkoun	Bohicon	C	50	Kpodjiguèguè		SE
10	Wankoun	Ouèdèmè	C	51	Sokan	Gbékandji	SE
11	Tontouin	Gbékandji	SE	52	Yèringo		NW
13	Kpodji-Wéwé	Bohicon	C	53	Glessissoafoado	Dani	C
14	Djèté	Dani	C	54	Soui Kpika	Sonoumon	NE
15	Atchawe ou Tola (Bohicon)	Bohicon	C	55	Togo grain	Ouèdèmè	C
16	Kpeïkoun (Bohicon)	Bohicon	C	56	Tanguieta	Dani	C
17	Kakè	Bohicon	C	57	Boto wéwé	Dani	C
19	Soui Zerma	Marégourou	NE	58	Katché Django	Alédjo-Kpataba	NW
20	Tchabè Funfun	Diho	C	60	Kaki	Yagbo	C
22	Azobahundé (Kpodjiguèguè)	Dannou	SE	61	Olodjou Maria	Pira	C
23	Ewa Egbessi	Egbessi	C	63	Boto vovo	Dani	C
24	Olikpokpo-doudou	Dani	C	64	Yanti Kpika	Donga	NW
25	Assitchénongbinhami	DamèWogon	SE	65	Katché Koukpédon	Alédjo-Kpataba	NW
26	Mahounan	Yagbo	C	67	Soui Kerri	Sonnoumon	NE
27	Téhivigboto	Dannou	SE	68	Mosso	Ouassa	NW
28	Wan akpavi	DamèWogon	SE	69	Kplobè rouge	Dani	C
29	Atama	Save	C	70	Djètoko	Glazoué	C
30	Malanville gros grain	Save	C	71	Kwx	Dani	C
32	Boto	Ouèdèmè	C	72	Egni-awo	Glazoue	C
33	Yawari gros grain	Dani	C	73	Kplobè wéwé	Dani	C
34	Sèhèkou original	Ouèdèmè	C	74	Ewa Nigeria	Diho	C
				75	Tchawa koubanguè / Grand Tchawa	Alédjo-Kpataba	NW
35	Sindjinnansin	Dannou	SE				
36	Tonton	Dani	C	76	Toura	Ouassa	NW
37	Tchadilè djofè	Diho	C	77	Nanwi	Dannou	SE
38	Tawa gros grain	Dani	C	78	Tola	Glazoué	C
39	Azangban	Dani	C	79	Ewa Zaffé	Glazoué	C
40	Atchawe Dangbo	Dannou	SE				
41	Matamaéko	Ouoghi	C				

Laboratory analysis

Five seeds of each accession were grown in pots and leaf samples were collected at seven days age from all the plants for DNA isolation and analysis.

DNA isolation

Fresh leaves from young plants were collected and frozen in liquid nitrogen. Leaves were ground with a mortar and pestle. DNA was isolated according to the Cethyltrimetylammonium bromide (CTAB) protocol described by Rogers and Bendich (1985), with slight modifications as described below. Up to 200 mg of ground leaf tissue was transferred to 2 ml eppendorf tubes, mixed with 500 µl of 2 × CTAB extraction buffer and incubated in a 65 °C water bath with frequent agitation for 90 min. The tubes were removed from the water bath and allowed to cool to room temperature before 500 µl of phenol was added and mixed thoroughly. The mixture was centrifuged at 12000 rpm for 10 min and the upper supernatant phase collected in a new tube. A second extraction was performed with 500 µl of mixture v/v phenol/chloroform isoamyl alcohol (24:1). After centrifugation, the supernatant was treated with RNase and the last extraction was performed with chloroform isoamyl alcohol. The upper phase was transferred into a new tube and DNA was precipitated with equal volumes of 2-propanol and Na-acetate. The DNA pellet was washed with 70% ethanol dried for 5 min in a heating bloc of 60 °C. The resulting DNA pellet was dissolved in 100 µl of distilled and sterilized water (Sigma). DNA quality was tested, using 1.5% agarose gel electrophoresis, and its concentration was determined with a UV spectrophotometer. DNA was then diluted to 25 ng/µl for PCR amplification.

PCR amplification

PCR reactions were performed in 25 µl volume in a mixture containing 3 mM $MgCl_2$, 1 × PCR buffer (50 mM KCl, 10 mM Tris-HCl pH 9.0), 0.1 mM of each dNTPs, 0.1 µM of random decamer primer, 50 ng of DNA and 1 unit of Taq DNA polymerase. The PCR amplification process was conducted in T3 Thermocycler Biometra. For each amplification process, an initial heat denaturation of DNA at 94 °C for 3 min was followed by 45 cycles consisting of 1 min at 94 °C, 1 min at 35 °C, and 2 min at 72 °C. A final incubation for 7 min at 72 °C was performed and the amplification products analysed on 2% agarose gel in Tris-borate buffer at 150 volts for 1 h. The agarose gel was stained in ethidium bromide, visualized under UV and photographed using digital camera. The 1 Kb ladder from SIGMA was used as standard molecular weight size marker.

Preliminary PCR amplification trials were conducted on four accessions, arbitrarily selected in order to standardize the DNA amplification conditions. These accessions were Vu5 (Azangban), Vu30 (Tanguieta), Vu33 (Tchabe Funfun), and Vu41 (Soui Kerri). Different concentrations of $MgCl_2$, DNA, dNTPs, and Taq DNA polymerase were tested to obtain the most reproducible and reliable DNA amplification profiles. Optimal conditions which revealed clear and reproducible amplification fragments were used in the study as earlier described.

Selection of the most informative primers
Mignouna *et al*. (1998) used 120 RAPD markers to investigate the genetic diversity of 95 cowpea accessions from diverse geographical origin across Africa, America and Asia and nine markers were the most informative. These nine primers were pre-selected for this study (Table 2). PCR amplification was performed on 24 cowpea accessions using individually the nine primers in order to select the primers that showed the most important polymorphic amplification fragments. As a result, four primers were selected for the whole study. The random primers used for DNA amplification were 10 base sequences obtained from Invitrogen Life Technologies as listed in Table 2.

Data analysis - Physiological, morphological and agronomic data

Qualitative seed and plant morphology characteristics
The qualitative data were encoded into 3 to 7 classes. Frequency distributions were performed for the following nine qualitative plant and seed morphology variables: growth habit, young pod pigmentation, flower colour, stem colour, grain shape, eye pattern, eye colour, seed coat colour, and seed coat texture. The frequency distributions were used to calculate the Shannon-Weaver diversity index (*H'*) for each characteristic (Grenier *et al*., 2004):

$$H' = -\sum_{i=1}^{n} p_i \ln(p_i)$$

where, n is the number of phenotypic classes, and p_i the frequency of the observation in the i^{th} class. Due to their additive property, the indices of each characteristic could be pooled over the characteristics and the global phenotypic diversity was estimated by calculating the mean index value using the SAS 8e program.

Quantitative plant and seed traits
Descriptive statistics were computed for each quantitative agro-morphological trait. Principal component analyses were performed on the 10 quantitative traits (see above). Principal component analysis reveals the importance of different quantitative traits in

Table 2. List and sequence of the 10-base nucleotide primers used for the RAPD analysis

Selected Primers		Not Selected Primers	
Primer Code	Nucleotide sequence	Primer Code	Nucleotide sequence
OPA-04	5'-AATCGGGCTG-3'	OPA-01	5'-CAGGCCCTTC-3'
OPB-01	5'-GTTTCGCTCC-3'	OPB-05	5'-TGCGCCCTTC-3'
OPC-05	5'-GATGACCGCC-3'	OPB-10	5'-CTGCTGGGAC-3'
OPD-18	5'-GTGTGCCCCA-3'	OPB-13	5'-TTCCCCCGCT-3'
		OPC-06	5'-GAACGGACTC-3'

explaining multivariate polymorphism (Mallkarjurna *et al*., 2003; Naghavi and Jahansouz, 2005). Data were standardized to a mean of zero and a variance of one. Following Kaiser's rule on standardized data, the components or factors to be retained were those whose eigen-values were greater than one (Sharma, 1996). In this chapter, data on quantitative plant and seed traits were analysed for 51 early-maturing varieties and 16 late-maturing varieties. Data are not presented on the other three varieties, because of lack of full emergence.

Genotype by environment interaction

An integrated full interaction analysis of variance was carried out. Such an analysis describes the phenotypic responses and allows a quantification by regression on the mean model of differences in environmental sensitivity between varieties (Finlay and Wilkinson, 1963; Van Eeuwijk *et al*., 2005). In the absence of explicit physical or meteorological characterizations of an environment, a good approximation of the general biological quality of the environment is given by the average phenotypic performance across the genotypes (Van Eeuwijk *et al*., 2005). The phenotypic responses of individual genotypes are then regressed on the average performance, and the genotype by environment interaction expresses itself by differences in the slopes between the genotypes. The model for the regression on the mean can be written as follows:

$$\mu_{ij} = \mu + G_i + E_j + \beta_i E_j$$

where, the genotype by environment interaction is modelled as differential genotypic sensitivity and represented by the parameters β_i to environmental characterization E_j, with the average sensitivity being zero.

In this study, the Generalized Linear Model of Analysis of Variance (GLM ANOVA) under SAS was performed to analyse the variation of yield components in response to change in date of planting, season and in the year effects. The GLM ANOVA is appropriate especially for unbalanced data, where there are unequal numbers of observations for the different combinations of class variables specified in the model structure. With this ANOVA, the number of pods per plant, the number of seeds per pod and the number of seeds per plant were analysed. The following effects were considered:

- Genotype (farmer-named variety);
- Variety-type (early or late maturing);
- Year (2003−2005 for early-maturing, and 2004−2005 for late-maturing varieties);
- Date (Year): Date or planting period nested within year effect. The season effect was considered for early-maturing varieties as they were planted during different cropping seasons and the date effect for the late-maturing varieties, as for the late ones two dates of planting were distinguished during the same cropping season. The late-maturing varieties can only be planted once a year.

Three interaction effects have been defined:

- Genotype × Year;
- Genotype × Date (Year);
- Genotype × Variety-type × Date (Year).

In this chapter, data were analysed on 35 early-maturing varieties over 2003−2005 and 15 late-maturing varieties over 2004−2005 for the genotype by environment interaction analysis. These varieties are those for which the yields are consistently available over three or two years for a comparison across years. In the first year (2003), the late-maturing varieties did not perform well.

Molecular data analysis

After electrophoresis separation, amplified DNA fragments detected in each accession were scored for presence (1) or absence (0) of a particular DNA fragment of a similar length. Faint fragments were omitted and only reproducible fragments were considered for the analysis.

To estimate genetic diversity, a pair-wise similarity matrix was generated using the Nei – Li similarity index (Nei and Li, 1979):

$$S = 2N_{AB} / (N_A+N_B)$$

where, N_{AB} is the number of RAPD fragments shared by two genotypes or cultivars (A and B); N_A and N_B are the total number of RAPD fragments analysed for each genotype (Levi *et al*., 2001).

A dendrogram was then constructed based on the similarity matrix data using the

UPGMA (Unweighted Pair-Group Method using Arithmetic Averages) cluster analysis of NTSYSpc-2.02j (Numeral Taxonomy and Statistical Analysis; Rohlf, 1998).

The genetic structure of the cultivars was investigated by an Analysis of Molecular Variance (AMOVA) (Excoffier *et al.*, 1992). The total molecular variance (σ_T^2) was partitioned into variance components due to differences among clusters (σ_{SC}^2) and within clusters (σ_{ST}^2). To analyse the genetic structure, the fixation index is a measure that is more and more used (Weir and Cockerham, 1984; Excoffier *et al.*, 1992; Schneider *et al.*, 2000; Weir, 1996; Dugoujon *et al.*, 2004; Kiambi *et al.*, 2005). This index, also called Wright's (1969) fixation index, was calculated for polymorphic loci and notated F_{ST}. F_{ST} is considered as the standardized variance of allele frequencies among subdivision (Excoffier, 2001). It reveals the proportion of the total variance of allele frequencies among clusters that could be explained by the group structure.

The AMOVA was performed based on a pair-wise squared Euclidean distance matrix using Arlequin ver 3.01 software (Excoffier *et al.*, 2006).

Combining morphological, agronomic and molecular analysis

The variables involved in the morphological, agronomic and molecular analysis were of different orders (i.e., nominal, binary, or quantitative). For a joint analysis, the data were transformed and analysed through the following steps. First, the morphological and agronomic variables were standardized. Second, Euclidean distance (i.e., a dissimilarity matrix) was calculated from each category of data (morphological, agronomic, and molecular). Third, a dendrogram was generated from each dissimilarity matrix. Fourth, a cophenetic matrix was derived from each dissimilarity matrix to test goodness of fit of the clusters by comparing the two matrices (dissimilarity and cophenetic) using the Mantel correspondence test (Mantel, 1967). Finally, the comparison between the different types of characterization was done using MXCOMP matrix comparison program of the NTSYS-pc package, with 250 random permutations. The Mantel test was used to establish the morphological, agronomic and molecular distances. A complete characterization of both morphological, agronomic, and molecular traits was done on 61 cowpea varieties of which 46 were early- and 15 late-maturing varieties.

Results and discussion

Morphological and agronomic diversity

The cowpea varieties greatly differed in their morphological and agronomic traits. Various classes of these characteristics were considered by farmers and used in this study. There were variations in growth habit and stem colour. Some varieties were spreading (prostrate and semi-prostrate), locally named late-maturing varieties, while others were erect or semi-erect. Table 3 reports the different plant and seed morphology characteristics. Some cowpea variety pods were entirely pigmented, while others were not, or just at the apex of the pod. There was a diversity in flower colour, white/whitish, white and purple-edge, purple, and yellowish. The stem was light green, green, purple or purple depending or the variety. The seed shape was either kidney, ovoid, globose or rhomboid. There was a diversity of the eye patterns: very small, small, narrow, and wide or in some cases absent. Where the eye was markedly present, its colour was blue, brown, black or red. The cowpea varieties were characterized by seed coat colour as white, cream/ivory, brown, red, black, and variegated (black and black-white, light-dark brown, red-black, brown-black, ivory-black, or beige-black). The texture of the seed coat was also different: smooth, rough, or wrinkled.

The frequency and Shannon-Weaver information index calculated from the plant and seed morphology of the different cowpea varieties evaluated showed a high mean global index of diversity in the total collection (H'=1.23), and ranged from 1.02 for pod pigmentation to 1.61 for seed coat colour. With respect to the individual traits, the seed coat colour showed the highest total diversity for all regions where these have been collected from (1.61). Within regions, this phenotypic diversity index varied from 0.33 to 1.57, depending on the characteristic. It varied from 1.05 to 1.46 (with a mean of 1.26) for the central region, from 0.65 to 1.57 for the north and from 0.30 to 1.46 for the south-east. The mean values for the regions were 1.26, 1.07, and 0.79 for the central part, the north, and the south-east part, respectively. Figure 1 presents the clustering made with the qualitative characteristics using the Gower General Similarity Coefficient calculated with the Multi-Variate Statistical Package (MVSP 3.1). At 70% similarity on the Gower General Similarity coefficient, nine clusters can be distinguished. The first six clusters were re-grouped in one large group comprising only white seed coat varieties, while the second cluster was composed of mixtures of seed colour and early-maturing varieties.

One particular trait the farmers recognized as being important in the late-maturing varieties was the growth habit (i.e., the tendency to be prostrate). Based on this characteristic, some varieties (such as Mata, Djetoko, Atama, Moussa and Egniawo) could be easily identified in the field and were considered to be a distinctive group. Within this group, plant pigmentation, flower colour, and morphological seed traits could be used to further distinguish the different types. Box 1 and Box 2 report some results of interactive sessions to characterize the different varieties with the local learning group. The leaf or the plant colour itself was sometimes not sufficient to make a clear distinction between varieties, but was useful to indicate a genotypic relation. Distinction was mainly made on the basis of pod and seed characteristics.

Table 3. Frequency distribution and Shannon-Weaver diversity index (*H'*) for qualitative characteristics.

Character-istics	Class	Centre Freq.	Centre *H'*	North Freq.	North *H'*	South-east Freq.	South-east H'	Total Freq.	Total *H'*
Growth habit	1= erect	0.39		0.64		0.10		0.40	
	2= semi-erect	0.37		0.36		0.50		0.38	
	3= prost+semi-prost	0.24	1.08	0.00	0.65	0.40	0.94	0.22	1.07
Pod pigment	0= absent	0.49		0.64		0.50		0.52	
	1= present at the apex	0.24		0.22		0.20		0.23	
	2= entirely colored	0.27	1.05	0.14	0.89	0.30	1.03	0.25	1.02
Flower colour	1= white/whitish	0.41		0.43		0.00		0.36	
	2= white & purple-edge	0.10		0.14		0.00		0.09	
	3= purple	0.34		0.36		0.90		0.43	
	4= yellowish	0.15	1.25	0.07	1.19	0.10	0.33	0.12	1.20
Stem colour	1= light green	0.27		0.14		0.60		0.29	
	2= green	0.10		0.07		0.40		0.14	
	3= green-purple	0.41		0.57		0.00		0.38	
	4= purple	0.22	1.28	0.22	1.11	0.00	0.67	0.19	1.04
Seed shape	1= kidney	0.43		0.36		0.37		0.41	
	2= ovoid	0.25		0.36		0.45		0.30	
	4= globose	0.11		0.14		0.09		0.12	
	5= rhomboid + crowder	0.21	1.28	0.14	1.29	0.09	1.16	0.17	1.28
Eye pattern	0= absent	0.36		0.21		0.82		0.41	
	1= very small	0.07		0.14		0.09		0.08	
	2= eye filling the narrow grove	0.05		0.00		0.00		0.03	
	3= narrow eye	0.22		0.22		0.00		0.19	
	4= small eye	0.07		0.29		0.09		0.12	
	5= wide eye	0.23	1.56	0.14	1.57	0.00	0.60	0.17	1.54
Eye colour	0= absent	0.36		0.21		0.82		0.41	
	1= blue	0.04		0.00		0.09		0.04	
	2= brown	0.41		0.43		0.09		0.36	
	3= black	0.17		0.36		0.00		0.17	
	4= red	0.02	1.24	0.00	1.06	0.00	0.60	0.02	1.24
Seed coat colour	1= white	0.48		0.64		0.09		0.45	
	2= cream + ivory	0.18		0.07		0.00		0.13	
	4= brown	0.16		0.07		0.00		0.11	
	5= red	0.07		0.00		0.18		0.07	
	6= black; black-white	0.00		0.00		0.09		0.13	
	7= light-dark brown	0.04		0.07		0.37		0.09	
	8= red-black; brown-black, ivory-black; beige-black	0.07	1.46	0.15	1.13	0.27	1.46	0.02	1.61
Skin texture	1= smooth	0.43		0.72		0.91		0.56	
	3= smooth to rough	0.36		0.07		0.09		0.26	
	5= rough	0.18		0.21		0.00		0.16	
	7= rough to wrinkled	0.03	1.14	0.00	0.75	0.00	0.30	0.02	1.05
Means			1.26		1.07		0.79		1.23
S.E.			0.056		0.093		0.129		0.072

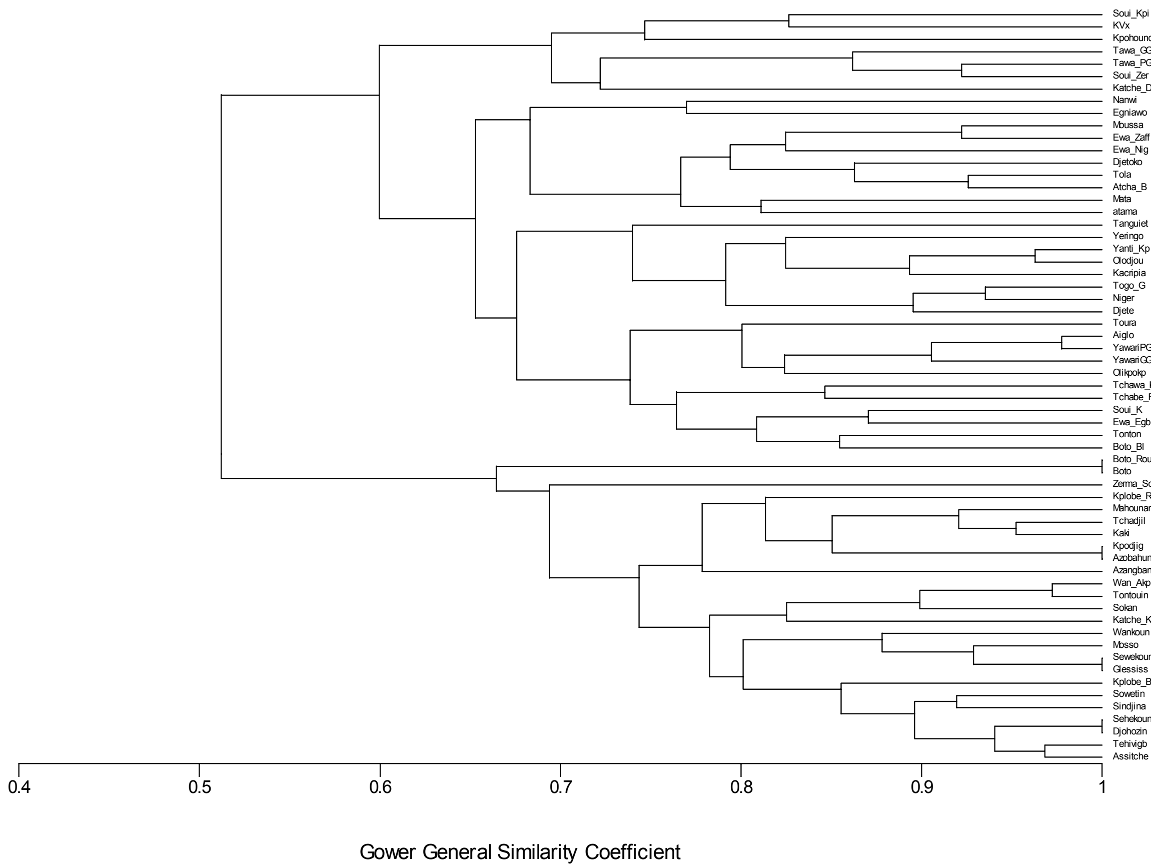

Figure 1. Clustering based on morphological characteristics of cowpea varieties.

Box 1. ***Plant pigmentation and seed traits***
Djetoko and Atama. The leaves of Djetoko were smaller and darker than the leaves of Atama. Djetoko is semi-prostrate (the main stem reaches some height before spreading while Atama is prostate (branches quickly flat on ground). The stems of Djetoko were taller and more red-purple pigmented than the stems of Atama. The pods of Djetoko were bigger than the ones of Atama. The seed eye of Djetoko was red-purple while the eye of Atama was black. Djetoko was easier to shell while the pod was difficult to shatter. However, Djetoko and Atama are similar in seed coat colour (white) in growth habit (spreading) and in flowering period.

Box 2. ***Earliness, plant vigour and photoperiodism.***
During field observations and data analysis with the farmers, it was noticed that some varieties which were supposed to be early maturing and were planted in the first rainy season, had not flowered till to 11–12 weeks after sowing. These varieties were Aïglo, Tchawa Koubanguè, Toura, Moro, Soui Kerri, and Ewa Egbessi. The leaves of one of them (Soui Kerri) began to turn yellow, indicating that senescence had started. It appeared that when cowpea spends its normal growth duration without flowering, the leaves dry out and drop, but the stem remains alive. Farmers noted that all varieties they would call late maturing are varieties that only flower in early October. The photoperiodic response appeared to be the basis of the late-maturing behaviour of the varieties farmers classified as late.

Quantitative agronomic traits analysis

Diversity of agronomic traits

Farmers suggested that the number of seeds per pod, number of pods per plant, and number of seeds per plant were very important characteristics. Overall, on average, the early-maturing varieties flowered within 40 days (Table 4). The coefficients of variation of the parameters days to first flowering, days to first pod, and days to 50% maturity were almost the same. Days to 50% maturity was, on average, reached 59 days after emergence. These early varieties ended their growth cycle at on average 68 days after emergence. The mean value of pods per plant was 19, whereas the number of seeds per pod was 14. As a result, the mean number of seeds per plant was relatively high (267). The coefficients of variation show that variation variance in the number of seeds per plant, in the number of pods per plant, and in the 1000-seed weight, was higher than the variation in variance of other parameters.

When planted at the appropriate date (based on local knowledge), the late-maturing varieties (locally recognized as having a particular period of flowering) took on average 53 days to first flowering, 55 days to first pods, and 76 days to reach 50% maturity (Table 4). The average duration of their cycle was 83 days. Thus, the productive period of the late-maturing varieties appeared to be longer than that of the early-maturing varieties. The overall mean number of seeds per plant of the late-maturing

Table 4. Descriptive statistics of yield components and agro-morphological and phenological characteristics.

V_type	Early					Late				
	Mean	Min	Max	SD	CV	Mean	Min	Max	SD	CV
DaFlow[1]	39.7	32.0	44.5	2.9	7.4	53.0	42.9	66.1	5.9	11.1
DaPod	41.9	34	48.1	2.9	7.0	55.2	45.4	68.1	5.7	10.3
DPodma50	58.7	51.7	71	4.5	7.6	76.3	63.7	88.7	6.3	8.2
Durcycle	68.0	56.8	88	8.2	12.1	83.2	70.4	95.3	6.7	8.1
Leng_pod	15.9	11.7	19.7	2.1	13.1	13.8	12.2	15.4	0.9	6.7
Seed_pod	14.1	9.5	18.9	2.2	15.6	12.2	10.4	13.9	1.7	8.7
Pod_plt	18.8	10.1	34	4.5	23.8	23.9	8.9	35.9	6.7	28.2
Seed_plt	267.1	156.9	480.2	71.3	26.7	298.9	117.7	505.2	94.2	31.5
1000-seed weight	129.3	64	219	28.7	22.2	128.6	91	239	34.8	27.1

[1] DaFlow= days to first flower, DaPod= days to first pod; DPodma50= days to 50% maturity, Durcycle= cycle duration, Leng_pod= pod length, seed_pod= number of seeds per pod, Pod_plt = number of pods per plant, Seed_plt= number of seeds per plant.

varieties was 299 seeds per plant. Figure 2 shows the dendrogram constructed based on the Euclidean distance of the quantitative traits using the NTSYS-pc package after standardization of the data. At 0.55 point of distance, nine groups of early-maturing varieties can be distinguished (Figure 2a). At 0.55 point of distance, the late-maturing varieties can be separated into six groups.

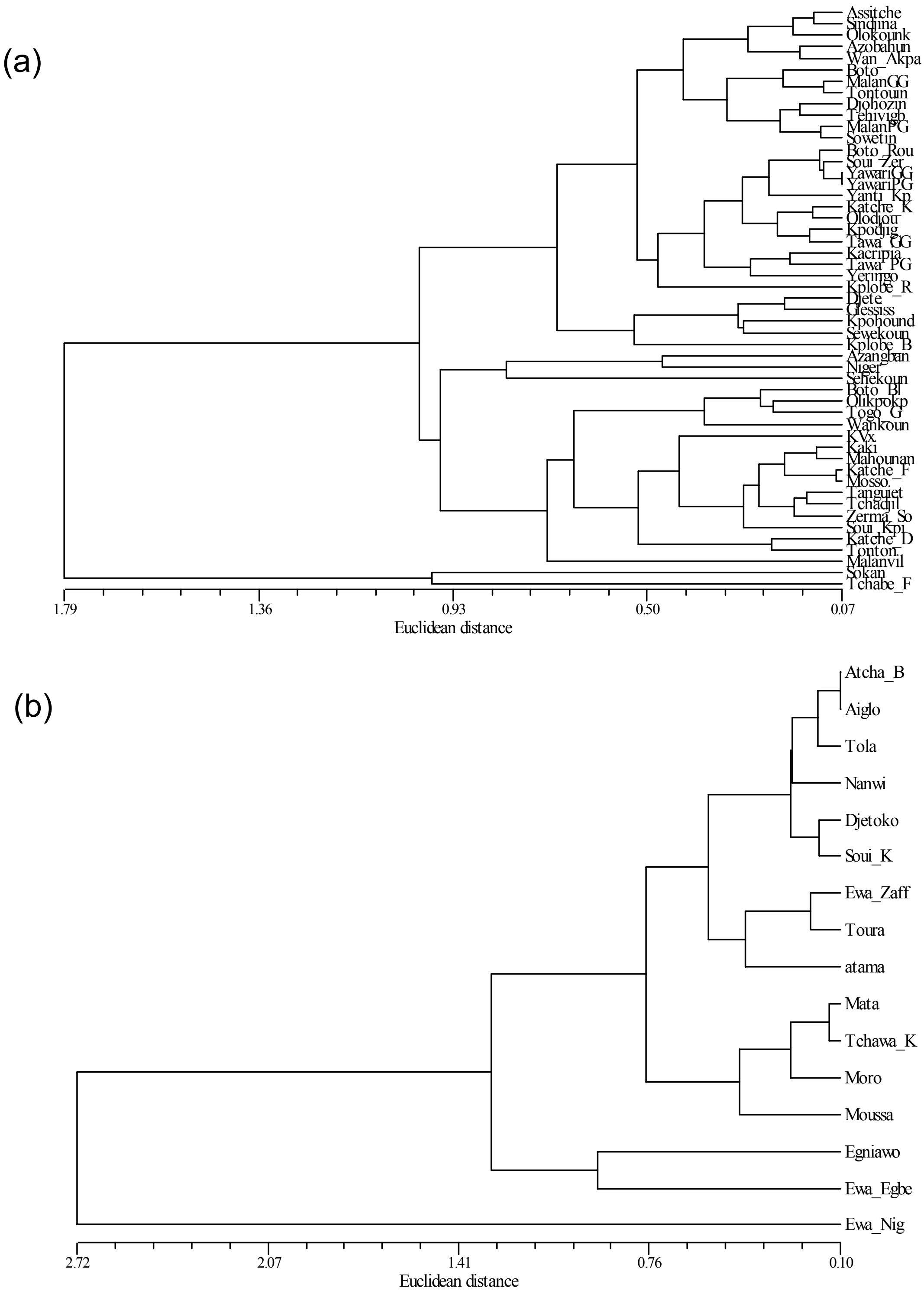

Figure 2. Clustering based on agronomic performance; (a) early maturing; (b) late maturing.

Correlations between agronomic traits

For both early- and late-maturing varieties (left and right parts of Table 5), there were positive and highly significant associations between days to first flowering, days to first pods, days to 50% maturity, and the duration of the growth cycle for early-maturing varieties. Within each of the two variety groups these characteristics are probably governed by the same genes. These characteristics, however, were not correlated with pod length, number of pods per plant, number of seeds per pod and number of seeds per plant, for either early- or late-maturing varieties. There were high and positive correlations between the length per pod and number of seeds per pod, pods per plant and seeds per plant, seeds per pod and seeds per plant. There was a negative association between the 1000-seed weight and the number of seeds per pod, number of seeds per plant and number of pods per plant.

Principal component analysis of the quantitative agronomic traits

The principal component analysis showed four significant components for early-maturing varieties and three main components for late-maturing varieties, following Kaiser's rule (Table 6). In total, the variance accounted for by the first four components was 89.4% (Table 6). Each of the four components accounted for 40.2%, 22.5%, 16.3% and 10.3% of the total variance of the original variables, respectively. The loadings provide an indication of the extent to which the original variables are important in forming the new variables or components. The days to first flowering, days to first pod and days to 50% maturity were influential in forming the first component. The number of seeds per pod and number of seeds per plant were influential in the second component; the number of pods per plant was the main determinant in the third component, whereas the 1000-seed weight and cycle duration had opposite effects in the fourth component. For the late-maturing varieties, the three main components accounted for 86.4% of the total variation. The first, the second and the third component accounted for 48.2, 26.7, and 11.4%, respectively. As for early-maturing varieties, the days to first flowering, days to first pod and days to 50% maturity were influential in forming the first component for early-maturing varieties. The number of pods per plant, number of seeds per pod, and number of seeds per plant were influential in the second component; the third component was determined by the length per pod and the number of seeds per pod.

Genotype by environment interaction: effects of planting date, season, and year on yield components

For both variety groups, the yield components – number of seeds per pod, number of pods per plant and number of seeds per plant – were significantly different from one

Table 5. Phenotypic correlations between yield components and agro-morphological and phenological characters. Correlation matrix from 51 early maturing (bottom left), 16 late maturing (upper right).

	Late-maturing varieties								
Early	DaFlow	DaPod	DPodma50	Durcycle	Leng_pod	Pod_plt	Seed_plt	Seed_pod	1000-seed weight
DaFlow	-	0.994***	0.922***	0.905***	–0.054	–0.029	0.058	0.125	0.299
DaPod	0.973***	-	0.910***	0.894***	–0.053	–0.038	0.049	0.123	0.307
DPodma50	0.622***	0.674***	-	0.973***	–0.092	–0.054	–0.026	–0.046	0.466*
Durcycle	0.278**	0.369***	0.814***	-	–0.137	0.033	0.047	–0.097	0.420
Leng_pod	0.164	0.193	0.351***	0.242*	-	0.187	0.287	0.551**	–0.074
Pod_plt	0.034	0.047	0.115	0.126	–0.114	-	0.962***	0.345	–0.160
Seed_plt	–0.082	–0.056	0.152	0.164	0.349**	0.824***	-	0.573**	–0.294
Seed_pod	–0.167	–0.140	0.140	0.164	0.811***	–0.121	0.447***	-	-0.500*
1000-seed weight	0.370***	0.377***	0.224	0.060	0.208	–0.036	–0.101	–0.099	-

Significance level: * < 10%; **; < 5%; *** < 1%.

[1] DaFlow= days to first flower, DaPod= days to first pod; DPodma50= days to 50% maturity, Durcycle= cycle duration, Leng_pod= pod length, seed_pod= number of seeds per pod, Pod_plt = number of pods per plant, Seed_plt= number of seeds per plant.

Table 6. Principal components for 10 quantitative characteristics for early- and late-maturing varieties.

	Early-maturing group (n=51)				Late-maturing group (n=16)			
	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4
Eigen values	4.02	2.25	1.62	1.03	4.82	2.68	1.14	0.90
Percentage variation	40.23	22.54	16.25	10.34	48.21	26.77	11.38	8.98
Cumulative variation	40.23	62.77	79.02	89.36	48.21	74.98	86.36	95.34
	Loadings (eigen-vectors)				Loadings (eigen-vectors)			
DaFlow[1]	0.43	–0.23	0.05	0.17	0.45	0.06	0.09	–0.08
DaPod	0.45	–0.20	0.05	0.12	0.44	0.06	0.10	–0.07
D50Podma	0.44	0.08	0.01	–0.33	0.44	–0.02	–0.03	0.06
Durcycle	0.32	0.15	0.03	–0.59	0.44	0.00	–0.13	0.01
Leng_pod	0.21	0.42	–0.43	0.23	–0.05	0.32	0.46	0.69
Pod_plt	0.06	0.28	0.69	0.17	–0.02	0.49	–0.56	0.07
Seed_plt	0.07	0.56	0.38	0.19	–0.00	0.56	–0.37	–0.01
Seed_pod	0.06	0.53	–0.42	0.04	–0.01	0.50	0.44	–0.06
1000-seed weight	0.21	–0.15	–0.10	0.62	0.20	–0.28	–0.31	0.69

The bold figures are the loading values with most significant impact.

[1] DaFlow= days to first flower, DaPod= days to first pod; D50Podma= days to 50% maturity, Durcycle= cycle duration, Leng_pod= pod length, seed_pod= number of seeds per pod, Pod_plt = number of pods per plant, Seed_plt= number of seeds per plant.

Table 7. Average values of yield components of cowpea varieties grown at different cropping seasons and planting dates over 2003–2005.

Variety-type	Factors	Factor levels	Total number of plants	Number of seeds per pod	Number of pods per plant	Number of seeds per plant
Early maturing	Season	Season-1	1207	15.2 a[1]	18.9 a	292 a
		Season-2	3000	12.9 b	18.8 b	244 b
	Year	2003	1057	11.8 c	22.4 a	271 a
		2004	2300	13.9 b	17.1 c	244 b
		2005	850	14.9 a	19.1 b	281 a
Late maturing	Date	Date-1	800	12.2 b	27.0 a	337 a
		Date-2	1010	12.5 a	23.5 b	297 b
	Year	2004	920	12.4 a	26.2 a	333 a
		2005	890	12.4 a	23.8 b	296 b

[1] For each factor, means followed by the same letters are different at the level of 5% with the test of Student-Newman-Keuls.

year to another, except for the number of seeds per pod for late-maturing varieties (Table 7). For early-maturing ones, the first season planting had significantly more seeds per pod, pods per plant and seeds per plant than the second season planting. For late-maturing varieties, the two planting dates gave significantly different values for the yield components, with the second date giving more seeds per pod, but fewer pods per plant and fewer seeds per plant than the first date.

The results of the combined analysis of yield components over the three-year experiments are presented in Table 8. All sources of variance were statistically highly significant ($P<0.001$) for all parameters, except for number of seeds per pod in the case of late-maturing varieties. The significant Season × Variety and Year × Variety interactions suggest that there were differences among varieties in their response to different season conditions in different years. The magnitude of these responses varied from one season to another, one year to another and from one variety to another. These results indicate that the yield components of cowpea are highly dependent on genotypes, season and year, and on the genotype by environment interactions.

The effect of year was larger than the effect of season and the effect of season was larger than the effect of variety for the early-maturing varieties, whereas for late-maturing varieties the effect of variety was higher than the effect of year, and the effect of year was larger than the effect of planting date for the three yield components. The effect of year was the highest for number of pods per plant and number of seeds per plant, whereas the effect of variety was largest for number of seeds per pods for the late-maturing varieties.

Within the early-maturing group, the varieties Sewekoun, Glessissoafoado, Djete, and Assitchenon had the highest number of seeds per plant, ranging from 311 to 470 seeds/plant, while Azangban and Olikpokpodoudou had the lowest value (162 and 172, respectively) (Table 9). The means of the other varieties ranged from 200 to 300 seeds per plant.

For the late-maturing varieties, the varieties Mata and Tchawa Kougbangue had the highest number of seeds per plant (505 and 439, respectively), whereas Ewa Nigeria, Atama and Ewa Egbessi had the lowest values (117.7 to 209.7) (Table 10). The mean yield of the other varieties ranged from 248 to 371 seeds per plant. The number of pods per plant appeared to be the most important yield component determining total number of seeds per plant.

Molecular characterization

RAPD primers' selectivity on cowpea genetic resources

Figure 3 shows PCR amplification fragments of the 24 accessions as detected by the

Table 8. Genotype by environment: effects of planting data, season, and year on yield components.

GLM-ANOVA	Degree of	Number of seeds per pod		Number of pods per plant		Number of seeds per plant	
Source of variation	Freedom	Mean Square	F_value	Mean Square.	F_value	Mean Square	F_value
Early maturing							
Season	1	931.5	239.69***	403.2	9.78***	702474.1	53.27***
Variety	34	215.8	55.52***	1814.7	22.95***	368365.7	19.78***
Year	2	1199.5	309.60***	1916.1	29.45***	456857.4	27.57***
Season × Variety	27	36.2	9.30***	725.1	13.17***	173411.2	12.76***
Year × Variety	45	118.6	30.51***	858.5	14.09***	230931.6	16.12***
Year × Season × Variety	4	31.3	8.06***	378.6	6.25***	85388.8	5.87***
Model	119	229.4	58.58***	1423.7	23.11***	343725.3	23.35***
Error	4067	3.9		61.6		14718.2	
R-Square		0.63		0.40		0.41	
Mean		13.6		18.8		258.5	
Late maturing							
Date	1	11.9	5.63**	11765.8	116.69***	1703273.5	92.84***
Variety	14	146.0	69.4***	5528.8	54.84***	1042799.1	56.84***
Year	1	22.5	10.71***	17126.9	169.87***	2600990.0	141.77***
Date × Variety	11	25.9	12.33***	1554.8	15.42***	309516.4	16.87***
Year × Variety	12	68.6	32.61***	2502.0	24.81***	545085.9	29.71***
Year × Date × Variety	3	31.4	14.9***	2474.2	24.54***	571053.2	31.13***
Model	45	81.8	38.87***	3988.9	39.56***	784681.8	42.77***
Pooled error	1764	2.1		100.8		18347.0	
R-Square		0.50		0.50		0.52	
Mean		12.4		25.0		314.8	

Significance level: * 10%; ** 5%; *** 1%.

Table 9. Genotype × environment (period of planting, season and year) interaction with GLM ANOVA: Tests of multiple range comparison (35 early-maturing varieties, 2003–2005).

Variety	Total number of plants	Number of pods per plant		Number of seeds per pod		Number of seeds per plant	
		Mean	SD	Mean	SD	Mean[1]	SD
Sewekoun	160	34.0 a	13.89	13.8 gh	2.06	471 a	203.0
Glessiss	160	24.9 bc	11.12	14.2 gf	1.65	354 b	164.1
Djete	102	25.7 b	12.31	13.3 hji	2.44	353 b	204.2
Assitche	52	18.6 efghijk	8.90	16.3 ab	1.77	311 c	171.5
Kpodjig	120	18.2 efghijk	10.90	15.6 bcd	2.98	295 cd	209.3
Djohozin	52	18.9 efghij	9.69	14.8 def	2.03	287 cde	164.4
Kacripia	130	17.6 efghijkl	7.10	16.0 abc	2.71	286 cde	133.3
Tonton	160	20.3 def	13.43	13.5 ghi	2.52	285 cde	207.3
Katche_K	120	22.7 cd	12.02	11.6 mn	3.23	282 cde	196.6
Tawa_GG	172	18.9 efghij	7.45	14.6 ef	2.50	280 cde	127.4
Tawa_PG	172	19.7 defgh	9.92	13.8 gh	3.37	274 cde	152.2
Boto_Rou	120	17.7 efghijkl	7.69	15.2 cde	3.21	273 cde	143.0
Mosso	90	21.6 de	10.64	12.1 klm	1.84	265 cdef	144.1
Katche_D	80	15.8 hijklmn	6.47	16.6 a	2.58	264 cdef	119.7
Soui_Zer	90	17.4 fhijkl	7.86	14.8 def	1.78	261 cdef	132.3
Mahounan	120	17.1 fhijkl	6.87	15.0 def	2.39	258 cdefg	116.3
YawariGG	200	20.5 def	9.12	12.5 jkl	2.18	258 cdefg	136.9
Tanguiet	130	19.2 defghi	7.26	13.2 hij	2.09	255 cdefg	109.6
Yeringo	90	19.4 defgh	7.37	12.9 ijk	1.54	250 defhg	95.2
Kaki	172	15.3 ijklmn	6.80	15.9 abc	2.02	245 defhg	114.7
Kplobe_B	90	19.2 defghi	10.49	12.0 ml	2.14	237 defhg	149.9
Yanti_Kp	130	15.3 ijklmn	6.93	15.6 bcd	2.30	237 defhg	113.0
Niger	132	20.8 def	12.09	11.1 no	2.67	231 efhg	139.6
Tchadjil	130	14.2 lmn	5.67	16.1 ab	1.77	229 efhgi	93.8
Katche_F	50	17.6 fghijl	8.76	12.5 jkl	1.98	228 efhgi	134.1
Zerma_So	120	14.6 klmn	6.56	15.1 de	3.12	227 efhgi	121.9
Soui_Kpi	120	13.2 mn	6.50	15.6 cd	1.65	206 fghij	107.7
Wankoun	160	16.1 ghijklm	6.79	12.1 klm	3.08	204 fghij	114.9
Togo_G	120	17.9 efghijk	9.52	11.3 mno	2.14	201 ghij	111.3
Kplobe_R	110	17.8 efghijk	10.50	10.2 p	3.52	200 ghij	176.8
Boto_Bl	160	16.8 fghijklm	7.83	12.5 jkl	6.02	197 ghij	141.4
KVx	120	16.8 fghijklm	7.86	11.6 mn	2.18	197 ghij	105.8
Tchabe_F	60	20.0 defg	8.55	9.5 q	2.55	192 hij	115.0
Olikpokp	142	15.3 ijklmn	6.83	11.4 mno	2.47	172 ij	85.5
Azangban	52	12.4 n	5.57	13.1 hij	1.65	162 j	76.1
Global	4207	18.8	10.01	13.6	3.21	258	155.1

[1] Means with the same letters are not statistically different at the level of 5% with the test of Student-Newman and Keuls under GLM ANOVA.

Table 10. Tests of multiple range comparison of Student-Newman and Keuls under GLM ANOVA (15 late-maturing varieties, 2004–2005).

Variety	No.	Number of pods per plant		Number of seeds per pod		Number of seeds per plant	
		Mean[1]	SD	Mean[1]	S.D.	Mean[1]	SD
Mata	160	35.9 a	21.89	13.9 a	1.02	505 a	321.6
Tchawa_K	120	35.3 a	16.44	12.4 c	1.27	439 b	213.8
Moro	80	28.9 bc	13.30	12.8 c	0.98	371 c	174.8
Aiglo	120	29.7 b	10.53	11.8 d	1.70	353 cd	135.2
Moussa	160	25.9 cde	11.42	13.3 b	1.40	345 cde	160.9
Djetoko	120	27.6 bcd	14.68	12.4 c	1.27	342 cde	193.9
AtchaweB	160	23.6 ef	8.66	13.3 b	1.85	321 def	136.6
Soui_Ker	120	24.2 def	13.87	12.5 c	1.40	302 efg	175.2
Tola	80	23.4 ef	9.19	12.7 c	1.59	299 efg	121.1
Egniawo	160	27.3 bcd	10.91	10.4 f	1.63	284 fgh	122.6
Nanwi	120	19.2 gh	6.44	13.8 a	1.86	266 gh	101.5
Toura	120	20.8 fg	8.06	11.9 d	1.32	249 h	104.4
Ewa_Egbe	80	18.3 gh	9.86	11.2 e	1.79	210 i	126.3
Atama	120	16.9 h	10.44	10.6 f	1.89	181 i	115.8
Ewa_Nig	90	8.9 i	5.67	11.7 d	3.74	118 j	116.5
Global	1810	25.0	14.06	12.4	2.02	315	193.4

[1] Means with the same letters are not statistically different at the level of 5% with the test of Student-Newman and Keuls under GLM ANOVA.

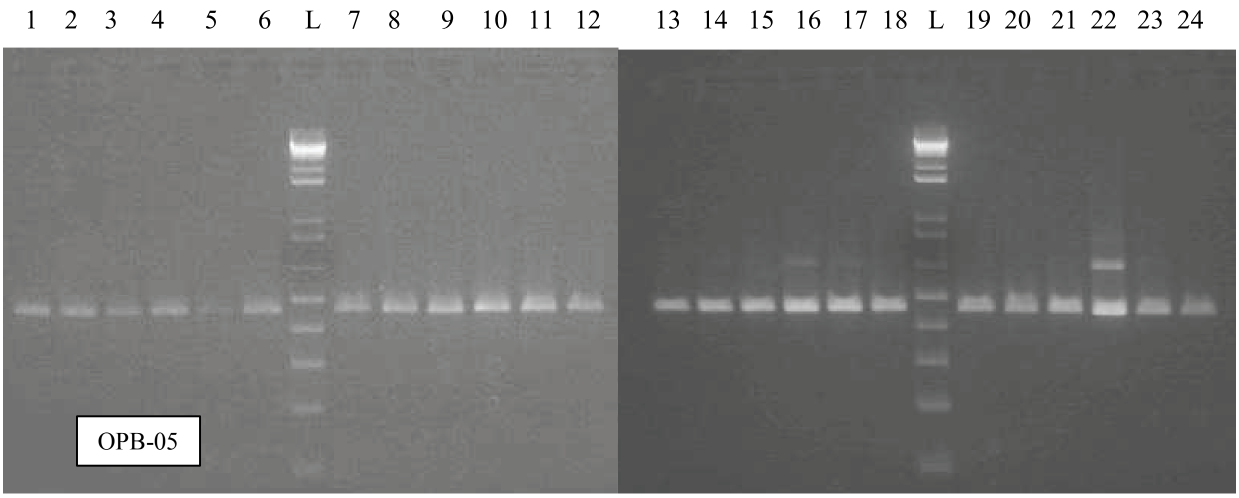

Figure 3. RAPD profile of 24 randomly selected accessions using the primer OPB-05. Lanes 1: Adjaïkoun (ancien), 2: Yawari petit grain, 3: Djohozin, 4: Moussa, 5: Kpohoundjo, 6: Séwouékoun, 7: Tawa gros grain, 8: Adjaïkoun, 9: Tontouin, 10: Kpobè rouge, 11: Djèté, 12: Atchawé ou Tola (Bohicon), 13: Kpeikoun (Bohicon), 14: Kake, 15: Soui Zerma, 16: Tchabe funfun, 17: Ewa Egbessi, 18: Assichenon Binhami, 19: Boto, 20: Yawari gros grain, 21: Sehekoun (original), 22: Tonton, 23: Katche funfun, 24: Niger, L: ladder (100 bp).

primer OPB-05. This primer revealed monomorphic bands in the size of about 470 bp on 23 accessions, and only on one accession (lane 22) an additional band of 600 bp was shown. A similar amplification pattern was also detected by primer OPB-10 which revealed monomorphic amplification bands in 23 accessions and only in one accession (lane 24) two additional bands were detected (Figure not shown). So, among the 24 accessions screened, primers OPB-05 and OPB-10 were able to distinguish only one accession from the others. Similarly, three other primers OPA-01, OPB-13, OPC-06 were also unable to distinguish these 24 accessions. Hence, these primers were not considered for the study. Taking into account their ability to reveal polymorphic bands, four primers (OPW-04, OPC-05, OPD-18, OPB-01) were selected. Figure 4 shows DNA polymorphism detected in the 24 accessions screened using primer OPC-05. While the primer OPB-05 was unable to distinguish these accessions (Figure 3), the primer OPC-05 detected polymorphic bands showing important variation among these accessions. However, PCR amplification profiles were similar in some of the accessions, as for example shown by lane 3 (Djohozin) and lane 4 (Moussa), and by lane 10 (Kplobè rouge) and lane 11 (Djèté) (Figure 4). Similarly, DNA polymorphisms were also detected by the three other primers used in the study. Hence, these four primers were used to characterize genetic diversity of the 70 cultivated germplasm accessions investigated (Table 1).

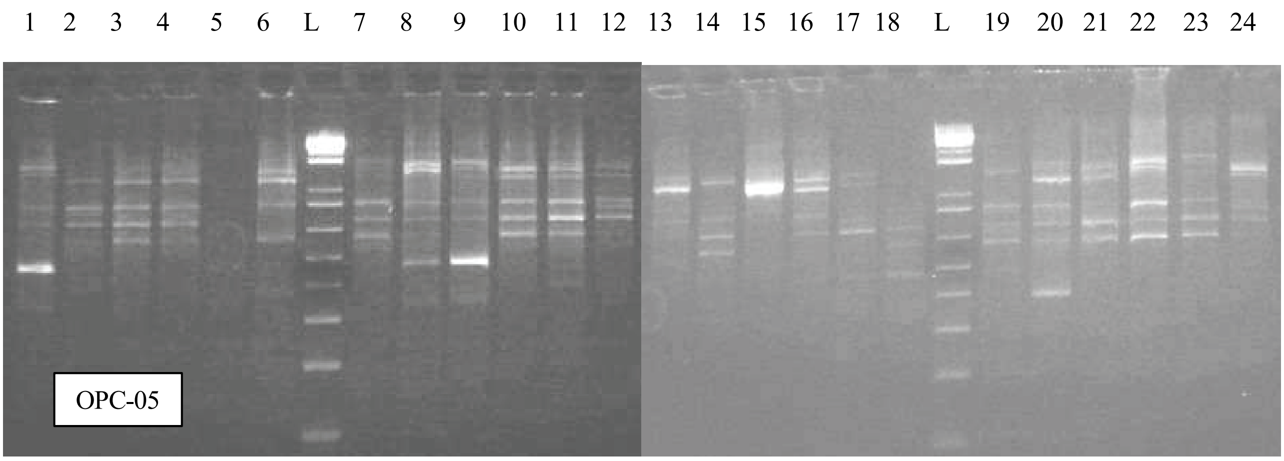

Figure 4. RAPD profile of 24 randomly selected accessions using the primer OPC-05. Lanes 1: Adjaïkoun (ancien), 2: Yawari petit grain, 3: Djohozin, 4: Moussa, 5: Kpohoundjo, 6: Séwouékoun, 7: Tawa gros grain, 8: Adjaïkoun, 9: Tontouin, 10: Kpobè rouge, 11: Djèté, 12: Atchawé ou Tola (Bohicon), 13: Kpeikoun (Bohicon), 14: Kake, 15: Soui Zerma, 16: Tchabe funfun, 17: Ewa Egbessi, 18: Assichenon Binhami, 19: Boto, 20: Yawari gros grain, 21: Sehekoun (original), 22: Tonton, 23: Katche funfun, 24: Niger, L: ladder (100 bp).

Cluster analysis and genetic estimates

The number of RAPD marker loci detected was 5 for the primer OPB-01, 8 for the primers OPC-05 and OPD-18, and 11 loci for primer OPA-04. The size of the amplified bands ranged from 0.3 kb to 2 kb. A total of 32 amplified DNA bands were generated by all primers. None of the primers considered was individually able to distinguish all accessions. Considering together all the fragments generated by the four primers selected for the present study, investigated accessions could be distinguished based on some unique bands.

From the presence or absence of DNA fragments, the estimates of distances among accessions were based on Nei and Li's similarity index and used to construct a dendrogram (Figure 5). At an agglomerative coefficient of 0.71 (similarity level) on the dendrogram, the cowpea accessions were clustered into nine groups. One group, cluster 2, contained the largest number of varieties, consisting of 27 accessions from different geographical origins: 15 from the centre, 5 from South East, 4 North West and 3 from North East (Table 11). The groups 1, 5, 6, 7 and 8 were mainly or predominantly consisting of varieties from the centre of Benin.

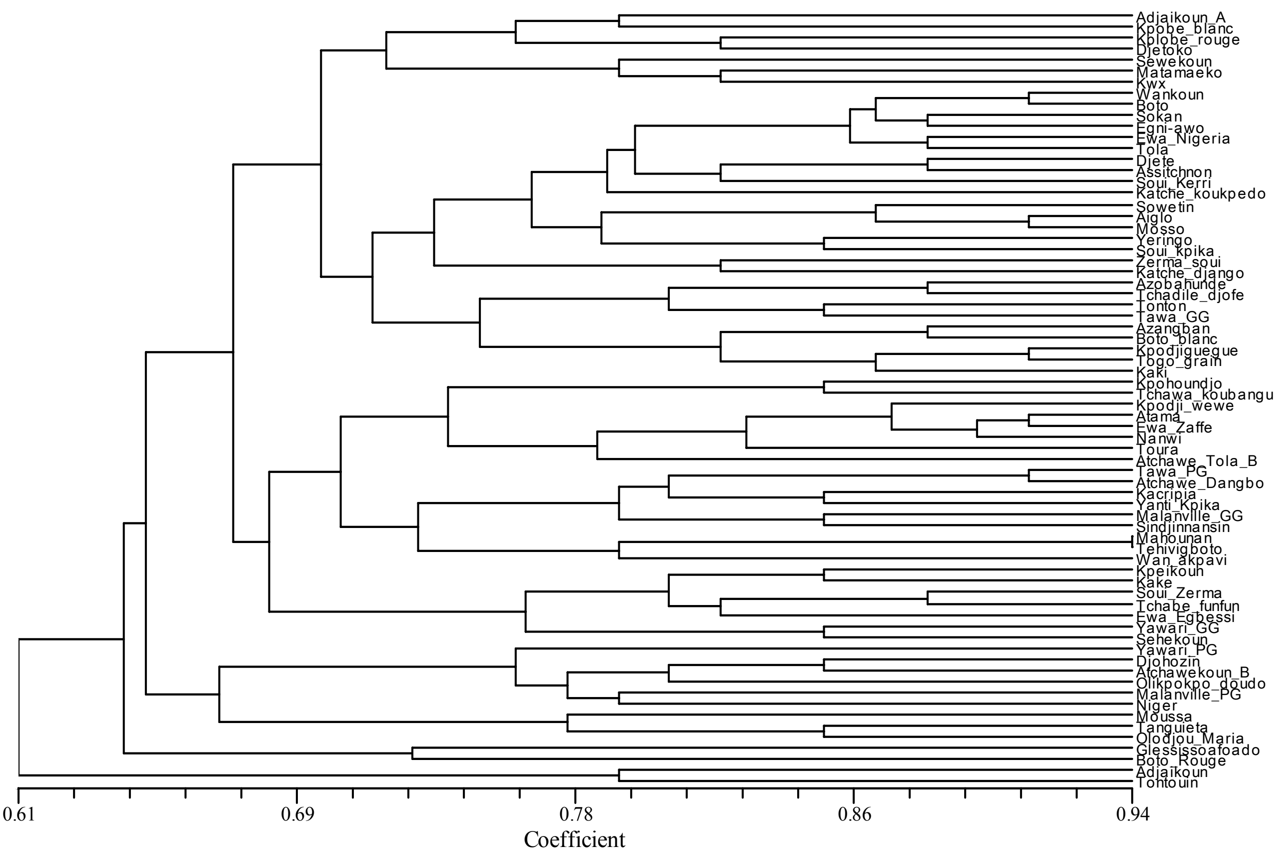

Figure 5. Dendrogram of the cowpea accessions based on coefficient of similarity matrix.

Table 11. Variety groups revealed by RAPD with respect to their origins. C: central, NE: north-east, NW: north-west, SE: south-east.

Cluster	Variety name	Origin	Cluster	Cultivar name	Origin
	Adjaïkoun ancien	C		Kpohoundjo	C
	Sèwékoun	C		Kpodji wewe	C
	Matamaéko	C		Atchawe - Tola (Bohicon)	C
1	Kplobe rouge	C		Atama	C
	Djetoko	C	3	Ewa Zaffe	C
	Kwx	C		Tchawa koubanguè	NW
	Kplobè blanc	C		Toura	NW
	Wankoun	C		Nanwi	SE
	Djèté	C		Malanville gros grain	C
	Mahounan	C		Atchawe_Dangbo	C
	Boto	C		Malanville petit grain	C
	Tonton	C	4	Boto rouge	C
	Tchadilè djofè	C		Kacripia	NW
	Tawa gros grain	C		Yanti Kpika	NW
	Azangban	C		Téhivigboto	SE
	Aïglo	C		Wan akpavi	SE
	Togo grain	C		Sindjinnansin	SE
	Boto blanc	C		Kpeïkoun (Bohicon)	C
	Kaki	C		Kake	C
	Egni-awo	C		Tchabè Funfun	C
	Ewa Nigeria	C	5	Ewa Egbessi	C
	Tola	C		Yawari gros grain	C
	Zerma soui	NE		Sèhèkoun original	C
	Soui Kpika	NE		Soui Zerma	NE
	Soui Kerri	NE		Yawari petit grain	C
2	Yèringo	NW		Tawa petit grain	C
	Katché Django	NW	6	Atchawékoun (Bohicon)	C
	Katché Koukpédon	NW		Niger	C
	Mosso	NW		Djohozin (Adjohozin)	SE
	Azobahundé	SE		Moussa	C
	Assitchénongbinhami	SE	7	Olikpokpo-doudou	C
	Sowétin	SE		Tanguieta	C
	Kpodjiguèguè	SE		Olodjou Maria	C
	Sokan	SE	8	Glessissoafoado	C
				Adjaïkoun	C
			9	Tontouin	SE

Genetic diversity

The 32 amplified DNA fragments frequencies revealed by the four primers are shown in Figure 6. The amplified fragment in size of 850 bp showed the highest frequency and was revealed by three primers (OPA-04, OPC-05, OPD-18), while the fragment size of 1000 bp was revealed in three other primers (OPA-04, OPB-01, OPD-18). Some of the amplified bands were revealed by two primers and some were specific to a particular primer such as 380 bp in OPA-04 and 350 bp in OPC-05. None of the amplified bands were simultaneously revealed by the four primers. The frequencies of the amplified bands 400 bp (OPC-05), 370 bp and 750 bp (OPD-18), and 500 bp (OPB-01) were very low. However, all 11 amplified fragments revealed by the primer OPA-04 were of high frequencies. This result showed that the primer OPW-04 was the best, followed by primers OPC-05 and OPD-18, in assessing the genetic variation in the cowpea accessions analysed. From the analysis of molecular variance (AMOVA) the percentage of genetic variation was 73.73% for among cultivars differentiation and 26.27% for among groups' differentiation (Table 12). The fixation index (F_{ST} = 0.26) is relatively high indicating that there was a large differentiation of cowpea cultivated varieties.

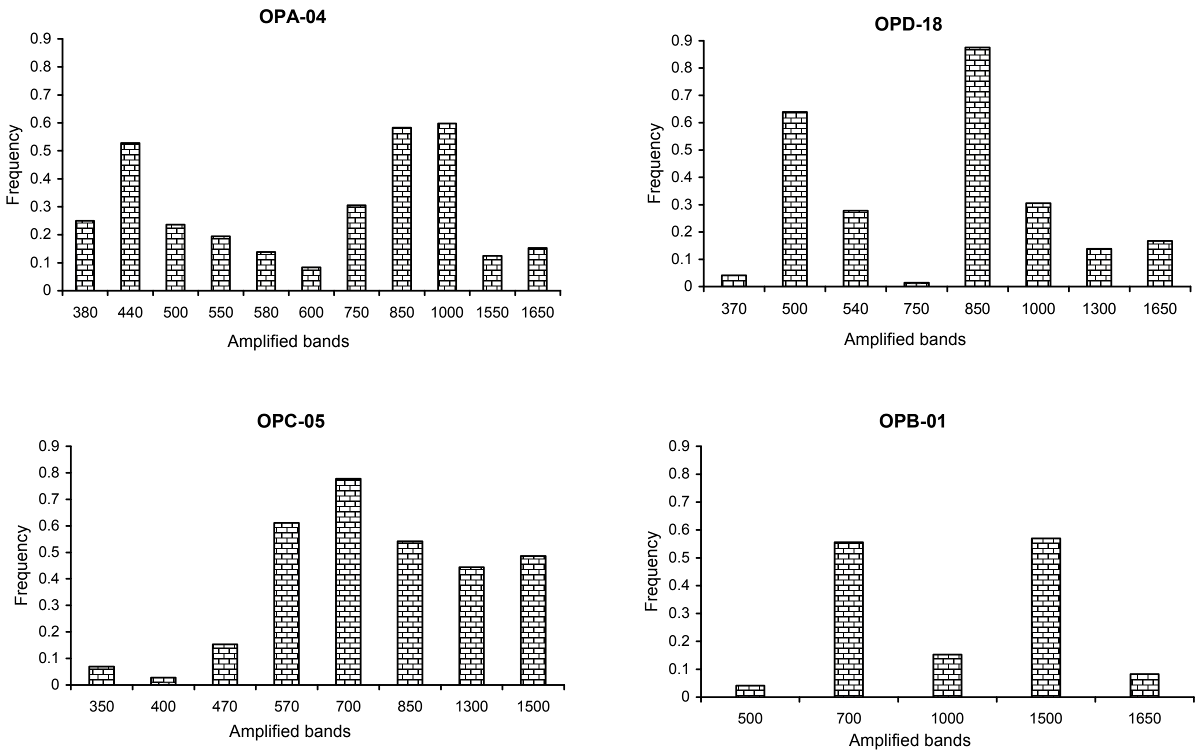

Figure 6. Amplified DNA fragments frequency as revealed by the four primers.

The comparison between the different characterizations using the Mantel matrix comparison test revealed an absence of relationship between the molecular and the agronomic (r=–0.04), and between the molecular and morphological (r=0.06) distances.

Discussion

Morphological and agronomic diversity

The cowpea varieties analysed with farmers were characterized via different, distinctive and diverse morphological and agronomic traits. The varieties varied in leaf, stem, flower, pod, and seed shape and colour, and in growth habit. While the white seed colour has dominant influence in the Guinea-Sudan zone of Benin, the red seed coat colour, and a variegated seed coat colour characterize most of the varieties from the south-east of the country. Recently, the central role of cultural preferences for the colour of some varieties has been analysed (Zannou *et al*., 2006). The white varieties are essential in rituals, and mostly preferred by consumers in the central part of Benin (see Chapter 6), whereas red types constitute the main element of rituals in the south and south-east of the country. Some white varieties have medicinal values in the central part of Benin (Zannou *et al*., 2004) and other less common colours, e.g., black types, are used by local medical practitioners in the southeast. On barley in Ethiopia, Kebebew *et al*. (2001) noted a local belief that the natural white colour increases the appetite of consumers, and black-grained types are mainly preferred for making beer, local distilled spirit, and for medicine.

The Shannon-Weaver index revealed a large morphological diversity within the cultivars, on average, 1.23. This value is greater than the overall mean value (0.77) found for sorghum (Abdi *et al*., 2002), for tef (0.31–1.00) by Kefyalew *et al*. (2000), and for barley (0.51–0.72) by Kebebew *et al*. (2001) in Ethiopia. This study on cowpea shows variation in individual traits between regions. While the white seed coat types dominated the varieties from the north and central parts of the Guinea and Sudan zone of Benin, the red and variegated seed coat colours characterize cowpeas from the south-east of the country. For barley in Ethiopia, Kebebew *et al*. (2001) reveal variation in individual traits between regions. In this study on cowpea, as in studies on other crops such as sorghum and barley, the central role of farmers in selecting varieties with different traits and use values is recognized as a factor in shaping local germplasm, in addition to the play of natural selection.

As apparent from an early study (Zannou *et al*., 2004), and confirmed here by the results of joint-experimentation, yield is an important criterion for farmers. Yield, along with other preferences and quality-related criteria, have been reported in other

Table 12. Analysis of molecular variance.

Source of variation	D.F.	Sum of Squared Deviations	Variance components	Percentage of variation	F-statistics
Among groups	8	113.115	1.452	26.27	F_{ST}=0.2627***
Within groups	61	248.571	4.075	73.73	
Total	69	361.686	5.527		

***Average F-statistics over all loci: F_{ST}=0.2627, highly significant (P<0.0001).

studies as criteria of farmer acceptability when breeding cowpea (Kitch *et al*., 1998). The present study has shown that yield components (number of seeds per pod, number of pods per plant and number of seeds per plant) were highly dependent on the variety, its physiological characteristics and the environmental conditions. In the Guinea and Savannah zones of Ghana, Padi (2004) realized that with increased stress, the experimental coefficient of variation of the yield increased, indicating that under stress there was a decrease in the precision with which grain yields could be assessed for the genotypes. At lower levels of stress, the genotypic variation closely approached the phenotypic variation. It was suggested that knowledge on the key stress factors underlying the genotype by environment interaction can permit delineating homogenous production zones for purpose of recommending specific cowpea varieties. Egli (1998) and Claudia *et al*. (2001) offered similar findings for cereals and oil-seed crops. Egli (1998) reported that the seed number, the main yield component of cereals and oil-seed, was strongly dependent on genotype, environmental and management factors. In soybean, sunflower, and maize, seed number depends on the sequential processes of flower morphogenesis and seed set (Claudia *et al*., 2001).

Photoperiod can have large effects on reproductive development, although some genotypes are insensitive (Ellis *et al*., 1994; Craufurd *et al*., 1997). This involves variation in earliness (i.e., minimum time to flower). The mechanism of timely flowering in a particular location is modulated in cowpea by responsiveness to temperature and photoperiod (Hardley *et al*., 1983; Robert and Summerfield, 1987). Most cowpeas are quantitative short-day plants, wherein flowering is delayed in periods longer than the critical photoperiod, or are plants that are relatively insensitive to photoperiod (day-neutral types) (Hardley *et al*., 1983; Lush and Evans, 1980). The initiation of floral buds and their subsequent development may require different numbers of inductive short days (Lush and Evans, 1980) or have different critical photoperiods. As photoperiods shorten towards the end of the rainy season in West Africa, these adaptive features ensure timely flowering (Wien and Summerfield, 1980). Warmer temperatures can hasten the appearance of flowers in both photosensitive and insensitive genotypes (Summerfield *et al.*, 1985). In our experiments most early-maturing varieties behaved as photo-insensitive cultivars, whereas other varieties considered by farmers as late maturing were more photosensitive (short-day) types, flowering only in October. However, there can be an interaction between photoperiod and temperature in these late-maturing varieties. Wien and Summerfield (1980) revealed that local cowpeas in West Africa are well adapted, so that they can start to flower at the end of the rains at a particular location. The duration of the reproductive period appeared in this analysis also to be a crucial factor, differing between cowpea cultivars. In our field experimental conditions, 60% of the late-maturing varieties yielded 300 to 505 seeds per plant while 11% of the early-maturing varieties yielded 300 to 470 seeds per plant.

The study also revealed that there is a negative association between the 1000-seed weight and the number of seeds per pod, number of seeds per plant and number of pods per plant. Similar results were found for three cultivated and one weedy cowpea by Ilori *et al*. (1996), who report that the 100-seed weight was negatively correlated with the number of pods per plant, number of seeds per plant, and number of ovules per pod in Nigeria.

Molecular characterization

RAPD analysis was performed to evaluate genetic diversity in 70 cowpea accessions collected throughout Benin. All accessions analysed belonged to the cultivar group *unguiculata*. Important genetic diversity was detected in the cowpea germplasm investigated herein confirming the results of Mignouna *et al*. (1998) who identified extensive genetic variability particularly in the cultivar group *unguiculata* compared to the groups *sesquipedalis* and *textilis*. In comparison to our results, the genetic diversity detected by Mignouna *et al*. (1998) was higher probably because of the higher number of accessions (95 compared to 70) and the geographically worldwide origins of their collections. The genetic diversity detected in the cowpea accessions analysed, probably indicated that accessions were originally generated by different ancestors of cowpea.

In this study within the informative markers, the primers OPA-04 and OPD-18 showed 11 and 8 polymorphic bands compared to 10 and 8 polymorphic bands respectively in Mignouna *et al*. (1998). Conversely, the primer OPB-10 which detected 10 polymorphic amplified bands was unable to distinguish accessions we investigated by showing monomorphic pattern. This monomorphic pattern was the same for the five primers which were not selected in this study.

Wright (1978) cited by Hartl (1987) and Kiambi *et al*. (2005) suggested that an F_{ST} range of 0–0.05 indicates little differentiation, 0.05–0.15 moderate, 0.10–0.25 large differentiation, and above 0.25 indicates a very large differentiation. In this study, basing on the AMOVA analysis, the fixation index is 0.26 suggesting a very large differentiation of cultivars in Benin.

At agglomerative coefficient of 0.71, the dendrogram shows nine clustering groups which contain large and small numbers of accessions. The classification of accessions into different groups is independent of collection zones, agro-ecozones and market-places. Accessions of morphologically different characteristics including shape of seeds, seed coat colour, etc., are very close according to the dendrogram constructed based on the presence or absence of amplified DNA fragments of a particular size. The discrepancy between molecular genetic diversity and morphological diversity has been well documented (Doebley, 1989). This result shows that during the process of domestication, modifications in a few genes can lead to marked phenotypic differences. Also as self-pollinated crop, cowpea accessions have tended to maintain some parts of their genetic components during the process of domestication. This can explain the monomorphism pattern shown by some of the primers like those in Figure 1.

Additionally, this study shows the presence of important genetic variability among the Benin cowpea germplasm which can be used to broaden the genetic bases of the crop for better use of its genetic potential. For germplasm management it is important, in addition to morphological characterization, to reveal the extent of genetic diversity present in a collection, using others means such as molecular marker.

Comparison of the different methods of characterization

The comparison between the different characterizations using the Mantel matrix comparison test revealed an absence of relationship between molecular and agronomic, and between molecular and morphological, distances. The RAPD markers showed high polymorphism in the varieties. The differentiation between varieties suggested by the molecular characterization using RAPD markers was higher than the morphological characterization. In a comparative analysis of molecular and morphological methods between perennial ryegrass varieties, Rodán-Ruiz *et al.* (2001) found that there was no correlation between the morphological and the molecular (AFLP-Amplified Fragment Length Polymorphism and STS-Sequence Tag Sites) distances and revealed that the variety relationships appeared inconsistent between the morphology and molecular markers. Fabrizius *et al.* (1998) investigated the relationships of heterosis genetic distance measured by descent, morphology and gliadin polymorphism and found no correlation. Barbosa-Neto *et al.* (1996) found no correlation between RFLP and genetic distance with yield heterosis (correlation ranging from 0.18 to 0.02). No significant correlations were found between genotypic variation for agricultural wheat traits and genetic similarity measured with RFLP, AFLP, and Simple Sequence Repeat (SSR) markers (Bohn *et al*., 1999). On winter triticale cultivars and lines, Gorál *et al.* (2005) investigated the relationships between AFPL-Genetic Similarity and Euclidean distances and mean values of eight traits measured, and found no significant relationships.

However, there are some studies reporting significant correlations, but based on few parameters, mostly the yields. RFLP-based genetic distance was significantly correlated with yield of maize and oilseed rape hybrids (Smith *et al*., 1990; Boppenmaier *et al*., 1993; Bernado, 1994; Diers *et al*., 1996). On a simultaneous agronomic and molecular characterization of genotypes of Cucumber, Bramardia *et al.* (2005) found significant correlations between agronomic and molecular markers.

Overall, we might conclude that the diversity revealed at the molecular level is not necessarily correlated with the variation revealed at morphological and agronomic levels. The molecular markers survey both expressed and silent genes. The morphological and agronomic traits are only a few traits reflected from the molecular background. Several mechanisms, biophysical and physiological, interfere on the expression of different genes as visible traits. This diversity of mechanisms in place in different varieties determines the variation in yield and other preferred traits farmers often obtain. The lack of fit between agronomic and molecular distances indicates not only complexity but degree of under-exploitation of genetic potential through local selection – i.e., there may be considerable scope still for farmer selection, and plant improvement strategies based on buffering and supporting farmer selection capabilities. This study has shown that knowledge concerning these mechanisms helps understanding the choice farmers often make, and provides insights into local plant genetic material used by farmers. More research studies are needed to analyse the different classification systems and their relationships.

CHAPTER 8

Main research findings and conclusions

Introduction

This chapter summarizes the main thesis research findings of a project on co-construction of knowledge and technology development concerning yam and cowpea diversity management in Benin. The thesis focused on yam and cowpea, two important crops in Benin, relatively neglected by formal science. The two crops are ancient in Benin, highly embedded within local agrarian cultures, and highly adapted. There is a lack of knowledge on the importance of the genotype by environment interactions reflecting local specificity and adaptation, which this thesis sought to fulfil. Often scientists assume that they know what the research problem is and miss the fact that most of farming problems are context-specific and culturally rooted. Thus it is important to take into account the socio-cultural characteristics of farmers. Farmers are continuously experimenting and managing those resources and they do so within the constraints of their economic and biophysical environment. Using a technographic approach, we addressed the role of varietal diversity in the farming systems of Benin, and the weaknesses and constraints of varietal innovation processes. The thesis also paid attention to how and why these processes failed to involve and satisfy the needs of farmers and consumers.

The thesis was interested in studying changes in planting materials used for food security crops occurring under farmer management in, order to reinforce local capacity for *on-farm and in-situ* management of genetic resources, and to provide lessons and guidance for crop researchers seeking to align their activities with local concerns. This is a major concern of the Convergence of Sciences approach adopted in this thesis. The core idea of Convergence of Sciences in relation to the management and use of yam and cowpea genetic resources is that working with farmers on the collection, characterization and systematic analysis of yam and cowpea varieties and their performance is to build a client constituency for the products of science and technology. It was thought that it would be especially interesting to develop convergent investigations with a population drawing upon such a legacy. But it was also thought important to take stock of the genetic diversity of these two crops. The loss of genetic diversity for such crops might have especially serious consequences on farmers for so long dependent on working with such diversity.

Research questions

- What are farmers' perceptions of the amount of yam and cowpea varietal diversity they possess? What are their specific preferences and varietal selection criteria?
- What economic, agronomic and technological variables explain demand and supply for yam and cowpea varieties, and the adoption of new types?

Research objectives

- To analyse farmers' perceptions on the concepts of genetic diversity management for yam and cowpea, and how they use diversity to for effective management of household resources;
- To analyse the adoption processes for new varieties of yam and cowpea in each of the selected villages;
- To quantify and characterize the varietal and genetic diversity of yam and cowpea;
- To analyse the effect of socio-cultural, market, and agronomic factors on the diversity of the cultivated varieties.

Working hypotheses

- Level of varietal diversity is related to socio-cultural perceptions and different use values in each farming system.
- Adopted varieties are agronomically and economically more efficient and respond to specific preferences of farmers better than alternatives, thus implying that diversity in the field is the conjoint result of agronomic and taste characteristics of each yam and cowpea variety.
- That market price for yam and cowpea in Benin offers a valuation of specific variety traits for yam and cowpea, and that this is useful evidence regarding the comparative merits of products researchers and farmers provide. Specifically, the study seeks to provide market evidence that the products of non-elite plant selection are not inferior to research products.
- The preference and characterization criteria that determine the choice and the maintenance of a variety in the farming system differ between farmers and scientists.

In addition to the technographic approach to define the research problem, different methodological approaches, including diagnostic study at village level, and joint farmer-researcher managed experimentation, have been combined with socio-cultural, market and consumer studies. Molecular tools have been used to assess the level of genetic diversity in these crops. The main findings are summarized for the chapters in which these results appear.

Main findings of the interactive co-research and technology development

In this thesis, Chapter 3 analysed the main outcomes from the diagnostic study. The purpose of this diagnostic study was to identify key factors that influence the level of diversity maintained by farmers, and from there to build the critical analytical frame for the in-depth research on biodiversity management in yam and cowpea. This study helped select appropriate villages with different characteristics for us to study the various contexts in which farmers' motivations change over time and how farmers proceed to face various constraints. The agronomic performance of cultivated varieties and their suitability to satisfy the household or community needs and the market demands constituted the basis of farmers' preferences. The different names and meanings farmers give to their varieties are indicative of their own varietal characterizations, in turn providing insights additional to yield related criteria mainly used by scientists. Several local yam varieties satisfied local food, religious and economic needs, and met the increasing demand for pounded, fried, peeled and dried yam. Also for cowpea diverse food needs, specific consumers' preferences and social aspects were relevant for the maintenance of diversity. Farmers' variety names point to agronomic characteristics, morphology, and genetics. Some varieties are consciously maintained by farmers through continuous cultivation, while others have been discarded and lost. Farmers' behaviour in the management of yam and cowpea diversity is related to the socio-cultural values, food security requirements over the year and agronomic and economic values associated with each variety. The reasons why some varieties are maintained or discarded, based on farmer socio-cultural preferences, farmers' domestic objectives, market demand, consumers' preferences, and conservation practices needed then to be thoroughly documented. On-farm diversity management requires understanding by the farmer of how specific varieties should be grown, stored and maintained in order to maximally realize the characteristics these farmers value. Therefore, a farmer-driven research agenda is necessary for optimal adaptation of these varieties to their cropping system. The diagnostic phase led to an establishment of local learning groups and setting the research agenda for the in-depth phase of the research programme, identification of topics for joint learning, and creation of mutual confidence with farmers for the experimental phases. This research agenda comprised a participatory varietal characterization of both crops, learning and creating knowledge on how to break the physio-genetic constraints of dormancy for rapid sprouting of planting material, based on a better understanding of the performance of seed tubers from different varieties in relation to the part of the seed tuber used for yam for propagation, and work on how the growth and yield of different cowpeas are constrained by the physical environmental conditions. In sum, the diagnostic study created a common understanding and ground for sharing knowledge on inter-disciplinary issues between researcher and local actors. For both crops, it was necessary to test different varieties through participatory variety characterization, taking into account farmers' planting dates and agricultural practices.

Chapter 4 analysed the socio-cultural factors playing an important role in varietal diversity management. It came out that yam and cowpea remain important components of religious rituals and ceremonies associated with the consolidation of social relations in the Guinea-Sudan zone of Benin. The findings showed a relationship between diversity of yam and cowpea varieties, socio-cultural diversity, and market preferences. Farmers' desire to guarantee food security all year round is an important factor enhancing the diversity of cultivated varieties. Yam varieties preferred for cultural reasons also happen to be of high economic values as reflected in market preferences. However, cultural and economic preferences cannot alone explain all of the diversity found in yam. Farmers in fact also select for varieties that perform well when others preferred for cultural and economic reasons become scarce. The range of yam varieties offered to farmers and consumers a range of food technological and agronomic traits. For cowpea, white-types are preferred in the area of study. Cultivated varieties comprised two agro-physiological types: early-maturing and late-maturing varieties. Together, these varieties offered farmers food security all year round and met various consumer food and technological preferences. The implication of this study for sustainable use and conservation of genetic resources is that farmers bring a variety of motivations to variety choice and management, and that this helps maintain a wider range of material than utilitarian selection alone. The maintenance of crop varieties in farming systems or the adoption of crop varieties by farmers should take into account all the relevant components of technological characteristics, socio-cultural values, market demand, agronomic characteristics, capacity to cope with climatic risks, and capacity to contribute to food security.

Chapter 5 analysed prices for yam and cowpea varieties sold on local markets and their variation over a 5-year period, 2000–2004. Some varieties are highly preferred by both traders and consumers, thus often yielding traders better profits, as they are easily sold (i.e., quickly, without wastage and deterioration). The yam market showed distinctive prices with regard to the types of food technology or meals required (i.e., poundability, ability to make paste or particular dishes). These food requirements demand distinctive traits from each variety sold. Some of the traits most sought after by consumers are taste, plasticity, swelling, scent, and flesh colour. Yam market place decision-making was analysed with regard to the importance of these intrinsic qualitative attributes confers different prices on different varieties. For cowpea consumers the study confirmed strong preferences in most communities from the central part of Benin for white cowpea varieties. A number of other attributes are also considered by consumers: swelling (during cooking), taste, softness, skin and eye colour, cooking time, and scent. Taste, absence of bruchids and swelling are the most highly ranked cowpea attributes for both men and women when considering boiled cowpea. Market research on yam and cowpea highlights and confirms the fact that successful variety improvement in crop research requires good knowledge of local preferences. It comes out from the present study on yam and cowpea diversity that consumer preferences are the driving forces determining the kinds of varieties brought to market. Analyses of market decision-making for yam and cowpea varieties confirm that successful varietal technology development on food crops ought to include reference to consumer preferences, including cultural preferences

Chapter 6 analysed the morphological, agronomic and molecular traits characterizing cultivated yam (*Dioscorea* spp.) varieties in the Guinea-Sudan zone of Benin through co-experimentation with farmers. Among the qualitative morphological characteristics, internal and external morphology of the tuber and the stem and leaf characteristics form groups of distinctive traits that allow farmers and consumers to differentiate between varieties, and guides choice of planting materials and food types. Earliness, post-harvest dormancy, number of days after planting to emergence, and yield are important agronomic and physiological characteristics of yam diversity in Benin. In experimenting under real farmer conditions, this study has shown that the duration of dormancy depends not only on the species but also on the variety, the physical storage conditions and the duration of the storage. Double harvesting practices appear to reflect an agro-physiological principle known and respected by farmers concerning the use of early-maturing varieties to avoid the losses of the planting material. Co-experimentation on different tuber parts revealed a gradient along the tuber in its potential for sprouting. The proximal part of most varieties has a high sprouting potential, while the distal part has the lowest potential. The study shows that the proportion of non-emergent plants was highest and yield lowest when the distal part was used as planting material. However there was some variation among varieties. The results suggest that there could be a complex genetic – physiological property governing the sprouting ability of each fragment of the tuber which future research might address. The results also confirmed that as environmental conditions change from year to year there is variation in yield of the same variety. The genotype by environment interaction was highly determinant of yam performance. This differential response of cultivar for a given trait is an essential component to consider in cultivar development. The molecular analysis showed a high polymorphism in these varieties and that genetic diversity changed along a spatial gradient within the region. This interactive research was well received by farmers. A simple evaluation of impact of co-research using the concepts of human and social capital suggested positive response. The test was somewhat limited, however, being based on only three years of joint experimentation. Farmers showed considerable willingness to add to their already rich knowledge of yam cultivars and cultivation strategies, confirming a possible knowledge deficit on a crop somewhat neglected by the national research system. Farmers quickly formed new expectations concerning systematic development of new yam-oriented technologies which will be helpful in creating demand for research products from formal-sector organizations.

Chapter 7 addressed co-research on morphological, agronomic and molecular characterization of cultivated cowpea (*Vigna unguiculata* (L.) Walp.) varieties. As in the case of yam, the cowpea varieties were mostly collected in the central part of Benin. The varieties evaluated also included some accessions from the south-east of the country. The study showed differences in growth habit, and in colours of leaves, stems, flowers, pods and seeds and in seed shape and texture. There is a high morphological diversity among the varieties, and between regions from which the varieties were collected. The cowpea varieties analysed with farmers were characterized via different, distinctive and diverse morphological and agronomic traits. The varieties varied in leaf, stem, flower, pod, and seed shape and colour, and in growth habit. While the white seed colour is predominant in the Guinea-Sudan zone of Benin, red or variegated seed coat colour characterize most varieties from the south-east of the country. Farmers used the photoperiodic response of the late varieties to distinguish between early-maturing and late-maturing varieties. The present study has shown that yield components (number of seeds per pod, number of pods per plant and number of seeds per plant) were highly dependent on the variety, its physiological characteristics, and the environmental conditions. In a 3-year experiment, the variety by environment interactions, as expressed by variety-specific effects of planting date, season, and year on yield and yield components, were highly significant. The molecular analysis revealed large important genetic variability in these cowpea varieties. Additionally, this study shows the presence of important genetic variability among varieties. This genetic variability can be used to broaden the genetic bases of the crop for better use of its genetic potential.

Research perspectives on variety development

The present study has pointed to a rather large gene pool in Benin for improvement of the locally most important yam types. Evidence that farmers remain active in domesticating wild materials also seems important information for scientists interested in yam improvement. What is not yet clear, and merits further work, is whether the constant domestication of wild materials serves to enrich the genetic base of cultivars more regularly reproduced through clonal methods. Seemingly, wild yam is propagated sexually and thus its constant domestication by farmers may represent a means of tapping an otherwise inaccessible genetic heritage. Future research on yam variety development will need to address at least three main challenges. One concerns socio-technical issues at the local level, the second concerns the biology and genetic research conducted by formal scientists, and the third is to undertake anthropological work that will help link the first and second sets of issues and approaches. At community level, the natural forest reserves of wild yams become more and more reduced from one year to another, and this tends to de-motivate yam domesticators. Bringing this loss, and its social consequences, into open discussion at the community level, while heightening the profile of domestication activity on wild yams as a contribution to sustainable management of food security will add social value to the domestication process, and help create local interest in and awareness of the need to preserve wild types in existing forest reserves. The past 35 years of research on yam hybridization has been rather unproductive, with only a very few varieties showing clear compatibility between wild parents and cultivars or between desirable male and female cultivars of different species. Just as farmers should be encouraged to value their own domestication activities more highly so researchers should be encouraged (and funded) to expand their work on hybridization.

In Benin, several farmer field schools have been developed on using botanical pesticides with mixed results. The number of applications of pesticides remains relatively high. The perspective for research on cowpea should be to develop low-cost or low-input dependent varieties in which modern techniques of quantitative trait loci will play a significant role in targeting genes for multiple pest-disease resistance. In this context, the wild perennial and annual subspecies out-crossers can be potentially useful sources.

Future research needs more focus on more diverse varieties, bringing in other actors – especially those farmers who have spent all their life working with these plant materials. Recent participatory developments in international agricultural research are putting more emphasis on interactions between farmers and scientists; these will be fully effective if scientists shift from segmented mono-disciplinary thinking to embrace different knowledge perspectives, based on balancing research between laboratory, field and market.

Conclusions

At the end of this thesis drawing on the Convergence of Sciences perspective, with its emphasis on integrating social and biological science perspectives, two major conclusions can be drawn. The first conclusion is that both social and natural sciences contribute to the understanding of the diversity of yam and cowpea varieties managed and maintained by farmers. This diversity is expressed at the molecular level and at farm level, but is also highly relevant on the market and in the socio-cultural life of the farmers. The second conclusion is that the pathway of convergent action research and of co-construction of knowledge with farmers is feasible and can contribute useful new technological knowledge. Joint experimentation on varietal characterization and joint participatory technology development showed that more effective research results can be obtained when farmers' perceptions and long experiences are continuously and iteratively incorporated in the research design, while the principle researcher draws on a wider web of socio-economic and biological knowledge to understand and explain the different outputs of co-research within a beta - gamma framework of thinking and analysis. In this regard, technography and diagnosis are continuously and iteratively reviewed allowing the incorporation of new ideas or innovations and new stakeholders in the experimentation process. Results assessment, with validation by farmers, remains an essential phase in the work, and should continue beyond this thesis, to allow farmers and the principal researcher to judge whether the new technologies or ideas they have generated do work under farmers' conditions to improve the livelihoods of the poor. Work on yam and cowpea varietal management confirms that the Convergence of Sciences approach is both inter-disciplinary and trans-disciplinary in its scope.

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Summary

Yam and cowpea are basic food crops for the population in Benin. There is a strong interest among farmers and consumers, and at the national research system level, in promoting the maintenance of the genetic diversity of these crops. Using a technographic approach, we addressed the role of varietal diversity in the farming systems of Benin, and the weaknesses and constraints of varietal innovation processes. We also paid attention to how and why these processes failed to involve and satisfy the needs of farmers and consumers. The main aim of this thesis is a better understanding by potential clients and suppliers of technology of what science could deliver to poor farmers. An integration of the elite crop science that has dominated the world until now and the neglected indigenous knowledge is necessary and advocated. The purpose of this integration is to contribute to better crop improvement, better use of innovations, a better awareness of crop characteristics insufficiently valued by scientists and to build a client constituency for the products of science and technology. Methodologically, this thesis aims at generating a new form of participative research integrating social and biological sciences and involving farmers, consumers and researchers in a sustainable use of genetic resources of yam and cowpea in Benin.

Taking into account the multidimensional character of the problems related to management of genetic resources of yam and cowpea by farmers or by scientists as revealed, the need to develop a trans-disciplinary and convergent action research is crucial. The research process has gone through four main phases: technographic studies, diagnostic study, the experimental phase in combination with socio-cultural and market studies, and the evaluation and validation phase.

Based on the diagnostic study, four villages (Yagbo and Kpakpaza for yam and Dani and Diho for cowpea) have been selected to analyse in-depth farmers' practices in yam and cowpea diversity management in the study area. Within these villages, Yagbo was the experimental village for yam and Dani the one for cowpea.

It comes out from the in-depth studies in these villages that yam and cowpea varieties are essential for the ritual ceremonies to divinities of the local communities. The diversity of rituals, food habits, technological traits and food security strategies for the two crops contributes to the maintenance of varietal diversity. Different varieties satisfy different socio-cultural and food security needs. Also, to satisfy actively their income needs, farmers try to meet market demands for different varieties.

Although there was a large diversity, an analysis of the relative frequency or occurrence of varieties showed that some of them were rare, and others were on the way to being abandoned or were already lost. Also, while some were grown on large

scale, others were on small plots. Socio-cultural as well as economic and agronomic characteristics explained why some varieties were still maintained. Farmers' preferences were based on a range of criteria.

The diversity of the varieties sold on the market and their availability over time reflect farmers' strategies and conservation practices. The large price differences between varieties matched variations in quality as perceived by consumers. Market price differences among cowpea varieties were much smaller than those for yam varieties.

Marketing decision making with regard to qualitative attributes revealed that the main quality criteria for poundable yam varieties were: plasticity, absence of knobs, taste, and swelling (ability to increase volume while being pounded). The quality of the paste depended on the quality of the dried chips (commonly called '*cossettes*'). The quality criteria of dried chips used to differentiate varieties included duration of storage, blackening during drying, presence of fibres inside the tuber, swelling and taste of the paste, and the taste of the '*wassa-wassa*', a kind of couscous made from yam.

Cowpea traders also had a strong preference for more profitable varieties. The quality criteria cowpea traders rely upon while negotiating price were purity of the variety, the grain colour, the grain size, the grain shape and beauty, absence of bruchids, and the quality of the product after storage. For cowpea consumers (both men and women) the study confirmed high preferences in most communities in central Benin for white cowpea varieties. These preferences were found both for men and women. While red cowpea seeds were somehow accepted by some consumers, most remained reluctant to buy the black one. A number of attributes are considered by consumers: the swelling, the absence of bruchids revealing that the grains were stored in good conditions or that the variety is resistant to bruchids, or the number of grains holed if attacked by storage bruchids, the taste, the softness, skin and eye colour, the cooking time, and the scent.. Taste, absence of bruchids and swelling were the main cowpea attributes highly ranked by men and women for boiled cowpea. These results show that consumers are very sensitive to the presence of bruchids in cowpea.

The participatory varietal characterization of cultivated farmer-varieties in experimental villages was based on yam varieties collected mostly from the Guinea-Sudan transition zone of Benin. These varieties were mainly from *D. cayenensis / D. rotundata* (Guinea yam) and *Dioscorea alata* (water yam). Experimentation took into account farmer knowledge and agricultural practices. The study showed that these varieties differ in tuber, stem and leaves traits, and in yield. In total, there is a large morphological variation and agronomic variation for yield potential among these yam varieties. An in-depth analysis of the yield variation suggested a high variety by environment interaction. The molecular analysis realized using random amplified polymorphic DNA (RAPD) revealed a high polymorphism in these varieties. The genetic diversity changed along a spatial gradient within the region.

Experimentation on how to break seed tuber dormancy and advance the sprouting using different storage methods and at different periods of storage revealed a diversity of agro-physiological properties in these yam varieties. The results tend to confirm farmer's genotype-specific handling of seed tubers. For management of seed tuber dormancy, these results led to the conclusion that farmers manage yam seed tubers of different varieties (with their differences in post-harvest dormancy) by planting them in the dry season in order to induce a rapid breaking of dormancy.

The experimentation on different tuber parts (proximal, medial, distal) showed significant differences in number of plants emerged, time of emergence, and in yield.

As for yam, different varieties of cowpea [*Vigna unguiculata* (L.) Walp.] were collected from farmers for participatory characterization. The study showed differences in growth habit, and in colours of the leaves, stems, flowers, pods and seeds and in seed shape and texture. This characterization revealed a high morphological diversity among the varieties, and also showed a variation in regions in which varieties were collected. Farmers used the photoperiodic response of the late varieties to distinguish between early-maturing and late-maturing varieties. In a 3-year experiment, the variety by environment interactions, as expressed by variety-specific effects of planting date, season, and year on yield and yield components, were highly significant**.** The molecular analysis using Random Amplified Polymorphic DNA (RAPD) markers revealed high polymorphism in these cowpea varieties.

Farmers' own experimentation on yam domestication was analysed. Farmer knowledge on the wild material, their practices in domesticating this material, the dynamic process of evaluating the material and the results of the evaluation process were assessed. With a thorough process of domestication a new variety can be developed in three years. Farmers evaluated new material based on yield, taste, suitability for food, size, colour, shape, and length of the tubers, as well as the presence of spines and bristles on the tubers. Farmers' innovations in domesticating increased the genetic diversity of yam.

At the end of this study two major conclusions are drawn. The first is that both social and natural sciences contribute to the understanding of the diversity of yam and cowpea varieties managed and maintained by farmers. This diversity is expressed at the molecular level and at farm level, but is also highly relevant on the market and in the socio-cultural life of the farmers. The second conclusion is that this study on yam and cowpea diversity management in Benin has taken a pathway of a convergent action research and of co-construction of knowledge with farmers. Joint experimentation of varietal characterization and joint participatory technology development showed that more effective research results can be obtained when farmers' perceptions and long experiences are incorporated in research design, while also the principle researcher used his web of socio-economic and biological knowledge to understand and explain different outputs of research within a beta - gamma framework of thinking and analysis. At this regard, technography and the diagnosis are continuously and iteratively reviewed to allow the incorporation of new ideas or innovations and new stakeholders in the experimentation process. The results assessment with, and validation by, farmers remains an essential aspect, allowing farmers and researcher to judge new technologies or new ideas under farmers' conditions. These two characteristics of the Convergence of Sciences approach applied to yam and cowpea varietal management mark this approach as both inter-disciplinary and trans-disciplinary.

Résumé

Les ignames et le niébé sont deux des principales cultures vivrières de base pour les populations au Bénin. La gestion de la diversité de ces deux cultures présente un intérêt non seulement pour les paysans et les consommateurs mais aussi pour les politiques agricoles nationales de recherche et de sauvegarde de la sécurité alimentaire. En se basant sur l'approche technographique dans cette thèse, le rôle de la diversité variétale dans les systèmes de production paysans a été analysé ainsi que les faiblesses et les contraintes au niveau des processus d'innovation variétale. Une attention particulière a été portée sur comment et pourquoi ces processus ont manqué d'impliquer ou de prendre en compte les besoins des paysans et des consommateurs. Le but visé par cette thèse est une meilleure compréhension par les acteurs du marché de l'offre et de la demande de nouvelles technologies agricoles de ce que la science peut livrer aux petits ou pauvres paysans. Aussi, une intégration du savoir formel classique qui a dominé le monde jusqu'à nos jours au savoir local endogène est nécessaire. Cette intégration a pour objectif d'une part, de contribuer à une meilleure amélioration et utilisation des innovations, une meilleure connaissance sur les caractéristiques des variétés des cultures insuffisamment valorisées par les scientifiques et d'autre part, de construire un corps d'utilisateurs potentiels pour les produits de la science et de la technologie.

Sur le plan méthodologique, cette thèse vise à générer une nouvelle forme de recherche participative intégrant les sciences biologiques aux sciences sociales et impliquant à la fois les paysans, les consommateurs et les chercheurs pour une utilisation durable des ressources génétiques des ignames et du niébé au Bénin. En prenant en compte le caractère multidimensionnel des problèmes liés à la gestion des ressources génétiques d'ignames et du niébé soulignés par les paysans ou par les scientifiques, le besoin de développer une recherche action trans-disciplinaire est devenu crucial. Cette recherche action trans-disciplinaire s'est déroulée en quatre principales phases:

1. la première phase est celle d'études technographiques pour l'identification des problèmes de recherche, des besoins en innovations, et des principaux acteurs sur le plan national;
2. la deuxième phase relative aux études diagnostiques a visé l'ancrage des innovations dans le contexte spécifique des acteurs locaux, l'identification des sites de recherche, des facteurs impliqués dans l'analyse ou la résolution du problème, et des besoins de la phase expérimentale;
3. la troisième phase est celle de recherche action inter- et trans-disciplinaire. C'est la

phase d'expérimentation avec les paysans, d'études socioculturelles, économiques et de diversité génétique. C'est une phase de recherche expérimentale qui intègre les études sur les facteurs socioculturels et les préférences des commerçants et des consommateurs qui sont les utilisateurs finaux de toutes les technologies variétales;

4. la quatrième phase est celle d'évaluation et de validation des résultats avec les paysans et d'autres chercheurs. A cette phase est associée l'étude d'impact de la recherche sur la population cible ou les paysans co-auteurs de la recherche.

Les études diagnostiques ont permis de sélectionner quatre villages plus ou moins contrastés par rapport à certaines caractéristiques socio-culturelles, de colonisation ou de pression sur la terre, de proximité par rapport aux marchés ou centres urbains, et de niveau d'intervention institutionnelle: Yagbo et Kpakpaza pour les ignames dans la commune de Glazoué ; Dani et Diho pour le niébé dans la commune de Savè. Yagbo est à dominance Mahi alors que les Idatcha prédominent à Kpakpaza. Dani est à forte majorité Idatcha pendant que Diho est essentiellement peuplé de Tchabè. La colonisation des terres est plus récente à Yagbo et à Dani que dans les deux autres villages. Le niveau d'intervention institutionnelle sur les ignames est plus élevé à Kpakpaza qu'à Yagbo, et plus élevé sur le niébé à Dani qu'à Diho. Parmi ces villages, Yagbo et Dani ont été retenus pour la co-expérimentation paysan-chercheur respectivement pour les ignames et le niébé.

Il ressort des études approfondies dans ces villages que les variétés d'ignames et du niébé jouent un rôle essentiel dans les cérémonies rituelles aux divinités et aux jumeaux de ces communautés locales. En somme, la diversité des rites socioculturels, des habitudes alimentaires, des traits de technologie alimentaire, et des stratégies de sécurité alimentaire contribue au maintien de la diversité variétale pour ces deux cultures. Différentes variétés satisfont à différents besoins socioculturels et de sécurité alimentaire. Aussi pour s'assurer des revenus substantiels, les paysans essaient de répondre à la demande du marché en différentes variétés.

Bien qu'il y ait une large diversité, l'analyse de la fréquence relative des variétés montre que certaines sont rares, et d'autres en voie d'être abandonnées ou déjà perdues de ces villages. Pendant que certaines variétés sont cultivées sur une grande échelle de superficie, d'autres le sont sur de petites portions de terre. Aussi bien les caractéristiques socioculturelles que économiques et agronomiques expliquent pourquoi certaines variétés sont toujours maintenues. En l'occurrence sur les ignames, les innovations personnelles des paysans en matière de création variétale par la domestication accroissent cette diversité. Les préférences des paysans se fondent sur une série de critères amplement analysés dans cette thèse.

La diversité des variétés vendues sur le marché et leur disponibilité dans le temps reflètent les stratégies et pratiques paysannes de gestion de la diversité variétale. Les larges différences de prix entre variétés correspondent aux variations en qualités perçues par les consommateurs. Pour les deux cultures, les différences de prix entre variétés ont été beaucoup plus petites pour le niébé que pour les ignames.

Sur le marché des ignames, les préférences des commerçants sont surtout orientées vers les variétés les plus rentables, en l'occurrence celles dont la demande du marché est plus forte. Les prises de décision du marché au regard des traits qualitatifs des variétés destinées à servir d'igname pilée montrent que les principaux critères de qualité considérés par les consommateurs sont la plasticité, le goût, l'absence de grumeaux, le gonflement au cours du pilage. La qualité d'une pâte d'igname dépend de la qualité des cossettes dont elle est issue. Les critères utilisés pour différencier des variétés conférant différentes qualités de la pâte incluent la durée de stockage, le brunissement au séchage, la présence des fibres à l'intérieur du tubercule, le gonflement et le goût de la pâte.

Sur le marché du niébé, les commerçants du niébé ont aussi une forte préférence pour les variétés qui paraissent plus rentables. Les critères de fixation des prix par les commerçants reposent non seulement sur la pureté du grain, la couleur du grain, la grosseur, la forme, mais également l'absence des insectes de stockage (bruches) et la qualité du produit après stockage. Les consommateurs du niébé, hommes comme femmes, confirment la forte préférence des communautés locales d'étude de la région centre du Bénin en variétés blanches de niébé. Pendant que les variétés rouges sont acceptées quelque peu par certains consommateurs, la plupart des consommateurs déprécient les variétés noires. Un certain nombre d'attributs sont considérés par les consommateurs tels que le gonflement, l'absence de bruches (indicatrice de la résistance de la variété aux insectes de stockage), le nombre de grains troués si les grains ont été attaqués, le goût, le degré de ramollissement, la couleur de peau des grains et de l'œil, l'odeur et le temps de cuisson. Le goût, l'absence de bruches et le gonflement ont été des critères de premier ordre classés à la fois par les hommes et les femmes.

La caractérisation participative des variétés d'ignames s'est basée sur les accessions collectées dans la zone de transition guinéo-soudanienne du Bénin. Ces variétés sont pour la plupart du complexe d'espèces *Dioscorea cayenensis / Dioscorea rotundata* (localement appelées *Tévi* en Mahi/Fon ou *Itchou* en Idatcha) et de l'espèce *Dioscorea alata (*localement appelée *Alougan* en Mahi/Fon ou *Aga* en Idatcha). Cette co-expérimentation paysan-chercheur a pris en compte le savoir paysan et les pratiques agricoles locales. L'étude a montré que ces variétés diffèrent par rapport aux caractéristiques des tubercules, des tiges, des feuilles, et des rendements. Au total, il y a une large variation morphologique et agronomique entre ces variétés. Une étude plus approfondie de la variation en rendement a mis en évidence une interaction Variété × Environnement très élevée.

L'analyse moléculaire basée sur l'utilisation de la technique d'amplification polymorphique aléatoire de l'ADN (RAPD) a révélé un niveau élevé de polymorphisme chez les variétés. Aussi, la diversité génétique suggère une certaine variabilité suivant un gradient spatial nord-sud.

La co-expérimentation sur la rupture de la dormance des semenceaux d'ignames pour accélérer et améliorer la germination en utilisant différentes méthodes de stockage suivant différentes durées a montré une diversité de propriétés agro physiologiques en ces ignames. Les résultats confirment la technique paysanne de gestion des spécificités des semenceaux d'ignames. Pour la gestion de la dormance, les résultats conduisent à la conclusion selon laquelle les paysans gèrent les semenceaux de différentes variétés d'ignames en les plantant en saison sèche pour pourvoir induire un rapide raccourcissement de la durée de la dormance des semenceaux.

L'expérimentation sur différentes sections (proximale, médiane et distale) des tubercules semenceaux a montré une différence significative en termes de nombre de plants ayant émergé, de durées pour l'émergence, et de rendement. Les semenceaux de tubercules entiers ont montré une émergence totale. En dehors du gradient de potentialité de germination et de perte de semenceaux le long du tubercule pour la plupart des variétés, certaines variétés révèlent des spécificités d'une forte potentialité de germination quoiqu'en soit la partie du tubercule utilisée comme semenceau, partie proximale, médiane ou distale.

Comme chez les ignames, différentes variétés de niébé [*Vigna unguiculata* (L.) Walp.] ont été collectées chez les paysans et soumises à une caractérisation participative. Cette co-expérimentation a montré des différences en type de croissance, en couleur des feuilles, des tiges, des fleurs, des gousses et des graines, en forme et texture de ces graines. Cette caractérisation révèle une grande diversité morphologique entre les variétés et aussi une variabilité entre régions d'où elles ont été collectées. Les paysans utilisent le caractère photopériodique de certaines variétés pour différencier les variétés précoces des variétés tardives ; les variétés tardives se distinguant le plus souvent par rapport à leur caractère photopériodique. Au cours de trois années d'expérimentation, l'expression des effets d'interactions Variété × Environnement s'est révélée très significative en termes de rendement et composantes de rendement par rapport aux dates de semis, à la saison, et à l'année.

L'analyse moléculaire basée sur l'utilisation de la technique d'amplification polymorphique aléatoire de l'ADN (RAPD) a montré, comme chez les ignames, un niveau élevé de polymorphisme chez ces variétés de niébé. La co-expérimentation sur la caractérisation variétale et le développement participatif de technologie ont montré que plus de résultats de recherche concluants peuvent être obtenus lorsque les perceptions et longues expériences des paysans sont incorporées dans les idées de mise en œuvre des protocoles de recherche.

En conclusion générale, il ressort de cette étude deux grands enseignements. Le premier enseignement est que les sciences sociales et les sciences biologiques contribuent à la fois à une meilleure compréhension de la diversité des variétés d'ignames et du niébé gérées et maintenues par les paysans au Bénin. L'expression de cette diversité s'est révélée très significative en terme de *gènes* à l'échelle de l'ADN moléculaire, en terme de *variétés* ou *cultivars* ou de leur performance à l'échelle de l'exploitation agricole des paysans, en terme d'utilité sociale et économique non seulement pour le paysan producteur mais surtout pour les communautés locales et pour les consommateurs à travers le canal du marché.

Le deuxième enseignement est que cette étude sur la gestion de la diversité des ignames et du niébé au Bénin a été conduite dans la voie d'une recherche action trans-disciplinaire et d'une co-construction du savoir scientifique avec les paysans. Dans ce processus interactif et itératif chercheur - paysan et savoir formel - savoir endogène de mise en œuvre et d'exécution des protocoles de recherche, le rôle du chercheur principal est d'utiliser ses connaissances socio-économiques et biologiques pour expliquer et valider les résultats de recherche avec les paysans. A cet effet, les études technographiques et diagnostiques sont revues de manière continue pour l'incorporation de nouvelles idées, innovations ou de nouveaux acteurs dans le processus d'expérimentation. L'évaluation et la validation des résultats avec et par les paysans demeurent un aspect essentiel permettant aux paysans et au chercheur de juger l'adaptabilité des nouvelles technologies aux conditions paysannes. Ces deux caractéristiques de l'approche Convergence des Sciences appliquées à la gestion de la diversité des variétés d'ignames et de niébé la déterminent comme une approche à la fois inter et trans-disciplinaire.

Samenvatting

Yam en koeienboon zijn belangrijke voedselgewassen voor de Beninese bevolking. Onder boeren en consumenten, maar ook bij het nationale onderzoek, bestaat er veel interesse in het bevorderen van het behoud van de genetische bronnen van deze gewassen. Met behulp van een technografische benadering werd de rol van diversiteit in rassen in de bedrijfsystemen in Benin onderzocht. Daarbij werd aandacht besteed aan de zwakten en beperkingen van de processen die moeten leiden tot rasvernieuwing. Tevens werd onderzocht hoe en waarom dergelijke processen niet in staat bleken rekening te houden met de behoeften van boeren en consumenten, laat staan daarin te voorzien. Het belangrijkste doel van dit proefschrift is bij mogelijke klanten en verstrekkers van technologie een beter begrip te kweken voor wat de wetenschap voor de arme boeren kan betekenen. Een integratie van de topwetenschap op het gebied van de gewaskunde die de wereld tot nu toe heeft gedomineerd en de (verwaarloosde) inheemse kennis is noodzakelijk. In dit proefschrift wordt daar ook nadrukkelijk voor gepleit. Het doel van een dergelijke integratie is bij te dragen aan een beter toegesneden gewasverbetering, een betere benutting van innovaties, en een beter bewustzijn van die gewaseigenschappen die door wetenschappers onvoldoende gewaardeerd worden. Daarnaast dient deze integratie bij te dragen aan het opbouwen van een gezamenlijke clientèle voor de producten van wetenschap en technologie. Het proefschrift heeft ook een methodologische doelstelling: het beoogt een nieuwe vorm van participatief onderzoek te genereren waarin de sociale en biologische wetenschappen worden geïntegreerd en waarbij boeren, consumenten en onderzoekers gezamenlijk betrokken zijn bij een duurzaam gebruik van de genetische bronnen van yam en koeienboon in Benin.

Het multidisciplinaire karakter van de vermelde problemen, die een rol spelen bij het beheer van de genetische bronnen van yam en koeienboon door boeren of onderzoekers, betekent dat het bijzonder noodzakelijk is om transdisciplinair en convergerend actieonderzoek te verrichten. Het onderzoeksproces omvatte vier fasen: technografische studies, een diagnostische studie, de experimenteerfase (waarin ook sociaal-culturele studies en marktstudies werden verricht) en als laatste de evaluatie- en validatie-fase.

Op grond van de diagnostische studie werden vier dorpen (Yagbo en Kpakpaza voor yam, en Dani en Diho voor koeienboon) geselecteerd om diepgaand te onderzoeken hoe in deze onderzoeksregio de diversiteit van yam en koeienboon wordt beheerd. Yagbo was het dorp waarin de experimentele fase met yam plaatsvond en Dani was dat voor de koeienboon.

Uit het diepgaand onderzoek in deze twee dorpen kwam naar voren dat bepaalde rassen van yam en koeienboon belangrijk waren voor de ceremonies die voor de godheden van de lokale gemeenschappen werden gehouden. Voor beide gewassen gold dat de diversiteit van rituelen, voedingsgewoonten en technologische eigenschappen, alsmede de gehanteerde strategieën om voedselzekerheid te verkrijgen, alle bijdroegen aan het instandhouden van de rassendiversiteit. Verschillende rassen voorzien in verschillende sociaal-culturele behoeften en in voedselbehoefte. Bovendien, om aan hun behoefte geld te verdienen te voldoen, proberen de boeren ook nog eens aan de markteisen voor de verschillende rassen te voldoen.

Hoewel er een grote diversiteit werd aangetroffen toonde een analyse van de relatieve frequentie van het voorkomen van de verschillende rassen aan dat sommige zeldzaam waren en dat andere op het punt stonden om niet langer geteeld te worden. Er zijn zelfs al rassen geheel verloren gegaan. Sommige rassen worden op grote schaal geteeld, andere worden slechts op kleine veldjes geteeld. De redenen waarom bepaalde rassen nog steeds geteeld worden moeten gezocht worden in het social-culturele, het economische of het agronomische domein. Zoveel werd wel duidelijk dat de voorkeuren van de boeren waren gebaseerd op een veelheid van criteria.

De diversiteit van rassen die op de markt werden verkocht en hun beschikbaarheid in de tijd weerspiegelden de verschillende strategieën en bewaarpraktijken van de boeren. De grote verschillen in prijs tussen de rassen kwamen overeen met de verschillen in kwaliteit zoals die door de consumenten werden ervaren. De prijsverschillen op de markt waren voor de koeienboonrassen veel kleiner dan voor de yamrassen.

Op grond van de wijze waarop op de markt tot een beslissing werd gekomen ten aanzien van de aanschaf van bepaalde rassen op basis van hun kwaliteitseigenschappen kon worden vastgesteld dat de volgende kwaliteitscriteria belangrijk waren voor yamrassen die gestampt worden: plasticiteit, afwezigheid van knobbels, smaak, en zwelvermogen (dat is het vermogen om toe te nemen in volume tijdens het stampen). De kwaliteit van het deeg hing af van de kwaliteit van de gedroogde schijfjes (algemeen ‘cossettes’ genoemd). De criteria voor de gedroogde schijfjes, gebruikt om de rassen te onderscheiden, omvatten onder meer de duur van de bewaring, het zwart worden tijdens het drogen, de aanwezigheid van vezels in de knol, het zwelvermogen en de smaak van het deeg, en de smaak van de ‘wassa-wassa’, een soort Afrikaanse couscous, gemaakt van yam.

De handelaren in koeienbonen hadden een duidelijke voorkeur voor de rassen waarop ze veel winst konden maken. De kwaliteitscriteria waarop de handelaren in koeienbonen vertrouwden bij het onderhandelen over de prijs waren de zuiverheid van het ras, de kleur van de bonen, de boongrootte, de vorm en pracht van de bonen, de afwezigheid van de zaadkever en de kwaliteit van het product na bewaring. De studie toonde aan dat consumenten van de koeienboon (zowel mannen als vrouwen) in de meeste gemeenschappen van Centraal Benin een duidelijke voorkeur hadden voor rassen met witte bonen. Sommige consumenten accepteerden tot op zekere hoogte ook nog wel de rode bonen maar de meeste consumenten wilden niet aan zwarte bonen. Consumenten nemen verschillende eigenschappen in beschouwing: het zwellen, de afwezigheid van zaadkevers (samenhangend met een goede opslag van de bonen dan wel aangevend dat het ras resistent tegen de zaadkever is) dan wel het aantal gaatjes als de bonen wel tijdens de opslag door de zaadkevers was aangetast, de smaak, de zachtheid, de kleur van de zaadhuid en van het oog, de kooktijd en de geur. Voor gekookte koeienbonen werden de eigenschappen smaak, afwezigheid van zaad-kevertjes en zwellen van koeienbonen door zowel mannen als vrouwen hoog aangeslagen. De resultaten lieten duidelijk zien dat de consumenten erg gevoelig zijn voor de aanwezigheid van zaadkevers bij de koeienboon.

De participatieve karakterisering van de rassen, die door boeren werden verbouwd, zoals die plaatsvond in de dorpen waar experimenteel werk werd uitgevoerd, was gebaseerd op de yamrassen die meestal bijeenvergaard waren in de ‘Guinee-Sudan overgangszone’ van Benin. Deze rassen waren meestal van het soortencomplex *Dioscorea cayenensis* / *Dioscorea rotundata* (Guinese yam) of van de soort *Dioscorea alata* (wateryam). Bij het experimenteren werd rekening gehouden met de kennis en de landbouwpraktijken van de boeren. De studie liet zien dat deze rassen verschillen in eigenschappen van de knol, de stengel en de bladeren. Bovendien verschillen ze in opbrengst. Over het geheel genomen is er tussen deze yamrassen een grote morfologische en agronomische variatie (ook ten aanzien van opbrengstpotentie) aanwezig. En diepgaande analyse van de variatie in opbrengst deed vermoeden dat er sprake is van een grote ras × milieu interactie. De moleculaire analyse liet zien dat er in deze rassen sprake is van een sterke mate van polymorfisme. De genetische diversiteit veranderde langs een ruimtelijke gradiënt in de regio.

Er werd tevens onderzoek gedaan naar de vraag hoe de kiemrust van het pootgoed kon worden gebroken en hoe het spruiten kon worden vervroegd in deze yamrassen met behulp van verschillende bewaarmethoden en voor verschillende lengten van de bewaarperiode. De resultaten van de proeven lieten zien dat er een grote diversiteit in agro-fysiologische eigenschappen bestaat tussen deze rassen. De resultaten leken te bevestigen wat de boeren al in de praktijk hanteerden: er zijn rasspecifieke bewaar- en behandelingsrecepten nodig voor pootgoed. Ten aanzien van de kiemrust van het pootgoed bleek dat de boeren hun pootgoed van verschillende yamrassen (met hun verschillen in kiemrust na de oogst) probeerden te beïnvloeden door het pootgoed in het droge seizoen te poten en het pootgoed zo tot een snelle kiemrustbreking te brengen.

De proeven waarin het effect werd nagegaan van het poten van verschillende knoldelen (te weten het proximale stuk, het middenstuk of het distale stuk) gaven significante verschillen te zien tussen de knoldelen. Deze verschillen manifesteerden zich in het aantal opgekomen planten, het moment van opkomst en de opbrengst.

Net als voor yam, werden er ook verschillende rassen verzameld van de koeienboon [*Vigna unguiculata* (L.) Walp.], ook wel ogenboon genoemd. Met deze rassen werd ook een participatieve karakterisering uitgevoerd. De studie liet verschillen zien in groeiwijze en in kleuren van de bladeren, de stengels, de bloemen, de peulen en de bonen. Ook werden er verschillen waargenomen in de vorm en de textuur van de bonen. Deze karakterisering liet zien dat er sprake was van een grote diversiteit in morfologie tussen de rassen. Deels was dit terug te voeren op het gebied waar de koeienboon werd verzameld. De boeren gebruikten de daglengtereactie van de late rassen om onderscheid te maken tussen vroege en late rassen. In een driejarige proef bleken de ras maal milieu-interacties (uitgedrukt in rasspecifieke effecten van plantdatum, seizoen, en jaar op opbrengst en opbrengstcomponenten) zeer significant. De moleculaire analyse met behulp van Random Amplified Polymorphic DNA (RAPD) merkers liet zien dat er een sterke mate van polymorfisme in deze koeienboonrassen werd aangetroffen.

Ook het experimenteren van boeren zelf werd geanalyseerd. Het ging hierbij om hun activiteiten bij de domesticatie van yam. Vastgesteld werd wat de boeren wisten over het wilde materiaal, welke praktijken ze gebruikten bij het domesticeren van het materiaal en het dynamische proces van het evalueren van het materiaal en de resultaten van dit evaluatieproces. Als het proces van domesticatie grondig wordt doorlopen dan kan er in drie jaar een nieuw ras worden ontwikkeld. Boeren evalueren het nieuwe materiaal op basis van opbrengst, smaak, geschiktheid voor voedsel, omvang, kleur, vorm, en lengte van de knollen, en tevens op afwezigheid van stekels en haren op de knollen. Door de innovaties van de boeren bij het domesticeren van de yam nam de genetische diversiteit in yam toe.

Aan het eind van dit proefschrift worden twee belangrijke conclusies getrokken. De eerste conclusie is dat zowel de sociale als de natuurwetenschappen bijdragen aan het begrijpen van de diversiteit in rassen van yam en koeienboon zoals die door de boeren wordt beheerd en in stand gehouden. Deze diversiteit komt tot uitdrukking op het moleculaire niveau en op het bedrijfsniveau, maar is ook zeer relevant op de markt en in het sociaal-cultureel leven van de boeren. De tweede conclusie is dat deze studie betreffende het beheer van de diversiteit van yam en koeienboon in Benin een route heeft gevolgd langs die van convergerend actieonderzoek en co-constructie van kennis met boeren. Het gezamenlijk experimenteren rond het karakteriseren van de rassen en de gezamenlijke en participatieve ontwikkeling van technologie toonden aan dat het mogelijk is om effectievere onderzoeksresultaten te verkrijgen wanneer bij het ontwerpen van het onderzoek rekening wordt gehouden met de percepties en lange-termijn ervaringen van boeren. Tegelijkertijd gebruikte de hoofdonderzoeker zijn web van sociaal-economische en biologische kennis om de verschillende resultaten van het onderzoek te begrijpen en te verklaren binnen een denkwijze en analyse gestoeld op een bêta-gamma denkraam. Hieromtrent was er sprake van een continu en iteratief beoordelingsproces met betrekking tot de technografie en de diagnose om het mogelijk te maken nieuwe ideeën of innovaties in te bouwen en nieuwe belanghebbenden in het experimenteerproces te betrekken. Het samen met boeren vaststellen in hoeverre nu resultaat is geboekt en het valideren van dat resultaat blijft een belangrijk punt, waarmee boeren en onderzoeker nieuwe technologieën kunnen beoordelen of nieuwe ideeën kunnen uitproberen onder boerenomstandigheden. Deze twee eigenschappen van de benadering in het Convergence of Science programma, zoals die werd toegepast bij het beheer van rassen van yam en koeienboon geven aan dat deze benadering zowel interdisciplinair als transdisciplinair kan zijn.

The Convergence of Sciences programme*

Background

This thesis is the outcome of a project within the programme "*Convergence of Sciences: inclusive technology innovation processes for better integrated crop and soil management*" (CoS). This programme takes off from the observation that West African farmers derive sub-optimal benefit from formal agricultural science. One important reason for the limited contribution of science to poverty alleviation is the conventional, often tacit, linear perspective on the role of science in innovation, i.e., that scientists first discover or reveal objectively true knowledge, applied scientists transform it into the best technical means to increase productivity and resource efficiency, extension then delivers these technical means to the 'ultimate users', and farmers adopt and diffuse the 'innovations'.

In order to find more efficient and effective models for agricultural technology development the CoS programme analysed participatory innovation processes. Efficient and effective are defined in terms of the inclusion of stakeholders in the research project, and of situating the research in the context of the needs and the opportunities of farmers. In this way stakeholders become the owners of the research process. Innovation is considered the emergent property of an interaction among different stakeholders in agricultural development. Depending on the situation, stakeholders might be village women engaged in a local experiment, but they might also comprise stakeholders such as researchers, farmers, (agri)-businessmen and local government agents.

To make science more beneficial for the rural poor, the CoS programme believes that convergence is needed in three dimensions: between natural and social scientists, between societal stakeholders (including farmers), and between institutions. Assumptions made by CoS are that for research to make an impact in sub-Saharan Africa: most farmers have very small windows of opportunities, farmers are innovative, indigenous knowledge is important, there is a high pressure on natural resources, the market for selling surplus is limited, farmers have little political clout, government preys on farmers for revenue, and institutional and policy support is lacking. To allow '*ex-ante* impact assessment' and ensure that agricultural research is designed to suit the opportunities, conditions and preferences of resource-poor

* Hounkonnou, D., D.K. Kossou, T.W. Kuyper, C. Leeuwis, P. Richards, N.G. Röling, O. Sakyi-Dawson, and A. van Huis, 2006. Convergence of Sciences: The management of agricultural research for small-scale farmers in Benin and Ghana. *NJAS–Wageningen Journal of Life Sciences* 53(3/4): 343-367.

farmers, CoS pioneered a new context-method-outcome configuration[†] using methods of technography and diagnostic studies.

Technographic and diagnostic studies

The technographic studies explored the innovation landscape for six major crops. They were carried out by mixed teams of Beninese and Ghanaian PhD supervisors. The studies looked at the technological histories, markets, institutions, framework conditions, configurations of stakeholders, and other background factors. The main objective of these studies was to try and grasp the context for innovation in the countries in question, including appreciation of limiting as well as enabling factors.

The diagnostic studies were carried out by PhD students from Benin and Ghana. They focused in on groups of farmers in chosen localities, in response to the innovation opportunities defined during the technographic studies. The diagnostic studies tried to identify the type of agricultural research – targeting mechanisms – that would be needed to ensure that outcomes would be grounded in the opportunities and needs of these farmers. Firstly, that not only meant that research needed to be technically sound, but also that its outcomes would work in the context of the small farmers, taking into account issues such as the market, input provision, and transport availability. Secondly, the outcomes also needed to be appropriate in the context of local farming systems determined by issues such as land tenure, labour availability, and gender. Thirdly, farmers also need to be potentially interested in the outcomes taking into account their perceived opportunities, livelihood strategies, cultural inclinations, etc.

The diagnostic studies led to the CoS researchers facilitating communities of practice of farmers, researchers, scientists from national research institutes, local administrators and local chiefs. The research was designed and conducted with farmer members of the local research groups. Their active involvement led to experiments being added, adapted or revised. It also made the researchers aware of the context in which the research was conducted. A full account of the diagnostic studies can be found in a special issue of NJAS[‡].

Experimental work with farmers

After completing the diagnostic studies, the PhD students engaged in experiments with farmers on integrated pest and weed management, soil fertility, and crop genetic diversity, in each case also taking into account the institutional constraints to

[†] See R. Pawson and N. Tilley, 1997. *Realistic evaluation*. London: Sage Publications.

[‡] Struik, P.C. and J.F. Wienk (Eds.), 2005. Diagnostic studies: a research phase in the Convergence of Sciences programme. *NJAS–Wageningen Journal of Life Sciences* 52 (3/4): 209-448.

livelihoods. They focused on both experimental content and the design of agricultural research for development relevance. Experiments were designed and conducted together with groups of farmers, and involving all stakeholders relevant for the study. The aim was to focus on actual mechanisms of material transformation – control of pests, enhancement of soil fertility, buffering of seed systems – of direct relevance to poverty alleviation among poor or excluded farming groups. The ninth PhD student carried out comparative 'research on research' in order to formulate an interactive framework for agricultural science.

Project organization

All students were supervised by both natural and social scientists from the Netherlands and their home countries. In each country, the national coordinator was assisted by a working group from the various institutions that implemented the programme. A project steering committee of directors of the most relevant research and development organizations advised the programme. The CoS programme had a Scientific Coordination Committee of three persons, including the international coordinator from Wageningen University.

CoS had two main donors: the Interdisciplinary Research and Education Fund (INREF) of the Wageningen University in the Netherlands and the Directorate General for International Cooperation (DGIS), Ministry of Foreign Affairs of the Netherlands. Other sponsors were the FAO Global IPM Facility (FAO/GIF), the Netherlands Organization for Scientific Research (NWO), the Wageningen Graduate School Production Ecology and Resource Conservation (PE&RC), the Technical Centre for Agricultural and Rural Cooperation (CTA or ACP-EU), and the Netherlands organization for international cooperation in higher education (NUFFIC). The total funds available to the project were about € 2.2 million.

CERES Training and Supervision Programme

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the CERES Research School for Resource Studies for Development which comprises of a minimum of total of 32 ECTS (European Credit Transfer System; 32 ECTS = 22 weeks of activities).

I. Orientation (17 ECTS)

- Literature research (Wageningen University, 2001-2002, 4 ECTS)
- Presentation research proposal (Wageningen University, 2002, 2 ECTS)
- Social Construction of New Agricultural Technologies (Department of Social Sciences/WUR, 2001, 3 ECTS)
- Ecological Aspects of Agricultural Systems (Department of Plant Sciences, 2001, 3 ECTS)
- Functional Biodiversity for Sustainable Crop Protection (PE&RC/WUR, 2002, 1 ECTS)
- Agricultural Knowledge and Information Systems (Department of Social Sciences/WUR, 2002, 3 ECTS)
- Spatial modeling in Ecology focusing on Biodiversity (PE&RC/WUR, 2002, 1 ECTS)

II. Research Methods and Techniques (10 ECTS)

- Methods and Techniques for Social Scientific Research (Department of Social Sciences/WUR, 2001, 3 ECTS)
- Methods and Techniques for Social Field Research (Department of Social Sciences/WUR, 2002, 3 ECTS)
- Training on Multi-Stakeholder Processes (International Agricultural Centre (IAC), Wageningen, 2004, 2 ECTS)
- Academic Writing (Language Centre/WUR, 2001, 1 ECTS)
- Scientific Writing (Language Centre/WUR, 2002, 1 ECTS)

III. Seminar Presentations (11 ECTS)

- Internal seminars of Technology and Agrarian Development (Department of Social Sciences/WUR, 2001, 2002, 2006, 1 ECTS)
- Internal seminars of Crop and Weed Ecology (Department of Plant Sciences/WUR, 2001, 2002, 2006, 1 ECTS)
- Internal seminars of Communication and Innovation Studies (Department of Social Sciences/WUR, 2001, 2002, 2006, 1 ECTS)
- International seminars of Convergence of Sciences (WUR/University of Abomey-Calavi/University of Ghana, 2001-2005, 8 ECTS)

Curriculum vitae

Afio Zannou was born in Benin in 1966. After completing his secondary school education in 1987, he entered the University of Abomey-Calavi to pursue studies at the Faculty of Agronomy where he graduated as Engineer in Agricultural Economics in 1994. From 1994 to 1996, he worked as a Research Assistant in the Department of Rural Economics and Sociology at the Faculty of Agronomy of the University of Abomey-Calavi. In 1996, he was granted a scholarship from the Belgium Cooperation Organization for Development (AGCD) to undertake post-graduate studies in Environmental Sciences at Fondation Universitaire Luxembourgeoise, Belgium. He obtained the degree of DES (Diplôme d'Etudes Spécialisées) in 1997 and the Masters Degree in Environmental Sciences in 1998. After his Masters programme, he continued serving at the Faculty of Agronomy in the Department of Rural Economics and Sociology as a Research and Teaching Assistant from 1998 to 2000. From July 2000 to September 2001, he was employed as a Scientific Assistant at the International Plant Genetic Resources Institute (IPGRI) for West and Central Africa, IITA-Station, Cotonou, Benin. In October 2001, he obtained a scholarship from the Interdisciplinary Research and Education Fund (INREF) and The Netherlands Directorate General of Development Cooperation (DGIS) under the Convergence of Sciences Project to complete this PhD thesis at Wageningen University, The Netherlands.