

Facilitating learning toward sustainable cotton pest management in Benin

The interactive design of research for development

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Antonio A.C. Sinzogan

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Propositions

1. The number of sprays, and level of active ingredients used in the conventional pest control recommendations for cotton in the Northern part of Benin are unnecessary and harmful to the environment. (This thesis)
2. Farmers resort to the conventional treatments, although alternative, cheaper and safer control measures have been developed, because of the ways in which powerful stakeholder interests dominate the organisation of the cotton industry. (This thesis)
3. Farmers are more likely to accept and use technologies that result from research designed with them and that aim to help to solve the problems they themselves have identified, than if technologies resulting from research centres are simply handed to them as the solution. (Stoop, 2002)¹.
4. *Only when people are carrying out their own analysis, making their own decisions, and taking their own action... only then can we say that they are empowered.* (Bartlett, 2004)²
5. *Les vrais "parasites" du coton sont en dehors du champ de coton... Parole d'un paysan du Bénin.* (Weziza, 1996. 2: 1, septembre 1996)
6. An interdisciplinary and trans-disciplinary doctoral dissertation can claim to be as much the result of the facilitation process used in the interaction with other academic and non-academic stakeholders, as the outcome of the excellent communication among the candidate and his/her supervisors of social and biological science background.
7. Doing a PhD at Wageningen University entails not only writing articles but also learning to socialize with other people in strange ways - like taking coffee at 3-30 PM!

Proposition accompanying the PhD thesis:

Facilitating learning toward sustainable cotton pest management in Benin: *The interactive design of research for development.*

Antonio A.C. Sinzogan

Wageningen, October 20, 2006

¹ Stoop, W.A. 2002. A study and comprehensive analysis of the causes for low adoption rates of agricultural research results in West and Central Africa: possible solutions leading to greater future impacts: the Mali and Guinea case studies. A study commissioned by the interim Science Council/ CGIAR, FAO Rome. 38 p

² Entry point for empowerment. CARE Bangladesh report. Bangladesh. 73p.

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Abstract

Over the last decade, the economic sustainability of the cotton industry in Benin has been questioned. Low yield caused by pests and socio-economic problems have been identified as the main problems facing cotton producers, leading to low income. This thesis has addressed the technical and organisational problems of crop protection in the cotton sector in Benin. It has analysed why technical alternatives to farmers' current dependence on purchased synthetic insecticides is necessary if cotton is to remain a worthwhile crop for farmers, and if the cotton sector is to regain the efficiency needed to compete in today's markets.

Findings showed a range of alternative methods for controlling economically significant cotton pests, principally by means of the integration of different pest control methods such as the use of botanicals, entomopathogens, and the reduction of the number of sprays and synthetic active ingredients by using action thresholds. The study also demonstrated a methodology for conducting site-specific, ecologically-informed Research for Development (R4D), that created the institutional potential to sustain innovation. The notable features of the methodology were: using a perspective relevant to farmers as the entry point, developing control methods in the context of a multi-stakeholder learning alliance, and altering the boundaries and conditions that affect the space for change.

1

General introduction

Antonio A.C. Sinzogan

Introduction

This study is about technology, change, and learning processes in the context of the cotton industry in Benin. It is based on the analysis of the Convergence of Science (CoS) project¹ that suggests in sub-Saharan Africa (SSA) that science and the technological products of science are too little used by farmers, and that their contribution to poverty alleviation is sub-optimal. This is also the case in crop protection, which forms the focus of this study. Farmers often resort to the use of pesticides, not making use of alternative, lower cost and safer control measures, which are, however, often also more knowledge intensive.

Cotton cultivation in West Africa is characterised by strong and increasing dependency on chemical pest control (Eveleens, 2004). The promotion of synthetic pesticides causes particular concern because of deficient registration and regulation of pesticides, and because small-scale farmers are not able to use the products effectively and safely. In Benin, the problem is nontrivial because of the adverse effects of the pesticides on human health, the crop ecosystem and the environment, and because of their impact on farm profits and income (Silvie et al., 2001; Tovignan et al., 2001; Williamson, 2005). The chemicals are relatively expensive while farm gate cotton prices have declined (Williamson, 2003). Most farmers need credit to obtain not only the synthetic inputs, but also seasonal labour for land preparation, and in this way they become easily trapped in credit dependency. Moreover, the payment of farmers for their cottonseed is often delayed. As a result farmers' cotton income typically does not provide the necessary cash in time to invest in the next crop and to provide for family needs. Nonetheless,

¹ Wageningen University Interdisciplinary Research and Education Fund (INREF) research programme entitled 'Convergence of Sciences: inclusive innovation technology processes for integrated soil and crop management' (CoS). The project currently operates in Benin, Ghana and the Netherlands. For details see annex.

they continue to produce cotton because this gives them access to the inputs and services they need for growing their staple food crops, and provides cash for other non-farm activities. The development challenge addressed by this thesis thus is how to produce cotton in a sustainable manner without compromising public health and the environment, while increasing private and public returns to investment in pest management.

This study's twofold research focus thus is: to develop and apply a methodology for improving existing pest management technologies, or testing new pest management options that might help cotton farmers escape the credit trap; and to place the methodology in a multi-actor learning process that seeks to create the institutional space for sustainable innovation. Field experiments were conducted with farmers and others stakeholders, constituted in a learning alliance, i.e. an investment in shared learning that allowed farmers to make informed decisions about pest management -which is necessarily a place-dependent and time-specific activity (Matteson, 2000).

The cotton industry in Benin

The cotton industry has been the largest foreign exchange earner in nine countries in West Africa. In Benin over the last decade, cotton contributed 67% of the total foreign exchange earnings, worth about 19.1 million US\$, and 3.7 % of the national growth (INSAE, 2002). Most of the cottonseed is produced conventionally using chemical fertilizers and pesticides. The greater

Table 1. Characteristics of cotton production agro-ecological zones

Characteristics	Zone 2	Zone 3	Zone 5	Zone 6
Climate	One rainy season		Two rainy seasons	
Population density (Habitants/km²)	20	19	24	30
Major rotation crops	Cotton, sorghum, maize. Cotton represents 45% of cultivated area.	Cotton, yam, maize, anacardium. Cotton represents 35% of cultivated area.	1 st rainy season: maize, cowpea/yam, groundnut/sorghum 2 nd rainy season: cotton is main crop	1 st rainy season: maize, cowpea/groundnut 2 nd rainy season: cotton and maize are main crops
Sowing calendar	1 - 20 June	10 June - 5 July	25 June - 10 July	
Recommended spraying calendar	Six sprays, starting at 45 days after sowing: 2 with Endosulfan, 2 with organo-phosphates and 2 with compounds against aphids			
Average Yield (kg/ha)*	1228	1035	600	700
Varieties	H279-1			

* Current yield (2005).

Source: adapted from Biau & Ahanchede, (1998); Raymond & Beauval, (1995); CRA-CF, (2002); Media & Technology, 2003& 2006.

part is concentrated in three agro-ecological zones, which differ in terms of environmental parameters, population distribution, and cropping pattern (Table 1).

N'dali the municipality and, Gounin, the village in which this study was undertaken, are located in agro-ecological zone 3 (see Figure 1 in Chapter 2). The local economy is based largely on agricultural production, and cotton makes a significant contribution. Those who grow cotton derive all or part of their cash income from the crop and it provides a cash insurance against food crop failure (Biaou and Ahanchéde, 1998). At the time this research was initiated, the cotton industry was depressed and urgently needed to become more efficient and profitable, at least cost to human health and the environment.

The reform process instituted throughout the public sector in Benin from the 1990s onwards brought a change in the organisation of relationships in the cotton sector but did little to improve communication and the efficacy of organisational linkages (see chapter 3). Farmer training and supervision, two of the most important elements used for technology diffusion, were suppressed. Farmers themselves have been left to solve complex problems like changing the insecticide formulation (such as ULV to EC) or estimating the action threshold in the application of the newly introduced pest control practice "*Lutte Etagée Ciblee*" (LEC)². The post-reform organisational context is analysed in this thesis (chapter 3) to evaluate whether it has been conducive to sustainable adoption of new pest management approaches.

The overall research problem and objectives

The need for sustainable pest management strategies

Improving cotton production in the smallholder farm sector in West Africa is an enormous challenge. The attainment of sustainable production is fundamentally linked with reversing the indiscriminate use of pesticides, while preserving public health and the environment.

In Benin bollworms are the major cotton pests (Youdeowei, 2001; Ton, 2002). The application of synthetic pesticides is the only control strategy recommended by the national cotton research institute "*Centre de Recherche Agricole Coton et Fibre*" (CRA-CF) (CRA-CF, 2002). However, the use of synthetic pesticides is not sustainable because of: i) the high financial, human, and environmental costs involved (PAN, 2000; Reddy, et al., 2000; OBEPAB, 2002); ii) the development of resistance by pests to the compounds (Martin et al., 2000; Ochou and Martin, 2002); and iii) the destruction of natural enemies causing pest resurgence and secondary pest outbreaks. Therefore, alternative and more sustainable control measures are sought.

² Control strategies based on a mix of calendar spraying of half the dose of recommended pesticides and periodic field scouting to assess whether insect pest numbers exceeds the economical threshold level, and if so a specific insecticide is used to control this pest.

Currently the cotton production system is changing (see chapter 3), following a process of organisational reform and state disengagement. The government has reduced drastically the training and supervisory staff. Subsidies on inputs (pesticides and fertiliser) and their distribution by the state have been abandoned, and the private sectors have been encouraged to take over the supply systems. As a consequence, the agrochemicals often are misused, because there is a lack of access to advice and training. Pesticide resistance has become more widespread, especially in the cotton bollworm *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) which has developed resistance to pyrethroids (Ochou and Martin, 2002; Martin et al., 2005). As a result of the changes initiated by the reform process, cotton output decreased steadily between 1997 and 2006 (Raymond and Beauval, 1995; CRA-CF, 2002; Ton, 2002; Media & Technology, 2003& 2006). The production in 2005 was 190 000 tonnes.

Low yield has been identified as the main problem facing cotton producers (see chapter 2), leading to low household income, as this cash crop is the main means of earning money. The main causes of the low yield are pest problems, low soil fertility, delayed cottonseed payments, low producer price, and expensive inputs. The problem of low yield in cotton is most severe in the N'dali municipality, where the cottonseed production fell by 78 per cent between 1996 and 2002. The current average yield in N'dali is under one tonne/ha.

Cotton production has become economically risky for the farmer. Farmers do not really respect the recommendations of the cotton researchers and advisers (see chapter 2). A significant number of farmers have abandoned cotton production altogether. It could be said that this outcome is the inevitable consequence of the industry's current focus on quick profits at the expense of sustainable production. The development of an appropriate '*filière*' (industry chain) and an appropriate '*recherche développement*' (policy-oriented development research) are needed to redress this situation.

In order to deal with the pyrethroid resistance that has built up in the cotton bollworm, *H. armigera*, population, an Insect Resistance Management (IRM) programme has been recommended, based on a pyrethroid-free season nationwide and the use of non-pyrethroid pesticides such as Endosulfan (1400g/ha) (this was inspired by the "Australian" strategy - Forester, 1993). However, the recommendation to use Endosulfan currently is being questioned because of its toxicity, environmental impact and its potential also to induce the build up of pest resistance – a problem that has been encountered with this pesticide in other countries (Ochou and Martin, 2002; WHO, 2005).

The research actors in Benin have used a reductionist approach to pest management technology development and research. It is argued in this thesis that these are inappropriate in and insensitive to local problems and contexts. The relation between farmers and the research actors is almost uni-directional, and weak (Kossou et al., 2004). Despite the intention to address issues

that farmers consider essential, the various farmer-based organisations in the cotton sector have not effectively transmitted their preoccupations to researchers, probably because they are not enough empowered to significantly influence the research agenda.

In all, it can be argued that the cotton production system in Benin has been degraded. It is apparently on the classical “pesticide treadmill” in which heavy reliance on synthetic pesticides works well for several years and then in the end proves to be disastrous (Castella et al., 1999). Once on the treadmill, the farmer faces spiralling pesticide input costs, increased pest problems and lower yields, leading to increasingly smaller returns on investments, thereby ending in an uneconomic production.

Recent years have seen two main efforts to address the problem described above. An NGO, “*Organisation Béninoise pour la Promotion de l’Agriculture Biologique*” (OBEPAB), has been carrying out experiments with farmers and scaling up technologies for organic cotton production. The national cotton research institute, “*Centre de Recherche Agricole Coton et Fibre*” (CRA-CF), has initiated a project to promote calendar-based applications of reduced insecticide dosages (half dose), along with periodic field scouting to reinforce the basic programme whenever necessary - the so called “*Lutte Etagée Ciblée*” (LEC). Actually, the stakeholders are aware of the environmental and health risks of synthetic pesticides and the need for a new way to manage cotton pests. However, the LEC strategies are recommended to the farmers without having consulted them, or taking into account their knowledge, cultural inclination, and enthusiasm. The top-down linear approach (transfer of technology) does not seem to work well in the cotton sector (PAN, 2000). Several studies have recognised already that farmers have been reluctant to adopt the technologies developed by formal research (Mutimba, 1997; Stoop, 2002). The goal of maintaining high levels of agricultural productivity and profitability while reducing pesticide use, becomes then a challenge not only of technology but also of the methodology used to develop the technology. This issue is addressed throughout the thesis but especially in chapters 4, 5, and 6.

This thesis thus reports the efforts made to address the following two general research objectives:

The technology challenge: the identification and development of locally-tested pest management technologies which would be cost-effective and have a minimum impact on health and the environment. From the outset, it was considered on the basis of the literature and the author’s previous experience in a cowpea project³ (Kossou et al., 2001) that a crop production system that does not rely heavily on chemical inputs but which nevertheless produces an adequate yield

³ Project dealing with Farmer Field School to facilitate the introduction of IPM in cowpea cropping system in Ouémé valley, Benin

will ensure economic and environmental sustainability, e.g. the Integrated Pest Management (IPM) approach (Mengech and Saxena, 1995; Röling and Van De Fliert, 1998; PAN, 2000; Matteson, 2000). Therefore, IPM options form the technological focus of the work reported in this thesis. IPM tries to work with the natural insect ecology in farmers' fields, minimize the use of pesticides, and at the same time reduce the costs of synthetic chemical control. However, IPM strategies also can fail and one of the key causes of failure revolves around a fundamental lack of appreciation of farmer's problems (Röling, 1996). IPM needs to be driven by farmers' needs and to build on farmers' knowledge. *What farmers don't know can't help them* (Bentley, 1989). Thus the technical work was complemented by a deliberate effort to construct a sustainable *research for development* (R4D)⁴ process that could institutionalise local problem-solving capacity.

The methodological challenge: Baseline studies that could provide a diagnosis of needs, problems, and opportunities, it is argued in this thesis, are a necessary first step in building an effective IPM strategy. Essential data include: the context; farmers' actual problems; the gap between research findings and farmers' practices; farmers' perspectives; and factors that influence their decision making. Then the entry points that are relevant from farmers' perspectives need to be carefully identified and verified with the farmers (Morse and Buhler, 1997; Van Huis and Meerman, 1997; Meir and Williamson, 2005). Thereafter, the R4D process reported in this thesis was constructed around the formation of a *learning alliance*, composed of farmers, national and local researchers, and local extension workers, who together selected the technical options to be tested, designed the experiments, reviewed and assessed progress, and interpreted the results, over two cotton-growing seasons.

We incorporated a negotiation phase with farmers at the beginning of each research cycle (chapter 6). We placed emphasis on co-learning and on strengthening farmers' capability to access external information when they need it, and on developing farmers' ability to experiment, draw conclusions and to take sound decisions. The strengths and limitations of this approach are contrasted to the more usual processes of technology promotion and extension.

Specific research objectives

The present research offers a re-conceptualisation of both cotton pest management problems and solutions to be applied. It uses an interactive approach that brought various actors with different perspectives on pest management strategies together to work in an integrated fashion towards a more sustainable and profitable small farmer cotton production.

⁴ *Research for development* emphasises the iterative, adaptive nature of innovation in complex ecosystem, which is achieved through systematic enquiry combined with learning based action (Ashby, 2003)

Specifically it explored and analysed:

- i) pest status in farmers' fields, and smallholder farmers' decision making in their choice and application of pest management strategies;
- ii) the stakeholders involved in the innovation process, the linkages among them, and their role and influence in the functioning of pest management practices;
- iii) from a biological and socio-economic perspective, the effectiveness of the existing methods (including farmers' initiatives) for cotton pest management, leading to the design and testing of improved technologies and management options;
- iv) the development and practise of collaborative and experiential learning and communication among local actors constituted in a *learning alliance*, for promoting and sustaining innovation processes.

Theoretical perspectives

Research on agricultural development research

For many years agricultural research results and technologies emanating from research centres were deemed sufficient for solving small farmer's problems. Extension was one-way process whose objective was to transmit to farmers the technical solutions obtained in the research centres. The solutions were demonstrated in the field together with well-supported model farmers, in the expectation that adoption would occur through spontaneous diffusion processes, spreading out from these carefully managed demonstrations (Rogers, 1995). This model was quite successful in the uniform and controlled conditions of irrigated or industrial agriculture (Hubert et al., 2000). However, even in these conditions, the sustainability of the solutions offered has been questioned. In the more complex, diverse and risk-prone rain-fed agriculture of much of the poorer South countries, this linear process of transfer of technology (ToT) does not work well (Chambers 1983, Stoop 2002). According to Lee (2002) criticism of the ToT model started in the 1970s. Specific criticisms included the universalising perspective of science as the solution to all problems, the unequal distribution of the impacts and benefits, the marginal use of local farmer knowledge, and the lack of consideration of the particularities of each person, situation or agro-ecological context (Stoop, 2002; Mutimba, 1997; Roling, 1976).

Agricultural development researchers were asked to modify their approach so as to 'put the farmer first' (Chambers et al., 1989). The whole farm rather than individual elements were taken into account in methodological innovations such as Farming System Research (FSR) (Collinson, 2000). FSR is driven as much by the overall welfare of farming households as by goals of yield and profitability. It takes a broad systems perspective and tries to increase understanding of complex inter-relations among natural, social and technical phenomena in specific contexts by integrating insights from a variety of natural and social science disciplines

(Van Huis et al., 2006). Through FSR, issues such as empowerment, indigenous knowledge, and farmer learning and experimentation were brought forth (Collinson, 2000). In this way, FSR led directly to Participatory Technology Development (PTD) (e.g., Van Veldhuizen et al., 1997). Farmers and local communities here are positioned as active partners and co-researchers in a problem solving process, with much of the research taking place on-farm. PTD makes use of Participatory Rural Appraisal tools and principles for local-level problem identification and for diagnosis of the 'windows of opportunity', the starting point for joint activity (Van Huis et al., 2006). However, in both FSR and PTD, the tendency has been to work on the design of new and/or more appropriate *technologies*, although it was recognised that there are institutional *boundaries* and *conditions*⁵ that affect the space for change.

A new beginning in recent years has been made to build on the lessons of experience and to emphasise *uniting science and participation in the process of innovation*, i.e. to emphasise innovation as 'research for development as a participatory approach involving stakeholders' experimentation, and building a capacity to learn about biological and ecological complexity' (Ashby, 2003). The challenge taken up by this thesis is to contribute to resolving the lack of impact in SSA on farmers' practices of the linear approach to Research and Development and also to address the urgency and policy relevance of pest management in cotton industry.

A better understanding of the conditions for technological and institutional innovation (in terms of cost-effectiveness, sustainability, and empowerment of resource-poor farmers) is necessary in order to indicate a more efficient and effective model for agricultural technology development in the cotton industry. This entails a careful specification of the contextualised opportunities for innovation, the inclusion of stakeholders in the research project, centring the research in the needs and the opportunities of the farmers, and altering the institutional boundaries and conditions that affect the space for change. This kind of research becomes 'a collective enterprise in which different stakeholders' values, knowledge and expertise are negotiated to produce results' (Van Huis et al., 2006). The process can be regarded as the kind of democratisation of science (e.g., Funtowicz and Ravetz, 1993).

Tekelenburg (2002) suggests that, if this R4D trajectory is followed, the following fundamental questions must all be answered to achieve efficient and effective outcomes: i) *what useful abiotic and biotic relationships can be constructed?* (fundamental research); ii) *what can technically make a difference?* (applied research); iii) *what can work in the context?* (incorporating agro-ecology, market, and input provision aspects); iv) *What can work in the farming system?* (farmers' knowledge, labour availability, and access to natural resources have to be taken into account); v) *what will be acceptable?* (farmers' cultural inclination, experience,

⁵ Boundaries and conditions stand as availability and/or functioning of input supply, credit systems, land-tenure arrangements, organisation of marketing, distribution of benefits, etc. (Van Huis et al., 2006)

livelihood strategies, and eagerness have to be taken into account); and vi) *how can the outcomes be scaled out?* (policy change). However, what remains an enigma, even to Tekelenburg, is how to design and manage the different research tasks in a project so that all the questions get answered (Röling et al., 2004).

Vernooy and McDougall (2003) proposed the following set of principles – grounded in concrete field experiences - of good practices in the kinds of participatory research for innovation that have been outlined here: i) *the research reflects a clear and coherent common agenda among stakeholder and it contributes to partnership building*; ii) *the research applies the 'triangulation principle' and links together various knowledge worlds*; iii) *the research process is based in iterative learning and feed back loops and there is a two-way sharing information*. These principles have guided the development of the initiatives described in this thesis.

Disciplinary linkages and methodology in the innovation process

The situation of cotton farmers in Benin described above is complex. Socio-institutional and economic problems lie at the root of the technical pest management problem. Following Mettrick (1993), the issue can be categorised as problem centred. By problem centred, he refers to the need to help farmers solve problems they have identified and prioritised. So the technical research becomes *problem oriented research*, that is, less interested in gaining new general scientific findings, and more concerned with the utilisation of general knowledge for practical questions and problems faced by farmers, i.e. problems which are not structured or delimited according to disciplinary categories. This implies inherent uncertainties in the researching process, and the necessity of inter-linking disciplinary knowledge (Conrad, 2001). Effective research in this tradition is research that is responsive to farmers' problems by constructing and fostering the natural and social science interface (*inter-disciplinarity*) and by involving non-academic stakeholders, especially farmers (*trans-disciplinarity*) (Van Huis et al., 2006). The art is to address the issues that arise at this interface scientifically in order to obtain operational answers to the practical questions and problems faced by farmers (Lee, 2002). Hard and soft information must be integrated, as must different stakeholders' perspectives, collaborative design and experimentation, co-learning, teaching and facilitation.

Agricultural research practitioners should provide a methodology for moving towards sustainable agriculture (e.g. Lee, 2002). In the setting of this research Integrated Pest Management is an entry point for developing a new process for linking various technologies and actors (Laxmi, 2006), and for co-researching with stakeholders. IPM here is treated not so much as the basis of an experiment in which a hypothesis is tested, so as the framework of constructing a new way of looking at and practising agricultural R4D (Lee, 2002).

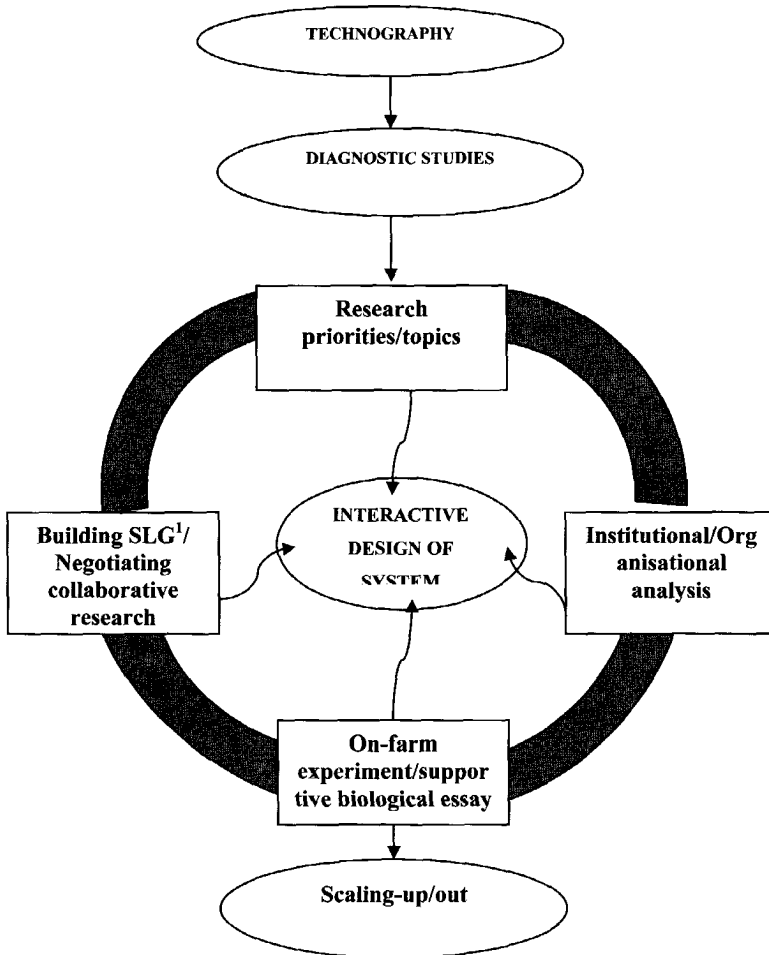
Research design and methodology

The present thesis has been undertaken within the framework of the “Convergence of Sciences (CoS) project”. CoS takes a critically fresh look at the process of innovation generation and diffusion as well as studying the real impact on agricultural development. CoS emphasises that effective research is a journey with a number of path-dependent steps (Houkonnou et al., 2006). The methodological basis of CoS is built on the concept of “research on research”, in order to draw out empirically tested guidelines for innovation systems and processes that are effective in SSA conditions. Technographic and diagnostic studies, and interactive design of systems of enquiry and innovation that work and are acceptable, are thus core components of the CoS methodology (Houkonnou et al., 2006).

The technographic study (Richards, 2001) reported briefly in this thesis aimed at identifying research priorities, with regard to innovation needs perceived by task groups made up of: farmers, policy makers, extensionists, researchers, etc. (rather than researchers’ own preferences and disciplinary background). It justifies to the ‘outside world’ the choices made for researchable issues in an increasingly democracy-oriented society. The technographic study played an essential role in making transparent the *pre-analytical choices*⁶ involved (Roling et al., 2004).

Despite the existence of improved recommended technologies for pest management, the stakeholders surveyed in the technographic study indicated an urgent need for further improvements and a larger range of options (Kossou et al., 2004). However, technographic studies by their nature arrive at a very high level of aggregation in determining research priority domains. Farmers’ knowledge, cultural inclination, and enthusiasm are not taken into consideration. Such aspects are more appropriately explored in relation to a specific research site, and that is where the diagnostic study becomes relevant, in order to ground the research in a specific context (Lee, 2002). The diagnostic study (Sinzogan et al., 2004) reported in this thesis was carried out using a variety of methods in order to take local knowledge into account and to allow the researcher together with the intended beneficiaries of the research results to set a common research agenda in a complementary way. It was undertaken as an entry point to a longer process of collaborative research. The technographic and diagnostic studies led to the identification of the village of Gounin (in N’dali municipality in the northern part of Benin) as the location of the field experimentation and co-learning activity studies (see chapter 2).

⁶ The notion of *pre-analytical choices* refers to the choices that are made before embarking upon a research project (Roling et al., 2004)



¹:stakeholder learning group.

Figure 1. Research path-dependent steps.

Figure 1 summarises the interactive approach with path-dependent steps that was adopted. These path-dependent steps include the technographic study carried out from October to December 2001 by the Benin CoS team, based on the guidelines developed by Richards (2001), the diagnostic study (chapter 2), and the interactive design of a system that works and is acceptable. The interactive design involved a series of agricultural research activities and process interventions that constituted the co-learning pathway, created the space for innovation, and institutionalised new relationships.

Outline of the thesis

Tekelenburg's questions have helped to structure this thesis. The technographic study and diagnostic study are dealt with in Chapter 2. An institutional and organisational analysis of the relationships among the main cotton industry stakeholders is presented and discussed in chapter 3. Chapters 2 and 3 thus seek to respond to Tekelenburg's questions 3 to 6 (see page 10). The design, execution, and results of a number of the on-farm experiments are presented in chapters 4 and 5. These deal with Tekelenburg's questions 1 & 2 and to some extent also question 4. The development of the stakeholder learning group and negotiation of the collaborative research (Chapter 6) offer insight into Tekelenburg's questions 4 & 5. The general discussion in Chapter 7 proposes further considerations and research needs with regard to the scaling-up question. A more detailed outline of the chapters follows.

Chapter 2 diagnoses cotton production constraints and opportunities. Farmers' perceptions and needs are brought into focus in the definition of the research problems. The chapter provides legitimacy for the choice of research domain and research location and points out the options for the next steps in the collaborative research process. The diagnostic studies revealed that socio-economic problems lie at the root of the technical pest management problem. An agreement was made with the farmers that some of their constraints, such as delayed cottonseed payment, low producer price, and the difficulty of obtaining inputs (related to distribution and price), would be investigated through an analysis of actor linkages.

Chapter 3 takes up this issue. A systematic analysis is made of stakeholders' interests, importance and influence, and of how the relationships among the institutional actors have developed in interaction through the reform process. It also presents and analyses the perspective of the actors on these organisational linkages. Finally, a critical reflection and analysis is carried out on the findings, in order to identify how farmers might become a more effective partner in the current organisational structures and institutional arrangements.

A Stakeholder Learning Group (SLG) was composed of farmers, extension agent, Local Research Agent and the author of this thesis - playing a varying role as scientist, expert, and as facilitator. The SLG innovation became the institutional arrangement through which collaboration in participatory, experiment-based agricultural technology development was carried out, linked to the farmers' needs, the dynamic of local pest ecologies, and various local practices.

Chapter 4 describes a participatory assessment by the SLG of an indigenous pest control method experienced by a few farmer members of the SLG. The bio-efficacy of various plants extracts viz., *Azadirachta indica*, *Kaya senegalensis*, and *Hyptis suaveolens*, either alone or in combination with half the recommended dose of synthetic pesticides, was studied in order to find a more sustainable strategy for the management of bollworms. The mixtures of Neem

with synthetic pesticides proved to be more cost-effective than the use of the full dose of the recommended synthetic pesticides. However, this technology, as practised by the farmers, was shown still to have some drawbacks: i) it does not conserve natural enemies; and ii) the number of applications may be too high as decisions to spray are based on the calendar and not on economic thresholds. The following questions arose: would it be possible to integrate the botanical/synthetic pesticides mixture into an IPM approach? And would it be possible to conserve as much as possible the natural enemies?

Chapter 5 evaluates how locally available alternative control measures, such as Neem seed extract mixed with half the dose of the recommended pesticides and entomopathogenic formulations of *Bacillus thuringiensis* (Bt) and *Saccaropolyspora spinosa* (Spinosad), could be combined to get “a best mix of control tactics for a given pest problem in comparison with yield, profit and safety of alternative mixes” (Kenmore et al., 1985). The chapter emphasises reducing the dependence on broad-spectrum pesticides such as Endosulfan, on lowering the concentration of synthetic pesticides by mixing them with botanicals, and relying more on the action of natural enemies by using selective pesticides such as Bt or Spinosad.

The research activities described in chapters 4 and 5 positioned the SLG as a ‘learning platform’. The diagnostic studies from the beginning had allowed the conventional approaches to agricultural technology development process themselves to come into question.

Chapter 6 describes and analyses the alternative approach to Research & Development built through this work, whereby researchers, farmers and extensionists learn together how to best manage the cotton pests in a sustainable manner. It provides the basis for the development of a framework that is bringing scientific and local knowledge systems together to support the identification and adoption of more sustainable pest management practices. The challenge ahead is how to expand the benefits of a locally successful approach to more people more quickly, whilst maintaining active farmer involvement in the process.

The thesis concludes with **chapter 7** that summarises the main results; assesses the methods/ methodologies and approach used; and discusses the policy implications of the results.

2

Farmer's knowledge and perception of cotton crop pests and pest control practices in Benin: results of a participatory diagnostic study

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Abstract

Cotton production constraints as perceived by farmers were studied from May to July 2003. The knowledge, perceptions and practices of farmers growing cotton under different pest management regimes were also analysed. The methods used were open and semi-structured interviews with groups and individuals, as well as participatory exercises (brainstorming, prioritisation, and problem analysis). Pest damage, low price of produce, late payment for seed cotton, and increasing input costs were the main production constraints perceived by producers. Regardless of the pest management system practised, most of the farmers adapt the recommendations of the research institute and NGOs to their livelihood systems. In general, farmers had a poor understanding of the key concepts underlying alternative pest control systems. Pest damage was considered important and farmers were eager to share their knowledge, perceptions and practices in pest management. The study provides the foundation for the creation of a learning platform; actors will be invited to collaborate in participatory experimental agricultural technology development, linked to the farmers' needs. In order to develop sustainable pest management strategies further interactive research is proposed, involving all stakeholders.

Additional keywords: integrated pest management, farmers' knowledge, interactive research, cotton

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Introduction

Cotton is by far the world's leading textile fibre. For many developing countries that grow and process it, the crop is vital for employment, and rural and industrial development (Morris, 1990). Cotton is the largest foreign exchange earner in nine developing countries, including Benin (Morris, 1990).

In less than 20 years, cotton production has increased fourfold in Benin (Raymond and Beauval, 1995; Biauou and Ahanchédé, 1998; CRA-CF, 2002). From 1994 to 1996 Benin was the second ranking sub-Saharan African country in terms of production. However, the higher production was not achieved by higher yields but by an increased acreage (400 % from 1988 to 1998). Over the last decade the production system has degraded, experiencing more expensive inputs, delayed cotton payments, problems of injudicious use of chemicals, and increased insect resistance to pesticides, e.g. *Helicoverpa armigera* (Lepidoptera: Noctuidae) against pyrethroids. As a result, the cotton yield dropped below 1000 kg ha⁻¹ between 1997 and 2000 (Raymond and Beauval, 1995; CRA-CF, 2002; Ton, 2002; Media & Technology, 2003). The Cotton Research Institute in 2002 conducted research that revealed that farmers do not respect the institute's recommendations, such as the pesticide quantities to be applied. The farmers cited as reasons the onerous price of pesticides and the fact that they are not convinced that the use of the recommended pesticide against aphids would improve yields (CRA-CF, 2002).

Cotton production in Benin seems to be on the classical 'pesticide treadmill' in which heavy reliance on synthetic pesticides works well for several years and then in the end proves to be disastrous (Castella et al., 1999). Once on the treadmill, the farmer faces spiralling pesticide input costs, increased pest problems and lower yields, which eventually make cotton production uneconomic. Indiscriminate use of pesticides often causes pest resistance and/or resurgence because they destroy the beneficial fauna.

The question is how to increase production in a sustainable manner without compromising public health and the environment, while conserving the natural enemies and avoiding the development of pest resistance? Are there ecologically based alternatives? It has been argued that a crop production system that does not rely heavily on chemical inputs but which nevertheless produces an adequate yield will ensure economic and environmental sustainability e.g. the Integrated Pest Management (IPM) approach (Mengech and Saxena, 1995; Röling and Van De Fliert, 1998; Matesson, 2000; PAN, 2000). Several IPM technologies have been developed but they have not been widely adopted. This could be explain by several reasons among which (1) a 'non-diagnosis' of farmers' real problems, (2) a lack of fit between the proposed techniques and the local farming systems and livelihood strategies, and (3) limited availability and access to external inputs.

Technographic studies conducted in Benin in 2002 (Kossou et al., 2004) aimed at getting a general overview of the technological innovation landscape of a socio-technical system in a country (Richards, 2001). These studies concluded that innovations in pest management (pertinent research priorities) need to be based on the perspective of the cotton producers. However, technographic study stay at a very high level of aggregation in determining fields of research priorities. Such a research priority should next be explored in relation to a specific research site and that is where diagnostic studies are aimed at (Richards, 2001). If scientists were to work more closely with farmers to improve crop production and protection, they might come to recognize farmers' constraints and their existing technical knowledge as the basis for an effective collaboration (Morse and Buhler, 1997).

So subsequent to the technographic studies, a diagnostic study were carried out, which addressed farmers' real problems, needs and opportunities. This in order to identify the most pertinent research priorities at each specific site. The study reported here is the first of a number of path-dependent steps (Lee, 2002), undertaken as an entry point to a longer process of collaborative research, as stated in the introductory chapter of this special issue (Röling et al., 2004). The study focuses on the following issues: (1) which plant production and protection problems do farmers perceive as the most important; and (2) farmers' knowledge, perceptions and practices (KPP) in pest management. At the end, the paper also points-out the options towards the next step of collaborative research.

Material and Methods

Study area

Cotton in Benin is produced in six agro-ecological zones (Figure 1), which differ in environmental characteristics, population distribution and cropping patterns. Three zones were selected, where most of the production is concentrated (II, III, and IV) and a low production zone (VI) was added for comparison. In these agro-ecological zones the extension service '*Centre d'Action Régionale pour le Développement Rural*' (CARDER) is actively providing services to cotton farmers as well the NGO '*Organisation Béninoise pour la Promotion de l'Agriculture Biologique*' (OBEPAB), and the project '*Projet d'Amélioration et de Diversification des Systèmes d'Exploitations*' (PADSE) sponsored by the World Bank, and of which the cotton pest management part was implemented by the Cotton Research Institute. A number of farmer organizations (FOs) are also present in these zones. In collaboration with CARDER, OBEPAB, PADSE and FOs, one municipality was selected in each selected zone (Figure 1) based on the presence of service providers and the type of pest management system used in order to include all the actors and the different pest control regimes applied. The three major pest management systems are: (1) the

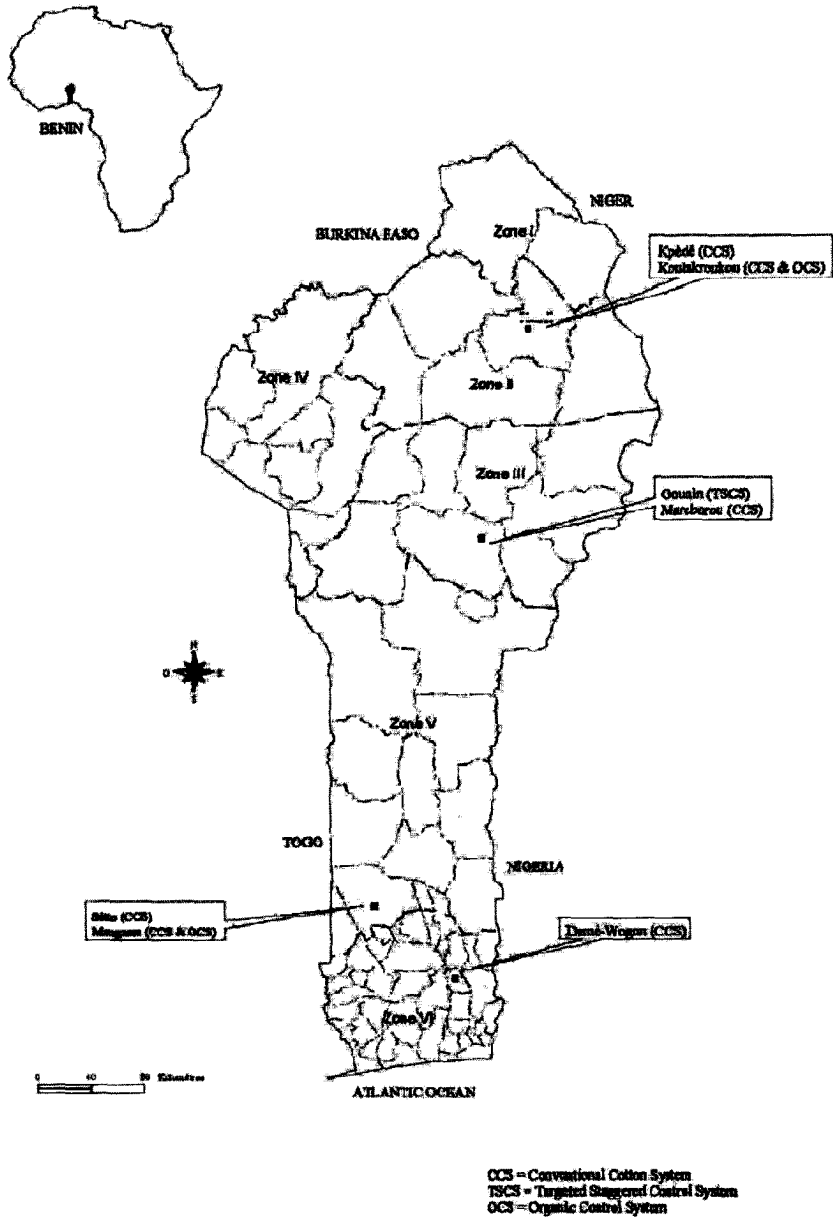


Figure 1. Map of the Republic of Benin, with cotton production agro-ecological zones (I-VI) and villages selected for the diagnostic study (adapted from Raymond & Beauval, 1995).

Conventional Control System (CCS) involving calendar spraying of chemical pesticides with in total 6 applications per season at 2-week intervals starting 45 days after planting (first two applications with a simple insecticide such as Endosulfan and the four subsequent ones with a mixture of two active ingredients); (2) Targeted Staggered Control System (TSCS), which is the CCS but with reduced insecticide dosages (half the amount of pesticide is used while periodic field scouting assesses whether insect pest numbers exceeds the economical threshold level, and if so a specific insecticide is used to control this pest); and (3) the Organic Control System (OCS) based on the use of botanical pesticides and manual removal of bollworms.

The pest control system in use was inventoried for the villages in each municipality. A total of seven villages (Figure 1) were randomly selected. In each zone (II, III and V), two villages were selected: one with only CCS growers, and the other with CCS and either OCS or TSCS growers. In zone VI where only conventional cotton is produced, one village was selected. The study was conducted from May to July 2003, which was the beginning of the cotton growing season.

Methods and tools

The methods used are based on the procedures of gathering evidence and analysing agriculture problems documented by Werner (1993), Pretty et al. (1995), Anon. (1997), Chambers (1997) and Mutsaers et al. (1997). Figure 2 shows the overall design of the data collection. Primary data gathering included group discussions (with farmers, key informants, and representatives of farmer organizations), individual interviews, and field observations. Secondary data gathering concerned the collection of general information. At the end of the village meetings (Figure 2), farmers were invited to participate in the continuation of the study. The selection of farmers for individual interviews or group discussions was based on the willingness of the farmer to participate. The total number of volunteers per village for individual interviews was limited to 20. An average of 112 male and female farmers participated in group discussions (69 CCS of which 7 females; 16 TSCS of which 2 females; 27 OCS of which 10 females); and 126 male and female farmers were interviewed individually (78 in CCS of which 7 females, 20 TSCS of which 2 females, and 28 in OCS of which 11 females). The difference between the number of participants in group discussions and individual interviews was due to the fact that some participants in individual interviews did not participate in the group discussions and vice versa.

The methods and tools used for collecting the information are listed in Table 1. Semi-structured interviews with groups, participatory exercises (brainstorming, prioritization, and problem analysis), and open discussions in a group setting, were used to identify production constraints. Selected farmers were individually interviewed using open and semi-structured interviews, combined with field observations, in order to elicit their KPP in pest management.

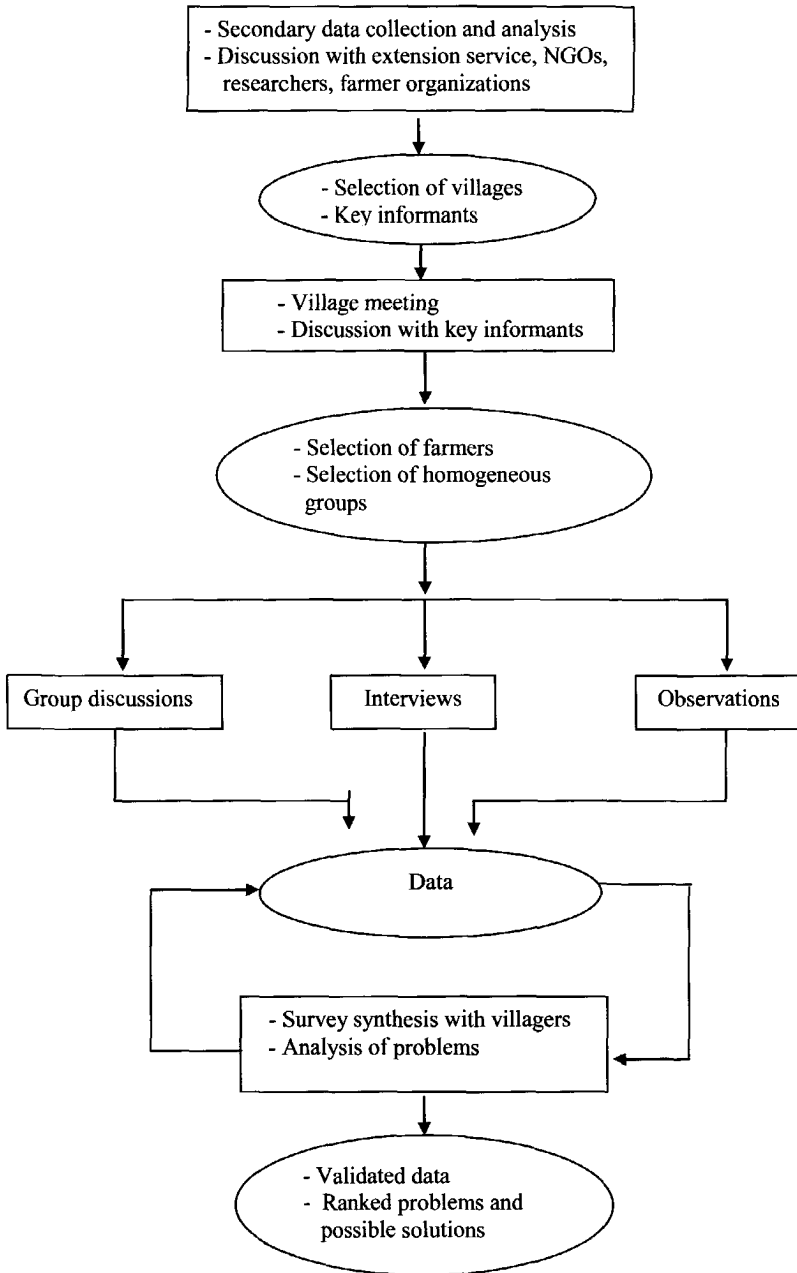


Figure 2. Master plan for data collection.

Table 1. Objectives and methods for the collection of data on cotton production and pest management in different villages in Benin

Objectives	Activities	Methods/tools	Information collected	Target respondents
Selection of villages	Collecting secondary data	Maps	Physical and socio-economic conditions	Scientists
Selection of key informants	Discussion with extension service, local leaders, missionaries, NGO's	Reports (government, NGOs, development project)	Village social structure	NGO agents
	Observations	Publications	Demography	Extensionists
		Personal communication	Cotton production strategies	Local leaders
Productions constraints	Village meetings	Check lists	Constraints by subject area	Individual farmers
Pest problems	Open and semi-structured Interviews	Papers for brainstorming and prioritisation exercises	subdivided into specific problems	Farmer groups
Solutions for constraints or problems	Group discussions (brainstorming and prioritisation exercises)		Pests problems	Women
	Verbal information		Possible solutions for each problem	organisations
Farmers' knowledge, perceptions and practices with respect to pests	Open and semi-structured Interviews	Check lists	Seasonal calendar of production and pest infestation	Individual farmers
Social aspects of pesticide use	Observations (cross-check farmers' answers)	Pest books	Identification of cotton pests and natural enemies	Farmer groups
	Verbal information	Existing pest strategies handbooks	Pest management practices	Farmer organisations
			Pesticide use	Women
			Timing and frequency of pesticide applications	organisations
			Advantages and disadvantages of pesticides as perceived by farmers	
			Use of pesticides outside cotton (medicine, poison, other crops etc.)	
Input (pesticides) supply system	Open and semi-structured Interviews	Check lists	Pesticides used	Individual farmers
	Observations		Pesticides provider sources	Farmer groups
	Group discussions		Role of farmer organisations	Farmer organisations
				NGO agents
				Local leaders

KPP issues were related to the farmers' ability to identify cotton pests and natural enemies, their knowledge of pest occurrence during the year, their pest management practices, their perceptions of the effects of pesticide use, and their application of pesticides meant for cotton, but applied on other crops. In addition farmers were interviewed about their age, education, etc., and their objectives in producing cotton. On the average each interview took one hour. Since the period of the survey coincided with the beginning of the cropping season it was not possible to cross check farmers' answers regarding the seasonal pest.

Results

Farming systems

Agriculture in all four selected zones used to be based on shifting cultivation. However, this practice is no longer used, due to the unavailability of idle land (increase of the active population with regard to land). Farmers now cultivate the same piece of land for a long time.

Smallholdings on which a small range of crops is grown represent the dominant farm type. The survey revealed that cotton production units average 5 ha with a maximum of 14 ha for CCS and TSCS, and from a minimum of 0.5 ha to a maximum of 4 ha for OCS. The percentage cultivated area planted to cotton decreases along a gradient from north to south. In the CCS and TSCS, cotton is grown as a monoculture in rotation with other crops. Organic cotton is grown in two- or three-year rotations with cereals and legumes and as an intercrop with a variety of other crops, including maize.

In the area where cotton is intensively cultivated (Kpèdè, Koutakroukou, Gounin), some farmers use animal traction to plough their fields. In the south of zone III, tractors are used to plough the fields because, according to the farmers interviewed, conditions are unfavourable for cattle keeping. In the south (Sètto, Mangassa, and Damè-wogon), cultivation is done manually using hoes. The labour used in the four zones is both domestic and hired. Women and children mostly do the time-consuming operations such as weeding, picking, and fetching water for mixing chemicals, while men handle the cotton inputs, mix the chemicals and wash out the containers. Women complained that they have to do these operations in their husbands' fields before they are allowed to cultivate their own. As a result they indicated that they are always late in carrying out necessary operations in their own fields, leading to low yields.

The cotton variety H279-1 is sown throughout the study area and provided free of charge by the cotton regulatory body '*Association Interprofessionnelle du Coton*' (AIC). In the CCS and TSCS, cotton seed is treated with fungicide before it is made available to the farmers. In the OCS, the use of pesticide-treated seed is prohibited. The Organic Cotton Project (OBEPAB)

tries to supply the farmers with seeds from crops not treated with chemical pesticides. Farmers are organized in producer groups called '*groupement villageois*' that take care of cotton seed purchases and issues such as seed and input distribution.

In the study area, cotton is the main source of cash income. In the most important production zones (II, III), everything is linked to cotton; farmers pay for everything with money that 'grows on cotton' (their clothing, building their homes). One farmer said, "We depend on cotton not just to live but also to survive".

Farmers' perceptions and analysis of production constraints

In the study area, low yield was identified as the main problem. The main priority of farmers is to look for ways to increase the yield. Farmers mentioned technical, institutional and socio-economic production constraints. Technical problems relate to pest damage, low soil fertility, and weed problems, while institutional and socio-economic problems relate to delays in payments for seed cotton, low price of produce, expensive inputs, lack of technical assistance, and lack of labour. Farmers prioritized these constraints differently in each pest control system (Table 2). Each of these constraints were analysed with the farmers in group exercises using participatory constraint analysis. It comes out from the participatory constraint analysis that institutional and socio-economic constraints lie at the root of the technical constraints (Figures 3 and 4). Only one technical reason was given, *viz.* the inefficiency of pesticides (Figure 5) as a cause of pest problems; all the other reasons given were socio-economic ones.

Farmers' knowledge, perceptions and practices

Farmers' profile, experience and objectives

The age of the cotton producers interviewed was between 20 and 70 years. Slightly more than 95% of the producers were younger than 45 years in the CCS and TSCS, whereas in the OCS most growers were older than 45. Almost all the growers using TSCS and OCS previously had used the conventional method. The main reasons given for changing their pest management system included: receiving crop payments earlier; pesticide poisoning problems; and larger profits gained by using cheaper inputs like botanical pesticides.

Most of the farmers interviewed were illiterate, and had not attended any extension courses on pest management, except in two villages (Mangassa and Damè-wogon) where some NGOs, like OBEPAB, or a project like the IPM-cowpea project (dealing with Farmer Field School (FFS) to facilitate the introduction of IPM in cowpea cropping system in Ouémé valley, Benin), had facilitated extension courses in previous years.

The farmers' main objective in growing cotton was to earn cash income, as it was almost the only crop able to provide it.

Table 2. Cotton production constraints as perceived by farmers in 9 villages of Benin, by pest control system. Responses expressed as product of number of farmers × their ranking; the lower the score the more important the constraint. Empty cells indicate 'no constraint'.

Production constraints	Conventional control system					Organic control system			Targeted staggered control system
	Kpèdè (n=18)	Koutakroukou (n=7)	Mardéborou (n=14)	Setto centre (n=8)	Mangassa (n=8)	Damè-wogon (n=14)	Koutakroukou (n=9)	Mangassa (n=18)	
Delay in seed cotton payment	48	9	14	24	9				32
Low price of produce	52	30	39		16	52			46
High price of inputs	70	18	48			46			
Late sowing	73						21		
Pest	75	25	28	22	23	17		21	28
Corrupt cotton quality controller		27		26					
Low soil fertility						24	14	42	
Lack of labour							16		54
Low yield of new varieties			29						
Weeds				8					
Lack of credit									55
Lack of rain									62

Source: Farmer survey, June & July 2003

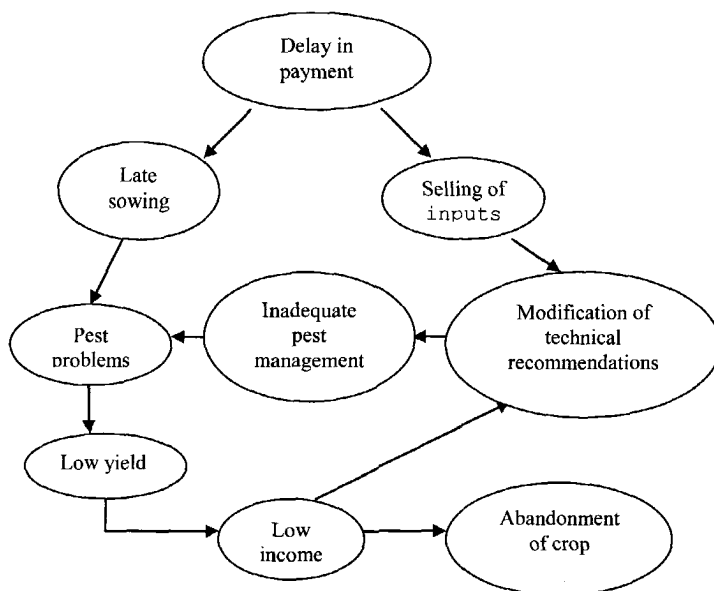


Figure 3. Analysis with farmers of the constraint 'Delay in payment'.

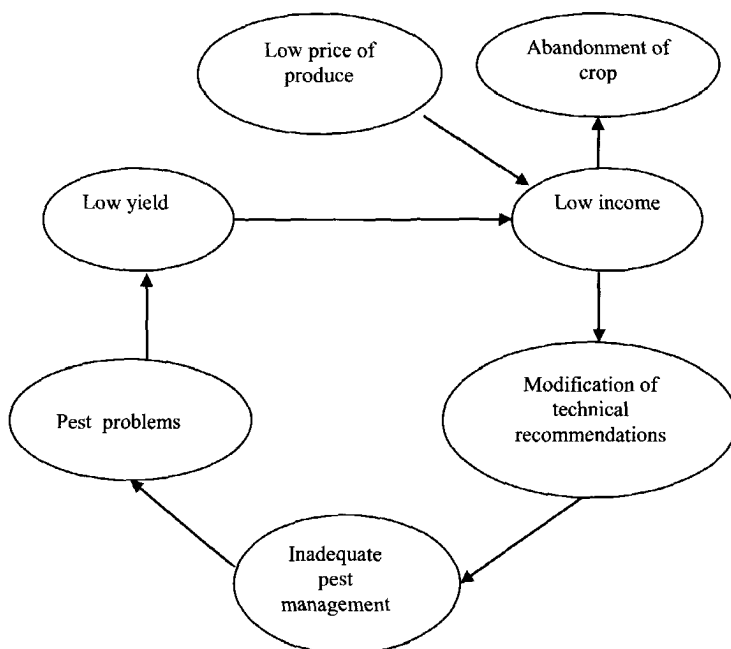


Figure 4. Analysis with farmers of the constraint 'Low price of produce'.

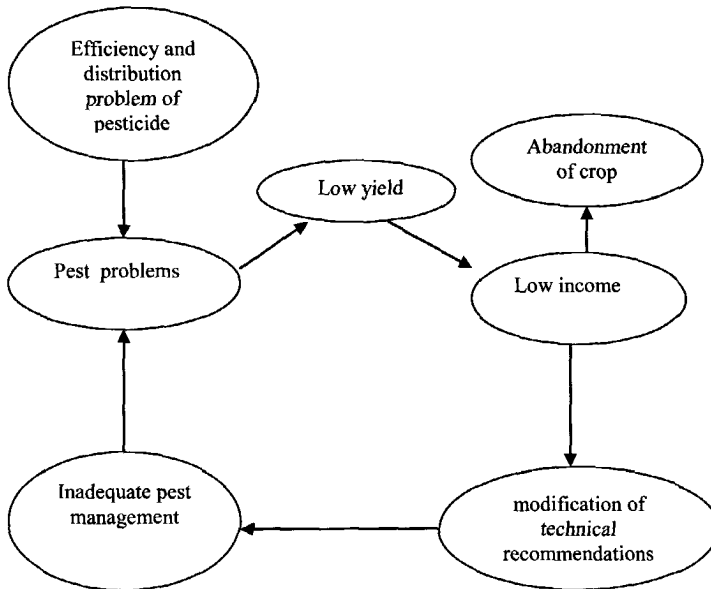


Figure 5. Analysis with farmers of the constraint ‘Pest problems’.

Farmers’ perception of pest infestation and natural enemies

The majority of farmers used descriptive rather than specific names when naming a pest. However, the organic cotton growers in Mangassa gave each insect a specific name because they had attended an extension course dealing with the recognition of cotton pests. In general, the same term was used for various insects. A commonly used term was *koko* or *wanvu* meaning worm or caterpillar, and *yeru kanounou* or *nouvinouvi*, meaning insect in the languages *Baatonou* and *Fon*, respectively. A specific name was given to the cotton stainer, *Dysdercus* sp. (Heteroptera: Pyrrhocoridae) in various local languages.

Among well-known insects were the leaf-roller, *Sylepta derogate* (Lepidoptera: Pyralidae) and the cotton stainer, *Dysdercus* sp. Farmers (except the farmers in Mangassa) had difficulties in distinguishing the different bollworms and only were able to describe its damage (young bolls drop, mature boll damage, etc.). They acknowledged in all of the four zones that the bollworms were present before the period when they were supposed to make the first pesticide application, and that the bollworms peaked in the period when they were supposed to give the third pesticide application.

About 75% of farmers, irrespective of the pest management system practised, were able to relate a pest to the phenology of the plant. They perceived the reproductive stage as the most infested and bollworms as the most damaging pest (Table 3).

Table 3. The most frequent and the most dangerous cotton insect pests and the most vulnerable plant stage as perceived by cotton farmers in five villages in Benin, by pest control system. Responses expressed as percentages of number of farmers (n) interviewed.

	Pest control system					Average
	Conventional			Organic	Targeted staggered	
	Kpèdè (n= 20)	Koutakroukou (n = 12)	Damè-wogon (n = 18)	Mangassa (n = 18)	Gounin (n = 20)	
<i>Most frequent pest</i>						
Leaf roller/ hopper	30	33	33	15	10	24
Bollworm	65	59	61	31	80	60
Cotton stainer	5	8	6	54	10	16
<i>Most frequent pest</i>						
Leaf roller/ hopper	20	17	0	11	20	14
Bollworm	80	75	100	72	70	79
Cotton stainer	0	8	0	17	10	7
<i>Most vulnerable stage</i>						
Vegetative	5	8	22	11	15	12
Flowering	90	75	73	78	80	79
Ripening	5	16	5	11	5	9

Source: Farmer survey, June & July 2003

Organic farmers identified the cotton stainer (*Dysdercus* sp.) as the most frequently observed insect whereas farmers in the CCS and TSCS recognized bollworms as the most frequently observed (Table 3). Only a few farmers from Mangassa and Damè-wogon had any knowledge about natural enemies. When asked how they had acquired this knowledge, the answer was that they had learned it through extension courses.

Farmers' knowledge and perceptions of pest control methods

Farmers using chemical pesticides differed in their opinion of the efficiency of pesticides (Table 4). More than 40% of the CCS farmers were of the opinion that Endosulfan (an insecticide used for the first and second application) controlled the whole pest complex when it was first introduced but that it did not do so at the time of the interviews, more than 50% thought that it still did. These perceptions were similar among the TSCS farmers (Table 4). Farmers in both systems indicated that the insecticides (different in the two systems) used for the third and following spray applications were not effective (Table 4).

Table 4. The efficacy of the first six chemical pesticide applications in cotton, as perceived by farmers using the conventional and the targeted staggered pest control system. Responses expressed as percentage of number of farmers (n) interviewed.

Efficacy	Pest control system					
	Conventional (n = 78)			Targeted staggered (n = 20)		
	Application:			Application:		
	1 & 2	3 & 4	5 & 6	1 & 2	3 & 4	5 & 6
Moderate	43	6	4	30	5	5
High	52	0	0	65	0	0
Low	0	90	95	0	90	90
No opinion	5	4	1	5	5	5

Source: Farmer survey, June & July 2003

Farmers using chemical pesticides (in CCS and TSCS) affirmed that they would only accept a protection programme that aimed to reduce the number of treatments if it ensured an equal or higher yield. The organic farmers thought that by using botanical pesticides they only 'put the insect into a dream' and were obliged to remove the insect manually. "This action is not possible over a big area", said a farmer.

Farmers' practices in pest management

There was a wide range in the number of spray applications. Nearly 70% of the CCS and OCS farmers did not respect the number of pesticide spray applications recommended by research (including botanical ones), which was six and seven, respectively (Table 5). In the STCS, almost all farmers interviewed respected the basic programme of spraying, which consisted of six spray applications of reduced insecticide dosages (half a litre of pesticide instead of one; using simple insecticides instead of binary mixtures). However, there were many who had not carried out the obligatory periodic field scouting to reinforce the basic programme. Many conventional farmers used less than the recommended eight litres of insecticides. Some of them

Table 5. Pesticide application regime used by cotton farmers. Responses expressed as percentage of number of farmers (n) interviewed.

Frequency of application	Pest control system		
	Conventional (n = 78)	Organic (n = 26)	Targeted staggered (n = 20)
Less than recommended	67	65	20
Same as recommended	20	23	70
High than recommended	5	3	5
Farmer does not know	8	9	5

Source: Farmer survey, June & July 2003

used only Endosulfan for all their applications although it was only recommended for the first two spray applications. Some combined half the dose of the recommended pesticides with some local botanical insecticides (*Kaya senegalensis*) and indicated that the mixture controlled the cotton pests. They also started applications later than the recommended six weeks after plant emergence and did not follow exactly the interval of 15 days between each application. It was very difficult to compare organic farmers' practice with what they had learned. The flexibility of the organic control system allowed adding some ingredients to the basic recipe of two kg of neem seed-based spray per ha. However, all of them admitted that they had difficulties in applying the quantity recommended and to respect the application time.

A number of farmers confessed that they used cotton pesticides for other purposes such as protecting maize in storage or cowpea in the field, and for controlling termites. Furthermore, they used cotton pesticide containers for water storage.

Discussion

Farmers were very clear about the constraints limiting their production. Low yield was identified as the main problem facing cotton producers, which is reflected in the official figures of yields lower than 1 t ha⁻¹. One reason underlying the causes for low yield is probably the recent policy change in the cotton industry. The leading role of the government has been transferred to new organizations and the private sector, and inputs are no longer subsidised. As a result, the input cost has increased. In addition, the producer price of cottonseed is linked to the price on the world market, which is unstable, with a slight decreasing trend over the last five years (ICAC, 2002). In response to the high price of inputs and the low price of produce, some farmers modify the input recommendations, while others abandoned cotton production altogether. Modification of input recommendations could lead to an inadequate pest management regime and thus contributing to the perpetuation of low yields. The development of an appropriate 'production chain' and an appropriate 'R&D system' are needed to cope with this situation. The World Bank, a major contributor to the agricultural sector and sector policy in Benin, argues, however, that such an approach would cost too much and it has been reluctant to invest in the development of a more effective pest management regime (Röling and Richards, 2002).

In the light of cotton growers' knowledge and perceptions of pest problems, there are several obstacles to improving cotton pest management in Benin. The farmers in this survey were modifying the research institute's and NGOs' recommendations. Thus it appears that "Technology usually changes as knowledge products change through the knowledge system, and that farmers 'reinvent' technologies before incorporating them in their production system" (Schoubroeck, 1999). The transfer of technology (ToT) model is not conducive for adoption of

more effective pest management regimes. In the ToT model, adoption is supposed to happen through a linear flow of information (Schoubroeck, 1999) and in this way lacks flexibility (Hounkonnou, 2001). It appears that the conventional process of innovation development itself needs to be questioned. Leeuwis and Van Den Ban (2004) suggested Kolb's (1984) model of 'experiential learning' for organizing the communication of complex innovations. A well-documented example of the experiential learning approach to IPM, the Farmers Field School, draws heavily on Kolb's learning theory (Van de Fliert, 1993).

Another constraint to improving pest management is the lack of knowledge among farmers of insect biology and ecology. For instance, farmers' lack of knowledge of the life cycle of bollworms, and of predators of bollworms, indicates the inappropriateness of using bollworm scouting as a tool for control decisions, as proposed by the TSCS. Another consideration is that it seems that relatively few farmers have ideas about beneficial insects; farmers more commonly regard these insects also as pests and would be inclined to apply insecticides when they are spotted. All the farmers relying on the CCS and TSCS used Endosulfan. The perceived high effectiveness of this insecticide, although by no means general, presumably induced some farmers to adopt this insecticide for all spray applications (instead of using it only for the first two spray applications as recommended). It might be concluded that appropriate rural education, based on discovery learning, could help farmers to acquire basic skills and understanding in terms of differentiating the insects found in the cotton crop; and developing confidence in the effectiveness of integrated pest management strategies.

The results show that farmers' technical problems are grounded in a range of socio-economic problems and that current recommendations do not fit well with these conditions. This finding gives rise to an "open door" that technical recommendations need to fit the real context – or that socio-economic interventions need to complement technical R&D. The results further suggest that because the cash return is the strongest motivating factor in cropping and livelihood strategies, 'effective' pest management must be a 'cost-effective' option. The discussions held with farmers and service providers indicate willingness for collaborative investigation, designing and testing of the selected options.

Options towards the next steps of collaborative research

Farmers in the Gounin village considered pest problems to be the primary cause of low cotton yields. Farmers in this village are enthusiastic about interacting with scientists concerning the development of their KPP in pest management. This eagerness could be seen as a prerequisite for the development of a participatory technology development programme (PAN, 2000). Therefore, the Gounin village have been chosen as the location of future studies. Gounin

growers deal only with the targeted staggered control system.

It was agreed with farmers that 'bollworm management' be taken as the entry point. Farmers considered the bollworm as the most dangerous or risky pest with regard to yield loss. However, the challenge is not just to develop pest management strategies that are more productive, effective and safe than the current systems, but also how to bring the different actors, who have different perspectives and experiences of pest management strategies, to work together in an integrated way. The choice of a methodology will be important, as its actors need to bring forth a jointly agreed strategy for pest management. The principle of experiential learning developed by Kolb (1984) can be used as a general guideline of the processes involved. At the end of the diagnostic study, the volunteers farmers selected will be establishing as a local 'learning group'. The research agenda for the subsequent phases of experimentation will be 'negotiated' with the 'learning group' in collaboration with the local extension agent and the local representative of cotton research.

The biggest challenge for those promoting more sustainable cotton pest management strategies is to find an arrangement by which scientists and farmers can interact to develop a control system that works and will be accepted by farmers. Instead of using only flipcharts, field days, and visits (PAN, 2000), a sensible involvement of farmers in research activities for adaptive/innovative purposes will form the basis of the research process. Alternative control methods identified during the diagnostic study will be tried out in collaborative experiments. That is, the experiments will be jointly planned, monitored and evaluated (Van Veldhuizen, 1995).

In the specific context of socio-economic problems that lie at the root of technical problem (pest), it was agreed with the farmers of all seven villages that some of their constraints such as delayed seed cotton payment, low producer price, and the difficulty of obtaining inputs (related to distribution and price), also would be investigated. In particular, the new roles of actors in the cotton production and processing chain, post-liberalization of the cotton production system, will be looked at.

Conclusion

This study reports the results of a participatory diagnosis of current cotton production constraints and opportunities, and has provided insight into farmers' capabilities and needs. The farmers described a complex situation in which a range of biotic and abiotic factors constrained their cotton-based livelihoods. Cotton farmers in Benin in many respects were similar to most traditional small-scale farmers in sub-Saharan Africa. Most were illiterate. They had limited comprehension of the key variables governing safe, effective and sustainable pest management.

In this context, it is a challenge to develop pest control strategies such as IPM or organic control systems that offer reliable alternatives to chemical-based strategies. Clearly, a need identified is the lack of basic knowledge and skills and a possible way to respond to this need is facilitating discovery learning.

The diagnostic studies allowed the conventional research process itself to come into question. An approach is needed that does not pre-define the variables to investigate or the solutions that could be proposed. The encounter described between farmers and researchers provides the basis for the establishment of a 'learning platform' on which actors collaborate in participatory, experiment-based agricultural technology development, linked to the farmers' needs and the dynamic of local pest ecologies.

3

An analysis of the organisational linkages in the cotton industry in Benin

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Abstract

A study of the institutional context of the cotton industry in Benin was conducted in 2004, based on an analysis of stakeholders' interests, and influence. The impact on innovation processes and production systems are analysed with respect to farmers' organisations, the research and extension system, and the economics of cotton production. The methodology includes qualitative tools and analytic frameworks applied to data from five villages in two municipalities. The reforms undertaken since 1990 to improve efficiency formally could be expected to lead to a harmonised system. But stakeholders' conflicting interests and personal strategies, more or less bound to networks organised as alliances, subvert the aim of the reform and have led to a further, unplanned re-structuring. As things stand now, the cotton industry encompasses the conventional network and a break-away network of stakeholders. In both, the primary stakeholders are the producers. They are directly affected by any change, but they have little power or influence. The study concludes that neither the reform process nor the unplanned re-structuring have been favourable to producers. We argue that unless farmers are assisted to a change in their production system, to release their dependence on production credit and pesticide inputs, they cannot be effective partners.

Keywords: Benin, cotton industry, institutional linkages, stakeholder analysis

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Introduction

In a number of French-speaking African countries (in particular Mali, Chad and Benin), the evolution of the domestic agricultural sector is linked to the increasing importance of cotton production (cotton fibre increased from 200,000 tons at the beginning of the 1980s to more than one million tons by 2003/04). According to Deveze (2004), the foremost drivers have been the organisation of the production system as a formal network and the increase in area cropped. This article focuses on the institutional actors in the formal network and in a 'break-away' network that emerged in reaction to the reforms. These actors are described briefly in Table 1.

Until recently the cotton industry was entirely under the control of public sector institutions. The main actors were (i) SONAPRA - "*Société Nationale pour la Promotion Agricole*" - a state-owned company in charge of input distribution, cotton commercialisation and marketing; (ii) CRA-CF - "*Centre de Recherche Agricole Coton et Fibre*"- the national cotton research center which develops new technologies; and (iii) CARDER - "*Centre d'Action Régional pour le Développement Rural*" - the regional extension service. Following a series of crises experienced by a number of public monopolies, reforms were undertaken to improve the competitive position of the agricultural sector and especially the cotton sector. These required the withdrawal of the state agencies from direct participation in economic activities, and a refocussing of their regulatory role. From 1990 onwards the cotton sector has been regulated by an intermediary organisation, the AIC "*Association Inter-professionnelle du Coton*", known as the 'inter-profession'. The linkages among the organisations have taken on the character of a network, in contrast to the former cotton *filière* (chain-linked organisation). The reform process also encouraged the emergence of farmers' organisations and the establishment of several institutions in which farmers' representatives play a role in expectation that producers would gain sufficient power to influence the path of the cotton sector's development. The key questions facing the stakeholders today are related to the functioning of the various organisations and the network arrangements.

The proponents of the new reform of the cotton industry claim that the new system is functioning well, although other question whether the arrangements will lead to greater efficiency (Goreux & Macrae, 2003). Our studies of stakeholders' perceptions of the new producer organisations reveal that the cotton sector faces a number of difficulties that hamper the normal functioning of the formal institutional structure (Sinzogan et al., 2004). They originate in our experience of participatory diagnostic research into cotton production constraints and opportunities (Sinzogan et al., 2004). This research brought to light evidence that very many institutional actors today are taking a living from the cotton income, and that the present arrangements offer little apparent benefit to producers. Over the last decade, farmers have

Table 1 Definition and meaning of institutions/organisations acronyms used in the entire article.

Abbreviations	Definitions	Functions	Network membership
ADIAB	<i>Association des Distributeurs d'Intrants Agricoles du Bénin</i>	Input providers' association	Break-away
AGROP	<i>Association des Groupements de Producteurs</i>	Farmers' organisation at national level	Break-away
AIC	<i>Association Inter-professionnelle du Coton</i>	Regulatory platform including the representatives of all the institutional stakeholders	Formal
APEB	<i>Association Professionnelle des Egreneurs du Bénin</i>	Ginning factories' association	Break-away
CAGIA	<i>Coopérative d'Achat et de Gestion des Intrants Agricoles</i>	Input supply cooperative, in charge of the granting of input supply licences to the input providers	Formal
CARDER	<i>Centre d'Action Régional pour le Développement Rural</i>	Municipal extension service	-
CIRAD	<i>Centre International en Recherche Agronomique pour le Développement</i>	Research centre in France	-
CLCAM	<i>Caisse Local de Crédit Agricole et Mutuel</i>	Local rural bank	-
CRA-CF	<i>Centre de Recherche Agricole Coton et Fibre</i>	National research institute	-
CSPR	<i>Central de Sécurisation de Paiement et de Recouvrement</i>	Clearinghouse for all financial transactions in the cotton sector	Formal
FECECAM	<i>Fédération des Caisses d'Epargne et de Crédit Agricole et Mutuel</i>	Association of local rural banks	-
FUPRO	<i>Fédération des Unions des Producteurs</i>	Farmers' organisation at national level	Formal
FENAPRA	<i>Fédération Nationale des Producteurs Agricoles</i>	Farmers' organisation at national level	Break-away
GPDJA	<i>Groupement Professionnel des Distributeurs d'Intrants Agricoles</i>	Input providers' association	Formal
GV/GP	<i>Groupement Villageois/ Groupement des Producteurs</i>	Farmer organisation at local level	Formal/Break-away
IDI	<i>Importateurs et Distributeurs d'Intrants</i>	Input providers' association	Formal
MCI	<i>Marlan's Cotton Industry</i>	Input provider and ginning factory	Break-away
OPCB	<i>Organisation des Producteurs de Coton Biologique</i>	Organic cotton farmers' organisation	Formal, organised in separate organic network
SDI	<i>Société de Distribution des Intrants</i>	Input provider	Formal
SONAPRA	<i>Société National pour la Promotion Agricole</i>	Former state-owned company in charge of input distribution, cotton commercialisation and marketing	Formal

experienced declining yields, higher input costs, delays in the payment for seed cotton and low prices for lint. In response to the high price of inputs and the low price of produce, some farmers have modified the input recommendations, while others have abandoned cotton production altogether (Sinzogan et al., 2004). Socio-economic constraints and technical thus beset the farmers (CAPE, 2004). An important question in the study reported here is how individuals and institutions themselves analyse the linkages, which they use to promote and defend their stakes. A detailed and realistic understanding of these multi-stakeholder linkages is critical to developing more equitable, harmonious and sustainable relationship (Chevalier, 2001).

We begin with a brief review of the key terms used in this paper: stakeholders, stakeholding, stakeholder analysis (SA), institutions, organisations, and conflict. The methodological section describes the study area and design, the research methods and tools applied. The findings section presents, first, a descriptive account of our results, followed by a detailed, multi-faceted application of SA, with special attention given to how different sets of stakeholders themselves perceive the functioning of the institutional arrangements. In the subsequent section we tease out the implications in the light of an ongoing policy debate about the merits and demerits of liberalisation and the reform process, paying particular attention to the question of producer empowerment. The article concludes with a short sketch of the steps required to move toward a more competitive, efficient cotton industry that returns profit both to the sector as well as to farmers.

Theoretical Framework

Stakeholders and stakeholder analysis

Freeman (1984) defines a stakeholder as “*any group or individual who can affect, or is affected by, the achievement of a corporation’s purpose.*” In the context of natural resource management, Röling & Wagemakers (1998) offer the following definition: “Stakeholders are ... natural resource users and managers.” Recent uses of the term apply it not only to persons or individuals but also to groups and organisations that have an interest in, or who are active players in a system of interest (Ramirez, 1999). They are taken to be any individual, group or institution who would potentially “affect” or be affected by, whether positively or negatively, a specified event, process or change within the situation or resource under consideration (Gass et al., 1997). Jiggins and Collins (2003) amplify these definitions by suggesting stakeholders are those who have a ‘stake’, a real, material interest, from their perspective, in the situation or resource under consideration. However, a person or group is not a stakeholder simply by asserting a claim but becomes a stakeholder through participating actively in the promotion and defence of their stake. This is what Jiggins & Collins (2003) call the stake-holding process. They argue that two

important points are inherent in the concept: (i) many individuals, organised groups, public as well as private agencies, are concerned about issues such as the quality, availability, accessibility, and sustainability of a resource under consideration; but (ii), they do not necessarily share the same view about what is desirable or what the 'purpose' is of the resource. Fundamentally, the use of the concepts of stakeholders and stake-holding signals a recognition of a diversity of perceptions that is based in action.

Stakeholder Analysis (SA) can be defined as "*a holistic approach or procedure for gaining an understanding of a system, and assessing the impact of changes to that system, by means of identifying the key actors or stakeholders and assessing their respective interest in the system*" (Grimble & Wellard, 1997). SA is widely used in the start-up phases of collaborative stakeholder process as a 'desk-top' exercise, as a preliminary inventory of the situation and context (Jiggins & Collins, 2003). SA also can be used as "*a dynamic instrument, to track how individuals and groups themselves analyse the processes of stake-holding, and the evolution in understanding of each-others' stake*" (Jiggins & Collins, 2003). In the present study SA was used for the latter purpose.

Understanding institutions and organisations

An organisation can be defined as a "*Structure of recognised and accepted roles*" (Uphoff, 1995), while institutions are "*complexes of norms and behaviours that persist over time by serving collectively valued purposes*" (Uphoff, 1995); or "*sets of, decision-making procedures, and programs that define social practices, assign roles to the participant in these practices, and guide interaction among occupants of individual roles*" (Young, 1994). Thus, an organisation bases itself on institutional norms or an institutional setting in order to function.

However, Uphoff (1992) and Flower (1992), cited by Pretty (1995) argue that in reality organizations can be seen as institutions, indicating that the interface between the notions of institution and of organisation is not a strict boundary. Guerra (2003) differentiates institutions from organisation by the degree to which an organisation has incorporated into its daily action a coherent worldview, values, culture, beliefs, rituals, myths, symbols, assumptions, paradigms, premises, theories, etc. He suggests that the institutional dimension of an organisation must have an internal consistency, between its mode of interpretation of reality and its theory of action to transform that reality. From this understanding, he concluded that all organisations are simultaneously an organisation and an institution, influencing the perception, decisions and action of those who constitute the organisation and of most of the social actors in context in which they act. The organisation's material infrastructure and resources, the spatial distribution of its infrastructure and material resources, and the functional stratification that assigns roles and functions to these people distributed in the material space of the organisation, serve to fix

and stabilise the institutional rules. Rules that may include worldview, values, culture, beliefs, rituals, myths, symbols, assumptions, paradigms, policies, mission, strategies, priorities, objectives, and norms.

In this article, we take institutions and organisations to be conceptually separated, and organisational arrangements (whether formal or informal) as incorporating the institutional rules of the game. An important question that arises is then the extent to which the participants see themselves as bound by the same institutional rules or engaged in the same game.

Notion of conflict

Conflicts we take to be situations of competition and potential disagreement between two or more stakeholders over the management of the same resource (Grimble & Wellard, 1997). Gluckman (1956) cited by Sardan (1995) conducted the first works in anthropology that systematically confronted social reality through the notion of conflict. Their notion of conflict brings to the fore three analytic dimensions: the empiric, structural, and functional.

From an empirical point of view, conflict is inherent in all social life; all societies and social organizations are crossed by conflicts arising from the diversity of their members' objectives and interests. The functional dimension reveals how conflicts can lead to anarchy or contribute, on the contrary, to social reproduction and social cohesion. Structural analysis, as developed by Gluckman (1956), shows how the notion of conflict is revealed in differences of position, which are sustained by cultural codes. Conflict in this view expresses the different interests embedded in social difference. We link this brief exploration of the notion of conflict to SA in the cotton industry by privileging the empirical and structural dimensions. We pay in addition some attention to the effect of personal strategies, more or less bound to networks of institutions organised in alliance (Long, 1989).

Methodology

Research methods

The research objects of concern are cotton producers who are members of a farmer-based organisation, and the institutions and organisations involved in the cotton industry. Following a literature review, three methods were used: a survey of cotton producers belonging to one or other of the various farmer-based organisations; key informant interviews with local level actors, and with office holders in the organisations involved in the two cotton networks which are the focus of this article; and participatory diagramming of the informants' perceptions of the institutional linkages in the organisational networks.

The literature review allowed us to list the official institutional stakeholders. It also provided

some insight into co-operation and conflict within the industry. The informal interviews used throughout the research allowed the stakeholder list to be enlarged. The survey was qualitative and involved informal, semi-structured, and structured interviews, oral case histories, and observations.

Participatory diagramming was used to clarify actors' perceptions of the functioning of the institutional linkages in the networks of concern, and as a visual prompt for exploring tensions, conflicts, and collusion.

The data collected were structured around two poles of interest: i) stakeholders' roles, importance and inter-relation; ii) the impacts of the new organisation of the cotton industry on production systems. The techniques of analysis have privileged qualitative approaches, specifically: SA, participatory diagrams, and a conflict matrix tool (IAC, 2004).

Study area

The survey of local actors was carried out in two cotton-growing municipal areas: N'dali (Borgou department, northern part of Benin), and Djidja (Zou department, central part of Benin). Three reasons justify the choice: (i) the problem of low yield in cotton production is severe in N'dali and Djidja; production has fallen by 78 per cent and 50 per cent respectively from 1996 to 2002; (ii) our previous studies had revealed the continuous presence of several actors concerned in the management of the cotton filière (chain), from production through to marketing; and (iii), contrasting cotton pest management strategies are under trial (in addition to the conventional calendar spray) – 'Lutte Étagée Ciblée' (LEC) targeted staggered control¹ in N'dali and organic control in Djidja.

The pest control strategy in use, and the various farmer-based organisations present, were inventoried for all villages, in each municipality. The inventory revealed the existence of four farmer-based organisations (see Table 1 for further descriptions): (i) GP-FENAPRA - "*Groupement de Producteurs- Fédération Nationale des Producteurs Agricoles*"; (ii) GP-AGROP- "*Groupement de Producteurs-Association des Groupements de Producteurs*"; (iii) GV-FUPRO - "*Groupement Villageois- Fédération des Unions des Producteurs*"; and (iv) OPCB - "*Organisation des Producteurs de Coton Biologique*", an organic cotton production organisation. GP-FENAPRA and GP-AGROP are both 'dissident' organisations that have split from the original GV-FUPRO. Based on this information, we defined three categories of villages, and a total of six villages were then selected (Table 2) for the execution of the survey.

¹ This control strategy is called « *Lutte Étagée Ciblée* » (LEC) in French. It consist of conventional calendar spraying of chemical pesticides (6 applications per season at 2-week interval) but with reduced pesticide dosage (half the amount of pesticide is used while periodic field scouting assesses whether insect pest numbers exceeds the economic threshold level, and if so a specific insecticide is used to control this pest).

Scope of the survey

The producers included in the survey were selected from the members' lists of the organisations present in the villages. The criteria to select the villages are given in Table 2.

The sample within each of the selected villages was stratified by area cultivated. The reference surface was the average farmed area in the municipality (2.5 ha for N'dali and 0.9 ha for Djidja). Each organisation's members' list was then split into two categories above and below the reference surface. From each category producers were selected based on 1/12 sampling coefficient. In total, 80 farmers, including 12 women, were interviewed individually.

Table 2. Villages selected for the study and selection criteria.

Categories	Villages	Farmer-based organisations				Pest management strategy		Accessibility
		GV	GP	GP	GP	LEC	BC	
		FUPRO*	FENAPRA*	AGROP*	OPCB*			
1	Suanin	+	+	+	-	+	-	+
	Sakarou	+	+	-	-	+	-	+
2	Kori	+	-	+	-	+	-	+
	Dèbou	+	-	-	-	+	-	+/-
3	Mangassa	-	-	-	+	-	+	+/-

+: Presence of the actors (farmer-based organization) or the pest management strategy (BC - *biological control* or LEC - *Lutte Étagée Ciblée*) or village easily accessible (accessibility).

-: Absence of the actors or the pest control strategy.

+/-: Not easily accessible.

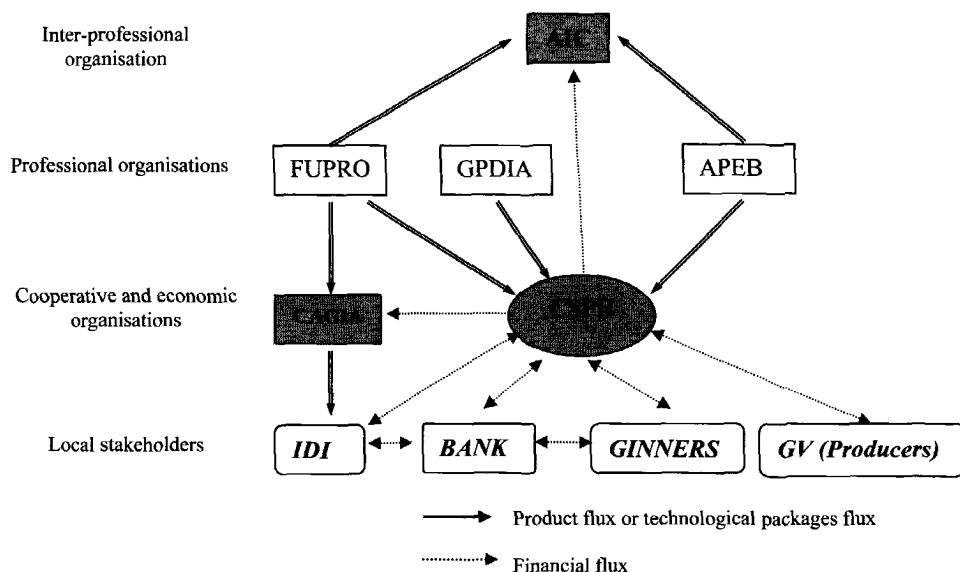
* See Table 1 for the definition and function/meaning of the abbreviations.

Findings

Official description of the formal institutional linkages

At the beginning of the 1990s, in the context of liberalisation and the privatisation policy, the government placed regulatory matters in the hands of the cotton industry itself, creating an intermediary organisation for this purpose known as the 'inter-profession' (AIC - *Association Inter-professionnelle du Coton*), a regulatory platform that includes the representatives of all the institutional stakeholders in the formal organisational network (Figure 1). New institutions have emerged and some existing ones, especially FUPRO - *Federation des Unions des Producteurs du Benin*, were strengthened. Other important innovations were the creation of the CSPR - *Central de Sécurisation de Payement et de Recouvrement* - as the clearinghouse for all financial transactions in the cotton sector; and CAGIA - *Coopérative d'Achat et de Gestion des Intrants Agricoles*, an input supply cooperative. The CAGIA has tried to limit the granting of input supply licences to the organisations in the formal network.

The post-reform formal arrangements encompass two organisational networks, one for conventionally grown cotton and one for organic cotton. We do not refer further to the



Grey shading highlight the new consultative bodies created to regulate the cotton industry.

See Table 1 for the definition and function/meaning of the abbreviations.

Source: adapted from: ME (France) (2002).

Figure 1. Formal cotton industry framework after liberalisation.

organic network in this article. Farmer-based organisations are well represented in both. The organisation of cotton production in these networks has been taken over by CAGIA, CSPR, AIC and FUPRO. The government remains responsible for cotton research.

The Stakes and Functioning of the AIC, CAGIA, CSPR, and FUPRO

(see Table 1 for definitions and the meanings)

The AIC: regulatory organ

The role of the AIC is to regulate the cotton sector from an institutional as well as technical point of view. It organizes and coordinates the processes of consultation and negotiation between the private sector and the government, with the objective of permitting the private sector to take over various crucial functions once carried out by the parastatal, SONAPRA. AIC also recruits extensionists from the national extension service to deliver technology to farmers. The inter-profession sets in place the mechanism for mediation among the actors. It also strives to ensure that the measures defined to assure the good functioning of the sector are respected. However, since it is functioning without a proper legal base, some stakeholders do not respect the regulatory rules.

The CSPR: a new credit recovery system

The creation of the CSPR was the first measure taken by the AIC in order to correct SONAPRA's irregularities in the recovery of production credits and in the payments to the producers. After specifying the amounts of cottonseed they agree to buy, ginning companies have to deposit with the CSPR 40% of the value of the cottonseed requested before being allowed to receive seed cotton. The CSPR uses these advances in order to clear input credits by repaying the bank which has advanced the credits through the CSPR, and - if there remains a cash surplus - to make some advance payment to the producers through the local banks "*Caisse Local de Credit Agricole et Mutuel*" (CLCAM). As soon as the producer delivers the cotton to the designated ginnery, the producer - in principle - is paid without delay.

However, this mechanism could work only with heavy regulation that ensured that every party follows the 'rules of the game'; but our survey data and focus group interviews revealed that up to the 2004/2005 growing season farmers sometimes have been paid only after one or two years and in some cases they have not been paid at all. Since the CSPR is a clearinghouse, it can redistribute only what it has received. If the ginners do not pay in time, arrears start accumulating. In principle the accumulation of arrears should be contained since a ginnery should not receive cottonseed until it has cleared its debts. Unfortunately, some indebted ginneries have been protected by the political system, thus blocking this regulatory safety valve. The indebted ginneries continue to collect the cottonseed from farmers by 'poaching'² them from their designated ginnery, sometimes in collusion with the transporters who often take kickbacks from the ginneries, as well as from the producers. Some farmers, after receiving credits from the CSPR for the purchase of production inputs, sell the cottonseed in Nigeria. Other malpractices also contribute to the malfunctioning of the CSPR mechanism.

Thus the production received from the producers (organised into GVs - *Groupements Villageois*) is insufficient to allow the CSPR to fully recover the input credits and thus it cannot assure full payment to all the producers. It might also be noted that the technical staff employed by the new structures (CSPR, AIC, CAGIA) are for the most part the former employees of the pre-reform organisations, whose bad management practices prompted the liberalization in the first place.

The CAGIA: the problem of inputs

Producers and input providers created the CAGIA in order to ensure the provision of inputs of reliable quality, in time, and at competitive prices. The CAGIA collects and evaluates the requests

² The strategy consists of selling seed cotton without paying the input credit due, generally as a result of collusion between buyers and sellers. For example, a grower having received inputs from a well-established company in the formal system does not sell his cotton to the designated ginnery company, as he should, because CSPR would deduct the cost of the inputs in order to repay the supplier. Instead, he sells his seed cotton to another ginnery, with no deductions, which makes it difficult for the CSPR to make the input credit repayments to the original input supplier.

for production inputs from its members and participates as the producers' representative in the agricultural input commission that selects and licences the input providers. The importation and distribution of inputs is based on the following principles:

- The merchandising of the input is permitted only to companies selected by the agricultural input commission.
- The licence to sell inputs is allocated to a single company in each municipal area.
- The selected companies are allowed a maximum of 120 days to complete input delivery to producers in their designated areas.
- The definition of the kind of inputs and control over their quality rests solely on the expertise of CRA-CF - *Centre de Recherche Agricole –Coton et Fibre*. Only after control procedures have been finalised are companies allowed to deliver the inputs.
- The inputs are sold at a uniform price throughout Benin.

The selection of the companies by the CAGIA remains a point of contestation. Some disaffected companies have created their own input provider association (*ADIAB - Association des Distributeurs d'Intrants Agricoles du Bénin*). It supplies inputs to disaffected farmers at a somewhat lower price compared to official prices. But the input quality is not controlled at all and the products supplied are often different from those recommended by CRA-CF. Moreover, the ADIAB members are not accredited by the CAGIA or the CSPR, further complicating the supply of inputs on credit and credit recovery. For their part, the members of the accredited input providers' organisation (*GPDIA - Groupement Professionnel des Distributeurs d'Intrants Agricoles*) are reluctant to deliver inputs on credit to the disaffected farmers, given the difficulties of credit recovery.

Farmer-based organisations in the formal network

The cotton producers' association FUPRO - *Federation des Unions de Producteurs du Bénin* – was established on the initiative of CARDER - “*Centre d'Action Régional pour le Développement Rural*” - the regional extension service, in order to facilitate cotton management. It is organised as a five-level pyramid, with producers organised into GVs – *Groupement Villageois* – at village level, UCPs – *Union Communale des Producteurs* – at municipal level, UDPs – *Union Départementale des Producteurs* – at department level, and FUPRO at national level. At municipal and department level, three agents remunerated by CSPR share the following tasks: i) provide technical advice to growers; ii) forecast the production level of the crop; and iii) participate in the allocation of input credit and check whether the advance was repaid in time.

At the local level, the GVs take care mainly of cottonseed purchases, and the distribution of seed and inputs. Cotton producers and farmers who did not grow cotton were initially part of the same GV. This gave rise to the “free rider” problem since farmers not growing cotton

could obtain inputs on a credit by pretending to grow cotton and use then use the inputs on their maize fields – a cost that would be repaid by the cotton growers due to the collective repayment obligation “*caution solidaire*”. For this reason, a smaller association limited to cotton producers, the GPC - *Groupement des Producteurs de Coton* - has replaced the GVs in order to exert stronger peer pressure on those tempted to “free ride”.

In the local producer groups studied, the GV's secretaries were found to be the main supervisors of the various activities, sometimes in association with the treasurers and the presidents. This concentration of activity in the hands of a few confers on them a power in farming society - and encourages malpractice. A common perception of the N'dali farmers interviewed is that

“Les secrétaires GV-FUPRO, ce sont ceux qui nous tuent, nous volent dans les villages; ce sont eux qui tirent profit de tout le coton” (The secretaries are those that ruin us, they are only ones who pull profit out of all the cotton production).

This quote illustrates how much the producers remain mindful of the interests bound to the position of secretary, and of the privileges that encourage local office holders to maintain their role.

The strength of the farmer-based organisations derives from their responsibility to guarantee the volume of production, and facilitate the access of the producers to the financial credit supplied by FECECAM “*Fédération des Caisses d'Épargne et de Crédit Agricole et Mutuel*”, a federation of local banks (CLCAM) (secured by the ‘*caution solidaire*’ i.e. the collective repayment obligation), and to input credit. However, over the last few years FUPRO has encountered a number of difficulties, notably indebtedness and bad management, because its structure allowing producers very little control over the rather complex relationships that characterise the cotton industry, or even over the way the GVs function. This has led to a crisis of confidence among cotton producers, and an increasing number are abandoning the crop. Many producers' resources have been exhausted by the poor distribution of the cotton funds or by the conflicts of leadership, and some of these disaffected farmers have joined the so-called ‘nonconformist’ organisations FENAPRA and AGROP (see Table 1), which act without following the inter-profession's (AIC) rules.

Disaffected stakeholders and the birth of a break-away organisational network

The actors who felt excluded by the new organisational networks soon developed a strategy to establish their own organisations: farmers created FENAPRA and AGROP; the ginners created APEB, and the input providers created ADIAB (see Table 1).

These organisations have fractured the reform settlement and operate outside the conventional system in a kind of break-away alliance.

The main reasons given by the disaffected farmers surveyed, who have joined FENAPRA or AGROP, are given in Table 3. Some also implicitly are seeking new avenues for exercising leadership, having failed to achieve positions of responsibility within the formal network; others are seeking to escape the bad debts they have incurred as members of the GVs or at higher levels of the FUPRO structure.

Table 3. Distribution of the cotton producers, according to their motivation for leaving the farmer-based organization GV-FUPRO.

Motivation	Percent citing this reason (N=23)
Delay in cottonseed payment	75
Bad management	70
Familial ties	15

Source: authors' survey, N'dali, July 2004.

FENAPRA and AGROP have set up new mechanisms to constrain or reduce the bad management experienced in the GVs. The local producer groups - *Groupement des Producteurs* – (GP) are constituted by affinity, are restricted in size, and sometimes are formed on an ethnic basis. To solve the problem of the delay in payment for cottonseed payment, the groups sell directly to ginneries that are members of APEB, who buy the cotton for cash. In order to solve the problem of unpaid financial credits, FENAPRA and AGROP do not provide a guarantee to the banks for the credit issued to their members.

Stakeholder Analysis

Institutional actors by stakeholder categories

The primary stakeholders are the producers (Table 4). They are directly affected by any change in the organisational networks, but they have little power or influence in the networks. In the formal organisational network, producer power is held by and confined to the farmers' consultative bodies (AIC, CSPR, CAGIA, FUPRO) (see Table 1 for definitions and the meanings). In the FUPRO-based network of production these are perceived as key stakeholders. In the break-away network, power over production is held by the ginners and input providers.

However, it is clear that stake-holding power is not conferred by the formal structure as such but by the actual functioning of the institutional relationships among them i.e. in collusion among the organisations' managers. The interviewed also see politicians as key stakeholders in all networks.

Table 4. Institutional actors in the formal and break-away cotton networks, by stakeholder category.

Classes	Definition ¹	Network	
		Formal	Break-away
Primary stakeholders	<i>Those who are directly affected, either positively or negatively</i>	Producers	Producers
Intermediate stakeholders	<i>The intermediaries in the delivery or execution of research, resource flows, and activities</i>	AIC, CSPR, CAGIA FUPRO Banks CRA-CF Ginners	AGROP, FENAPRA Input providers, Ginners
Key stakeholders	<i>Those with the power to influence or 'kill' activity</i>	Gvt (politicians) AIC, CSPR, CAGIA, FUPRO Ginners, Banks	Gvt (politicians) AGROP, FENAPRA Input providers, Ginners

¹ Jiggins and Collins (2003).

Gvt= government.

See Table 1 for the definition and function/meaning of the abbreviations.

Conflicts and competing interests among stakeholders

The investigation of the ambiguous relationship among stakeholders has been pooled in a matrix to allow the identification and assessment of the significance of conflict of interests among stakeholders (Figure 2). Conflict arises both among the stakeholders of the same network be it official or break-away, and between different networks. Conflict is frequent between the farmer’s consultative bodies and other stakeholders, especially between them and actors in the break-away network. The conflicts originate in the divergence of objectives and interests, and especially in the personal strategies pursued to satisfy private gain.

Stakeholders’ perspectives on the functioning of the linkages

The case of the formal network

The technologies developed by the research actors are financed by the AIC. The results are returned to the AIC also is in charge of disseminating the technology to farmers through its technicians (“*Technicien Spécialisé/AIC*” TS/AIC). There is no direct contact between researchers and farmers. (A few innovations such as the LEC - *Lutte Étagée Ciblée* - are tested in the field with farmers). On the request of the FUPRO, AIC also verifies whether the recommended technologies reach farmers. The CAGIA intervenes in this relationship in order to select input providers and to train farmers on how to use the inputs supplied. Figure 3 reveals producers’ discontent with input management in the formal network. The CAGIA, the institution in charge of input management was no longer included in the official network producers’ institutional linkage perspective. The main reason evoked is the inability of CAGIA to assume the training function on the use of input and the control of input qualities that is devoted to it. The training

	AIC	CSPR	CAGIA	FUPRO	FENAPRA	AGROP	ADIAB	MCI
AIC				•	●	●	●	●
CSPR				•	●	●	●	●
CAGIA				●	●	●	●	●
FUPRO					•	•	●	●
FENAPRA						•	•	•
AGROP							•	•
ADIAB								•
MCI								

The symbol • represents the existence of conflict, the size of the symbol indicating its relative extent or significance.

See Table 1 for the definition and function/meaning of the abbreviations.

Source: authors' survey.

See Table 1 for the definition and function/meaning of the abbreviations.

Source: Group interview with FUPRO members (N= 13), N'dali, 08 / 2004.

Figure 2. Matrix showing occurrence and extent of conflicts among cotton industry stakeholders in Benin (Matrix format adapted from IAC, 2004).

function has been delegated by CAGIA to the input providers who do not assumed it properly creating then producer mistrust of the efficacy of the inputs.

The CSPR is perceived by the producer as an important actor in its function as a

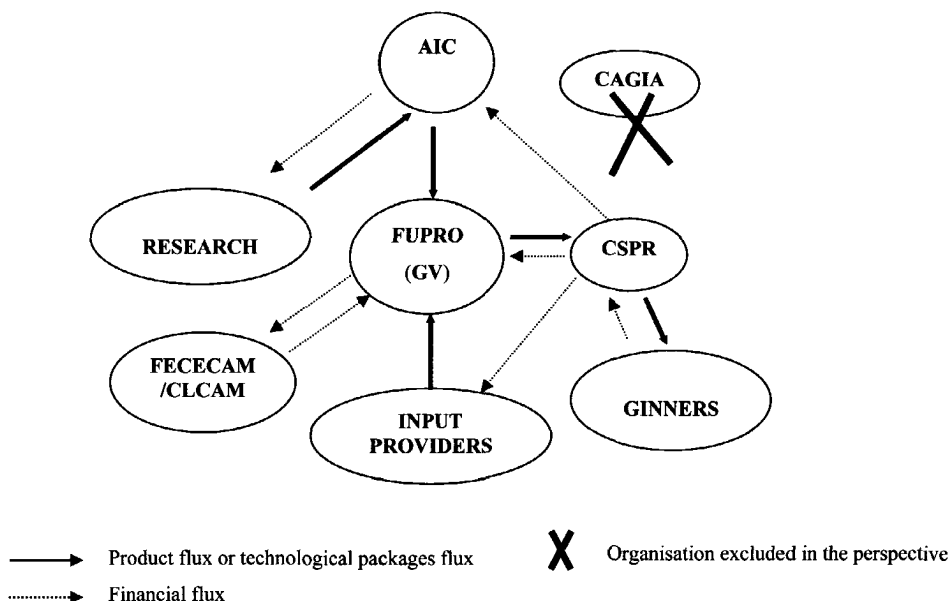


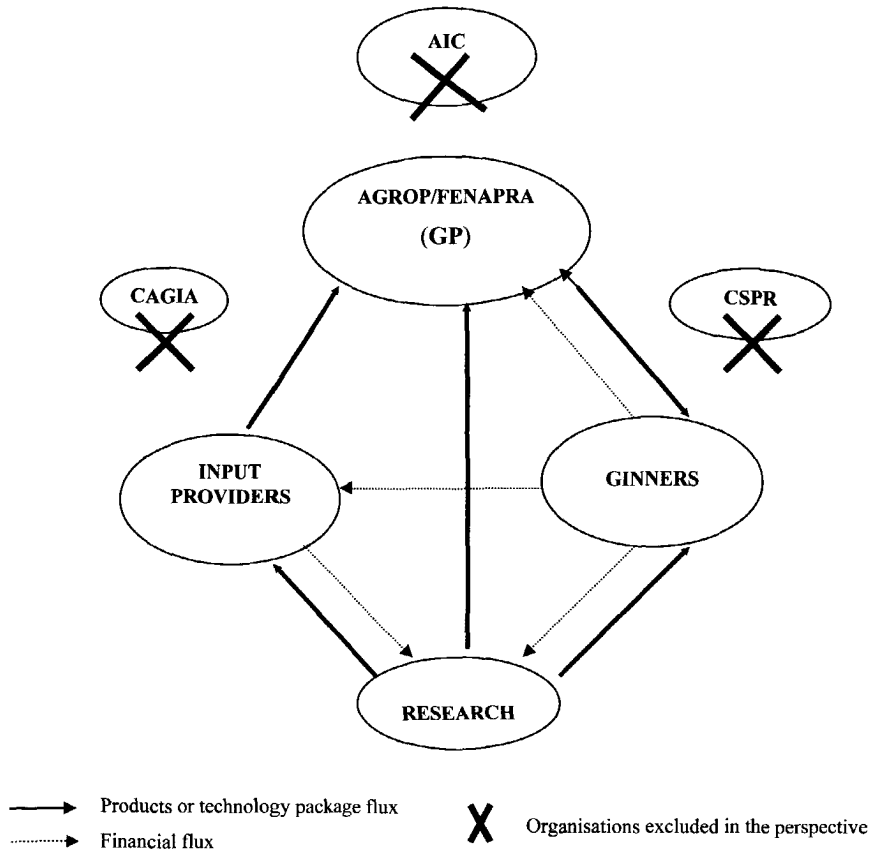
Figure 3. Participatory diagram of the functioning of institutional linkages, from the perspective of formal network farmers.

clearinghouse and is the institution best known throughout the cotton industry. Although 65 per cent of interviewed farmers identified the CSPR as responsible for the current difficulties in the industry they still considered it an important institutional actor. The FECECAM, through its system of local “cash-boxes”, intervenes in the network in order to guarantee credit to the producers, and bad management did not prevent the producers from valuing the usefulness of these credits. However, many acknowledged: “*The FECECAM credits kill the producers*”. Cotton producers who correctly use these credits feel exploited by those who fail to repay because of the “*caution solidaire*”.

The case of the break-away network

Figure 4 illustrates the perception of break-away producers’ of the key institutional linkages. The producers excluded the new consultative bodies (AIC, CSPR, and CAGIA) created by the formal arrangements.

These producers see these institutions, in addition to the GV secretaries, as responsible for the bad management of the cotton industry. The producers’ interviewed note that the creation of these new institutions incurred significant administrative costs and that the greater the number of intermediary organisations, the lower the benefit for producers. The break-away networks



See Table 1 for the definition and function/meaning of the abbreviations

Source: Group interview with AGROP/FENAPRA members (N= 23), N'dali, 10/ 2004

Figure 4. Participatory diagram of the functioning of institutional linkages, from the perspective of break-away network farmer

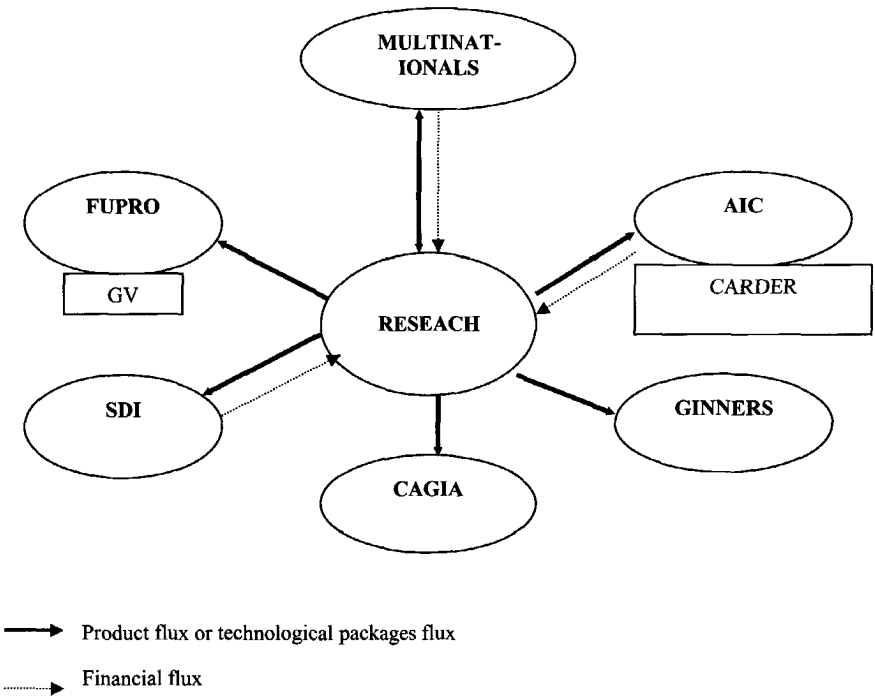
deal directly with input providers and sell directly to the ginneries. Credit recovery is self-managed by these actors.

Because of their experience of the *caution solidaire*, the producers interviewed from the break-away network did not want to include banks in their analysis of the network. As individual credit can now be obtained from banks, they do not see the need for a collective credit guarantee. They also thought that cotton research could be financed by the ginneries and input providers. The latter were also considered to be organisations that could disseminate technology directly to their clients (farmers).

The case of the research institution

The research institution CRA-CF - “Centre de Recherche Agricole Coton et Fibre” is in a close relationship with the formal institutions of the cotton industry and according to our focus group interview with key cotton researchers, they would like to maintain this (Figure 5). It presently recommends to the CAGIA, after experimentation, the products that input sellers should provide to farmers.

The research institution also validates the protocols of multinational suppliers concerning the active ingredients. The AIC, assisted by the extension officers of the national extension service, disseminates the technology recommended by the researchers. The research institution also maintains a relationship with input providers, which finance pest management research. It also collaborates with ginners in identifying improved cotton varieties.



See Table 1 for the definition and function/meaning of the abbreviations.
 Source: Group interview with researchers (N= 8), Cotonou, 10/2004.

Figure 5. Participatory diagram of the functioning of institutional linkages, from the perspective of researchers.

Impact of the reform in the cotton industry on the innovation process and production system

Institutional traps: a systemic pathology

On the one hand, the attempt to stabilise relationships in a liberalised and privatised industry has failed: the authority of the inter-profession (AIC) has ceased to exist among the break-away networks. On the other, opening up competition in input provision has diversified the suppliers but neither safeguarded the quality of the products nor resulted in lower prices. Producers have been the victims of the resultant disorganisation and their attempts to empower themselves have so far been blunted by collusion among key institutional stakeholders. For instance, the government's decision to assign a licensed input provider to each municipality to ensure timely input provision has not led to a satisfactory outcome: the selected companies in some regions have proved incapable of delivering in time, on their part claiming that the period between the government's decision and the beginning of the crop season was too short to meet the demand, especially for the inputs needed to apply the LEC. One company therefore negotiated with SDI "*Société de Distribution des Intrants*", a large enterprise that had a significant stake in the previous cotton chain and is a licensed provider to the formal network, to make up the shortfall. This company failed to provide the LEC inputs so that producers, fearful of not having any means to protect their crop, resorted once more to the conventional crop protection products. The company also required the producers to sell the cottonseed to designated ginneries in the formal system, thus entrapping the nonconformist producers once more in the formal institutional linkages. All the cards of the game seem to be in the hands of those who distort and subvert the intentions of the cotton industry reforms.

Research system

CRA-CF's research programme often is sponsored by the government through funding from overseas collaborators, such as CIRAD (*Centre de coopération Internationale en Recherche Agronomique pour le Développement*) (see Table 1). Liberalisation and the disengagement of the government from the cotton industry have meant that the government's funding of cotton research has declined in real terms and the institute has increasingly had to rely on external assistance and contributions from the cotton industry. The industry's contribution is regarded as a "critical function" and has been set at 10 per cent of the value of seed cotton, shared among the cotton companies according to their purchases of seed cotton.

Two examples illustrate the actual impact of the reforms on the industry's research support:

i) the introduction of a new variety, and ii), the LEC - *Lutte Étagée Ciblée*.

- (i) Before the reform, it was SONAPRA that sponsored cotton research and CRA-CF had to satisfy its needs by providing varieties with a high ginning rate and long fibre length. After the reform, CRA-CF has to satisfy all stakeholders as they now provide the research funding, but it is difficult to meet everyone's different preferences. As the result, the introduction of a new more pest resistant variety (H.289.1), that was expected to be widely in use by the 2002/2003 season, was delayed because it has a fibre length shorter than the ginneries would have liked.
- (ii) The private input suppliers are supposed to provide producers with the pesticides authorised by CRA-CF. CRA-CF researchers recommend the LEC approach to cotton pest management in place of calendar-based spraying; however, LEC has been abandoned because the input suppliers do not want to supply LEC inputs as they make more profit promoting calendar-based spraying.

Extension system

Before the reform, the government supported extension field workers. After the reform, in the context of structural adjustment and the privatisation of the cotton sector, the government cut the number of extension field staff by about two thirds. The inter-profession (AIC) and input providers thus have recruited their own extension agents, called *encadreurs*, who instruct growers in the sequence of technical steps they should follow ("*itinéraire technique*"). As a result, farmers are trained in applying the pesticide companies' recommendations and are not encouraged to practise alternative methods of control. Some growers are becoming more sophisticated and have started to challenge the quality of the instructions but they lack advisers to support them.

Cost effectiveness of cotton production

Almost 75 per cent of the producers interviewed revealed that their lack of alternative sources of income and the increasing need for money for consumption and agricultural production provide their main motivation to produce cotton. They also said that the cotton crop is a very demanding of labour and investments and that the increasing price of inputs after the reforms turned cotton-growing into an uneconomic speculation. Today, a producer's margin on one kilo of cottonseed is only 10 FCFA, or 5.5 % of the total costs of production (Table 5), viz. 12,000 FCFA or € 18.30 per ha. In N'dali municipality the average producer gross margin taking into account average farmed area per producer (2.5 ha) and the average yield (1,200 kg/ha), was 30,000 FCFA or € 45.75 per year. In response to the question of why they continue to produce

cotton, farmers cited two main reasons: i) cotton is the only crop that gives cash income; ii) it is a well-organised production system (in comparison with other crops) in that it allows access to inputs and financial credit.

Table 5. Cotton producer trading account in the N'dali municipality.

Parameters	Quantities	Cost (FCFA)	
		Unit Price	Total
Input			
- Fertiliser	175 kg	198	34,650
- Insecticide	7 l	4,500	31,500
- Herbicide	5 l	6,000	30,000
Labour and small tools	-	-	120,150
Total costs/ha	-	-	216,300
Yield/ha	1,200kg	-	-
Costs per kg	-	180/kg	
Selling price per kg	-	190/kg	
Producer gross margin per kg	-	10/kg	
Average producer gross margin ¹ (FCFA)			30,000

¹ Calculated for 2.5 ha, the average farmed area per producer in the N'dali municipality.

Source: Authors' survey, N'dali, 12/2004.

That is, farmers do not produce cotton because it economically worthwhile, but because participation in the industry provides a way to secure the means to develop other crops.

Analysis and discussion

The institutional framework: a well-directed play or an 'arena' of struggle?

The official description of the institutional linkages in the cotton industry could be described in the metaphor of a play, with well-composed scenes and each actor playing to a script - a favourite metaphor of Goffman (cited in Sardan, 2001).

Indeed, the official institutional framework is surprisingly like a stage in a theatre, in which all the constitutive elements of a successful play have been carefully designed and directed so as to lead to a harmonised production system. But in reality our research shows that the institutional framework is an "arena" or, as defined by Sardan and Biereschken (1994), a "*Social space where social actors confront each other*". Every actor enters the space in order to satisfy his own needs; those who do not feel that their interests are taken into account or who feel threatened, leave the space (Nouatin, 2004), just as the members of the break-away networks have done.

Liberalisation of cotton sector: salvation or an impasse?

Liberalisation and privatisation of the cotton industry has been a difficult undertaking, and not without risks, since cotton is an annual crop needing large fixed investments, which have to be amortised over many years (Goreux & Macrae, 2003). The necessary restructuring could have taken a number of forms, ranging from total liberalisation to a simple restructuring of the state-owned company, SONAPRA, without dismantling the chain-based institutional linkages (the *approche filière*). Many studies indicate that the *approche filière* has sustained rural development in West Africa (Dévèze, 2004; Ton, 2001).

The new decision centre formally is the inter-profession as an industry-wide platform on which the various stakeholders are represented. The stakeholders have become partners in a game that was previously run by a monopoly. It was assumed that farmers' organisations and the private sector were capable of assuring the coordination and the execution of the required activities, motivated by the potential for increasing their profits. But such changes in the organisation of a sector do not guarantee that the producers will get sufficient incomes or a fair share in the profits of the sector. The assumption that competitive pressures would lead to more efficient input markets also has not been confirmed; rather, our evidence suggests that collusion among the institutional stakeholders has thwarted competition.

The entry of the new private actors has given rise to increased difficulties in coordinating the various activities of the industry. The marketing of cottonseed is not more transparent and problems of scheduling appear all along the chain of production. The transfer of responsibility for input provision to the private sector and the removal of input subsidies have resulted in increased input costs for the producer and the new actors' performance has contributed to the deterioration of the input distribution system, notably the input providers' lack of professionalism and the poor quality of the inputs imported.

Another reform objective was the transfer of responsibility to farmer-based organisations, supported by measures to strengthen their capacity to play a larger role and become a strong partner *vis-à-vis* the other actors. However, the transfer to poorly prepared organisations has given rise to problems of leadership and to bad management. The "*mal parties*" see the management of local level activities as an asset to be exploited for private gain or as a 'door' to conceal private profit from the collective interest. Moreover, the organisations' involvement in decision-making with regard to e.g. cottonseed pricing, remains very weak (Ton, 2001). To this day, the farmer-based organisations occupy only a 'small room' (*petite chambre*) in deliberations concerning the future of the sector. They are considered by the more powerful stakeholders as recipients of patronage (*receveuse de politique*)³ rather than as partners.

Our interviews indicate a widely-shared perception that there is one more factor that

³ This expression is from Olloulotan (2001)

undermines the functioning of the new institutional arrangements: monitoring remains in the hands of the technical staff who were for the most part employees of the former, poorly administered, institutions. They are widely believed to be less concerned to service the interests of the new stakeholders than to develop the system so that it keeps vested interests in charge. If the reform process was, above all, a reaction to a major crisis in the cotton sector, at present it has led to a deep crisis of confidence among all the actors. The institutional restructuring has more than ever fractured the relations between different stakeholders and created within every group an increasing number of the disaffected.

The break-away networks: a solution or a perpetuation of the exploitation of producers?

It is clear, as indicated by Berkani (2002), that the official institutional framework is undergoing a second, unplanned re-structuring, driven by the interests of the disaffected. Each of the disaffected institutional stakeholders - ginners, input providers, and farmer-based organisations - have tried to satisfy the expectations that the inter-profession (AIC) was unable to satisfy. But in the process, producers have once again become the means to satisfy others' interests. They are manipulated by the leaders of the disaffected farmer-based organisations in order to satisfy the ginners' interest in acquiring the maximum possible stock of cottonseed and also the input providers' interest in distributing as much inputs as possible, regardless of needs and whatever the quality. In compensation, those responsible benefit from the numerous favours granted by these actors. The producer is once more trapped between the stakes of their leaders, and those of the ginners and input providers. Is it possible for producers to act as key stakeholders, even in the break-away networks? It would seem not, for so long as the producers cannot free themselves from technical dependence on chemical pest control, the input providers have a stranglehold. And as long as cotton incomes remain low (in part because input costs are not reduced), producers' dependence on production credit implicates them in the circular relationship between credit suppliers and the ginneries. Given that the input providers strongly influence the input prices set by the national price fixation committee (although it includes farmer representatives), it seems that farmers not only in the formal, but also in the break-away networks are doomed to remain subordinate.

Faced by this reality, some farmers are seeking to use their 'social web' of relationships to create solidarity among farmers irrespective of the organisation they belong to (it is common to find members of different networks in the same family). Producers are, for example, exchanging inputs between groups. The multiplication of networks has not led to the 'balkanisation' of social linkages based on natural affinities. Rather natural affinities seem to provide a new base for solidarity.

Producer empowerment and change in the production system

In the light of the preceding analysis, the question to be asked is *who benefits?* Is the institutional re-structuring really helping producers, or is it sustaining the position of the rich and powerful actors? The concept of empowerment is at the heart of this debate because the issue of *who benefits* is closely related to the issue of *who decides*, (Bartlett, 2004). When producers gain greater control of their own organisations, when they gain control of their production by shifting to alternative pest management regimes that free them from dependence on credit and designated ginneries, they will be far more likely to achieve a sustained improvement in their well-being.

We conclude that producer empowerment should be the driving force of further developments within the cotton industry. Bartlett (2004) argues that all of us – government, consultants, project managers and field workers – can do a better job if we recognize and foster the empowerment of the people we work with, and suggests a three-element model for achieving this goal, which we have adapted for application to the industry (Figure 6).

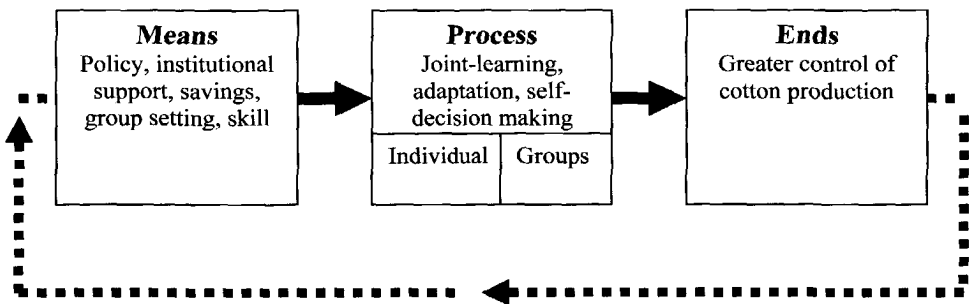


Figure 6. A transformation model of producer empowerment in the cotton sector (adapted from Bartlett, 2004).

The means in the Benin context range from conducive policies and institutional support to the mobilisation of producers’ savings and skills. The current policy setting is not conducive to producer empowerment. An illustrative example is the current research and extension strategy that assumes a linear flow of recommended technologies from scientists to farmers through extensionists. The research institution has made the flow complicit in an institutional relationship that sustains the interests of pesticide companies and ginneries that block the dissemination and adoption of the recommended technologies such as LEC (Floquet and Mongbo, 2003). What process might lead to producer empowerment based on producers’ own economic capacity and skills? A learning system approach (Van den Berg et al., 2001) seems to hold out some promise

(Houkonnou et al., 2006; Chapter 6). However, we are aware that the adoption of any change in the current production system on management practices will be determined by other factors such as national cotton policies or economic forces.

Conclusion

This study has used stakeholder analysis and participatory diagramming to explore the current institutional context of cotton production in Benin. It provides insight into stakeholders' interests in the institutional arrangements and in sustaining – or re-structuring - the linkages among the key organisation. This has led to a clear understanding of how stakeholder interests and relationships develop in interaction.

We have shown how, formally, the institutional linkages are fair and should guarantee a harmonised production but also how the actual rules by which the game is played subvert the aims of the 1990 reforms. The malfunctioning of the formal arrangements under pressure of stakeholders' interests in turn has led to a further, unplanned restructuring by those whose interests have not been served by the formal arrangements. But neither the reform nor the unplanned re-structuring has been favourable to producers and their interests remain subordinate to those of the other stakeholders. We conclude by arguing that only a change in the production system, to release producers from dependence on production credit and pesticide inputs, can empower farmers so that they can become effective partners.

4

Participatory evaluation of synthetic and botanical pesticide mixtures for cotton bollworm control

Sinzogan, A.A.C., D.K. Kossou, P. Atachi, A. van Huis

Abstract

The bio-efficacy of various plants extracts viz., *Azadirachta indica*, *Kaya senegalensis*, and *Hyptis suaveolens*, either alone or in combination with half the recommended dose of synthetic pesticides, was studied with farmers in order to find a more sustainable strategy for the management of bollworms. A number of the treatments were farmer innovations. The treatments were compared six times during the season to the application of the full dose of synthetic pesticides and to a control with no pesticide application. Applications of either the full recommended dose of the synthetic pesticides or the combination with a Neem seed extract (6 kg/ha) were most effective in reducing bollworm incidence and damage. Both treatments gave the highest yields of cottonseed, the latter being the most cost effective. All the pesticides used, except Neem alone, had a toxic effect on bollworm predators. This study has increased farmers' confidence in endogenous technology. The researcher's interaction among the local learning group members, who conducted the experiments, facilitated the introduction of a cost-effective alternative to the standard full-dose synthetic pesticide recommendation.

Keywords: Cotton, plant extracts, synthetic pesticides, bollworms, endogenous technology

A slightly modified version of this chapter is in press as:

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Introduction

Bollworms are one of major cotton pests in most of the cotton growing areas of the world (Bruno, 1997; Reddy, et al., 2000), and particularly in Benin (Youdeowei, 2001; Ton, 2002). Synthetic pesticides are often used to control these pests. In Benin it is the only control strategy recommended by the national cotton research institute “*Centre de Recherche Agricole Coton et Fibre*” (CRA-CF) (INRAB, 2002). However, the use of synthetic pesticides is not sustainable because of: i) the high costs involved (PAN, 2000; Reddy, et al., 2000; OBEPAB, 2002); ii) the development of resistance (Martin et al., 2000; Ochou and Martin, 2002); and iii) the occurrence of resurgence and secondary pest outbreaks. Cotton farmers in Benin have questioned the effectiveness of synthetic pesticides against bollworms, and complain about the high costs of procurement (Sinzogan et al., 2004). Therefore, alternative and more sustainable control measures are sought. The use of plant-based pesticides would be an option. Numerous plant materials have proven to be effective against bollworms either as repellents or as toxicants. Among these, Neem (*Azadirachta indica* A. Juss) is the most well known (Schmutterer, 1990&1995), and formulations based on Neem plant parts have been recommended to control cotton bollworms (Gupta and Sharma, 1997; Gahukar, 2000). However, the effectiveness of Neem-based pesticides for cotton bollworm control has been questioned (Bharpoda et al., 2000; Sarode et al., 2000; and Rawale et al., 2002). This corroborates the farmers’ saying: “*Neem seed extract only pushes bollworms into a dream*” (Sinzogan et al., 2004).

In practice, farmers have been found to adapt the research recommendations to suit their socio-economic and environmental conditions (Sinzogan et al., 2004). These ‘reinvented’ technologies have been incorporated into their production system. Schouwbroeck (1999) demonstrated such a process when dealing with fruit fly control methods in Bhutan. In that context, the technology supplied by research and extension systems became the ‘raw material’ for farmer experimentation (Sumberg and Okali, 1997).

Diagnostic studies were conducted in several cotton production zones of Benin (Sinzogan et al., 2004) in order to assess farmers’ problems, needs and opportunities. Farmers were found to have adapted the recommended bollworm control technology by mixing half the dose of the recommended pesticides with locally available botanicals such as *Kaya senegalensis* Desrousseaux (A. Jussieu) (Meliaceae). They indicated that the mixture has a synergistic effect on bollworms. Neem-based products combined with synthetic pesticides have been found elsewhere to be effective against cotton bollworms (Bharpoda et al., 2000; Sarode et al., 2000). However, these studies do not report on the bio-efficacy of Neem or other plant-based products when combined with synthetic pesticides.

A ‘stakeholder-learning group’ composed of farmers, extension agent, Local Research

Agent (LRA) (the national research institute representative in the research area) and the author of this thesis (as scientist and facilitator) was established to test several control practices. A survey intended to ground the research in the needs and opportunities of these farmers was conducted and revealed the various local practices (Sinzogan et al., 2004).

Two farmers in the learning group used mixed applications of *K. senegalensis* with synthetic pesticides to control bollworms. The other farmers in the group and the LRAs were very much interested in testing this technology. They suggested adding to the trial two other plants known to have toxic or repellent properties, viz. Neem (*A. indica*) and *Hyptis suaveolens* (L.) Poit..

The study aimed to assess jointly with the 'stakeholder learning group' the bio-efficacy of three botanical extracts, viz. *A. indica* seed extract, *H. suaveolens* leaf extract, and *K. senegalensis* bark extract, either alone or in combination with half the dose of the recommended pesticides.

Materials and methods

The experiment was carried out from June to November 2004 in the village of Gounin where farmers used a mixture of botanical and recommended synthetic pesticides (see table 1 for a listing of pesticides applied). It was a 'farmer managed and farmer implemented' experiment (Stroud and Kirkby, 2000). The topic, the experimental set-up, as well as the non-experimental variables (such as the roles of different learning group members) were negotiated with the "stakeholder learning group" (Chapter 6). The group decided on all the implementation modalities, except for the layout, which was planned by the researchers as a complete randomised block design. To assess the effect of the treatments, the researcher, the LRAs, and the farmers developed their own criteria (see below).

Experimental design

The layout was a complete randomised block design with the following eight treatments replicated four times: 1) no pesticides (control); 2) recommended synthetic pesticides (SP); 3) Neem seed extract (Neem); 4) *Hyptis* leaf extract (Hyptis); 5) *Khaya* bark extract (Kaya); and three treatments involving the above mentioned botanicals plus half the dose of recommended synthetic pesticides, respectively 6) Neem-SP; 7) Hyptis-SP; and 8) Kaya-SP. The botanical pesticides were sprayed weekly and the mixtures - made up of these and synthetic pesticides-, and the synthetic products alone were applied at two weeks intervals.

Neem seed extract was applied by spraying, at a dosage of 6 kg/ha (Stoll, 2002 and farmers' practice), *Hyptis* leaf extract at 37.5 kg/ha (Kossou et al., 2001), and *Khaya* bark extract at 25 kg/ha (farmers' practice) (see Table 1). The cotton was sown in 20 x 10 m plots at a theoretical planting density of 1,250 plants per plot. Plants were spaced 0.8 m between rows and 0.4 m within the row. Between plots there were ten buffer rows (8 m).

Table 1. Spray schedule (Days after Sowing – DAS) and dosages of recommended synthetic pesticides (RI) in L/ha, and Mixtures (M) of synthetic pesticides (L/ha) plus extracts of botanicals (kg/ha).

Dates (DAS)	Active ingredients (g/L)	RI dosage (L/ha)	M dosage per ha (L/ha + kg/ha)		
			Neem	Kaya	Hyptis
51	Endosulfan ¹ (350)	2	1 + 6	1 + 25	1 + 37.5
65	Endosulfan (350)	2	1 + 6	1 + 25	1 + 37.5
89	[Cyperméthrine (72), Acétamipride (16), Triazophos(300)] ²	0.5	0.25 + 6	0.25 + 25	0.25 + 37.5
93	Spinosad (48) ³	0.1	0.05 + 6	0.05 + 25	0.05 + 37.5
107	[Cyperméthrine (72), Acétamipride (16), Triazophos(300)] ²	0.5	0.25 + 6	0.25 + 25	0.25 + 37.5
121	[Cyperméthrine (72), Acétamipride (16), Triazophos(300)] ²	0.5	0.25 + 6	0.25 + 25	0.25 + 37.5

Commercial names: ¹ Thionex 350 EC; ² Conquest Plus 388 EC; ³ Laser 480 SC.

Data collection

By farmers and local research agents

Farmers considered replicated observations in space not necessary. They therefore selected for observation only two plots in each of the four blocks, such that the eight treatments were covered. Within each plot (12 rows of 20 m) they selected two rows (numbers 4 and 7) and counted the number of bolls damaged by bollworms on the plants in the row. At 114 Days After Sowing (DAS), on three randomly selected plants in each selected row, the number of healthy bolls on the terminal area of plant (20 cm) was recorded. The general appearance of the whole plot and that of individual plants were also used as assessment criteria of treatment effectiveness.

To assess the efficacy of the pesticides, the local research agents carried out destructive sampling on bolls at 106 DAS (one day before the spraying day), 110 DAS (three days after the spraying day) and 113 DAS (one day before the subsequent spraying day) in the weekly sprayed plots; and at 106 DAS (one day before the spraying day) and 114 DAS (one week after the spraying day) in the two-weekly sprayed plots. Three bolls were collected on each of five randomly selected plants each time when walking diagonally through the plot. The number of healthy as well as damaged bolls was counted. The number and species of bollworms found were recorded.

By research scientists

Research scientists counted the bollworms and their predators, and assessed bollworm damage (Youdeowei, 2001; INRAB 2002; OBEPAB, 2002; Ton, 2002; Sinzogan et al., 2004). Sampling was conducted in all plots at 7-day intervals throughout the whole cotton growing season (from July to September).

Samples of ten cotton plants per plot were randomly selected during the whole growing season. Each of the ten plants was examined weekly for bollworm larvae. Sampling concentrated on the terminal area (upper 20-30 cm) (MSU, 2003) and reproductive organs (flower buds and bolls). In addition developing squares were checked for small larvae (Van den Berg, 1993). The number of healthy and bollworm damaged flower buds and bolls also were recorded.

After checking without touching any plant parts for predators on all ten plants (Van den Berg, 1993), the plants - including the flowering/fruitlet parts were scrutinised. The predators encountered were recorded and collected for identification at IITA, Cotonou, Benin, and at the Laboratory of Entomology of the Wageningen University in the Netherlands.

Cottonseeds were harvested October 29 and November 15 in an area of 4 x 8 m² located in the middle of the plot to avoid border effects.

Data analysis

The sampling data were pooled per plot. Transformations ($\text{Arcsin}\sqrt{X}$, x =percentage; $\text{Log}_{10}[x+1]$, x = number of insects) were used to achieve normality and homoscedasticity before analysis. Statistical analyses were made using SAS software version 8. Farmers' data were evaluated using a ranking system that combined the results for the number of damaged bolls and the number of bolls on the terminal area of the plant (20 cm), and completed with the general appreciation of the plot.

The Incremental Cost Benefit Ratio (ICBR) (Sarode et al., 2000) for each treatment was based on pooled data over three years using costs of the pesticides (excluding application costs), labour (to prepare the botanical pesticides), and the price to producer of the cottonseed. The "stakeholder learning group" together estimated the labour price for preparing the botanical pesticide.

Results

Effect of pesticide treatment on bollworm damage

Flower buds and bolls were significantly less damaged in the plots sprayed with the recommended synthetic pesticides (SP), at full dose, and with the mixtures of Neem, *Kaya* and *Hyptis* combined with half the dose of SP applied six times at fortnightly intervals, than in the control

plots (Table 2). The bolls were significantly less damaged in the plots sprayed with the SP-full dose and the Neem-SP mixture than in the plots treated with botanical pesticides alone. There was no statistically significant difference in the number of flower buds and bolls damaged by bollworms between the plots treated with botanical pesticides alone and those not treated.

Table 2. Effect of mixtures of botanicals and synthetic pesticides (SP) on the damage of bollworms on buds and bolls, as evaluated by researchers, Local Research Agents (LRA) and farmers, using different criteria as described in the text.

Treatments	Researcher		LRA	Farmers		
	Bud damage (% ± SE)*	Boll damage (% ± SE)*	Non-damaged bolls/ 60 bolls (% ± SE)**	Average number of damaged bolls/ 2 rows***	Average number of bolls on terminal area/ plant****	Rank
Control	5.2 ± 2.2 a (0.43)	10.2 ± 1.0 a (0.65)	40.0 ± 3.1 a (1.37)	16.25	3	8
Hyptis	2.2 ± 0.6 ab (0.29)	9.2 ± 0.4 ab (0.61)	51.0 ± 3.0 b (1.59)	11.00	4	7
Kaya	3.5 ± 1.5 ab (0.34)	8.5 ± 0.8 ab (0.59)	51.5 ± 1.5 b (1.60)	11.25	5	6
Neem	2.0 ± 0.4 ab (0.27)	9.2 ± 1.4 ab (0.61)	52.7 ± 2.9 b (1.62)	9.00	5	5
Hyptis-SP	0.7 ± 0.2 b (0.15)	5.7 ± 0.8 bc (0.48)	69.2 ± 0.8 c (1.96)	8.50	5	4
Kaya-SP	1.0 ± 0.0 b (0.20)	6.0 ± 0.9 bc (0.49)	68.7 ± 1.4 c (1.95)	7.00	6	3
Neem-SP	0.7 ± 0.2 b (0.15)	4.2 ± 0.2 c (0.41)	80.0 ± 2.1 d (2.21)	4.00	8	2
SP	1.0 ± 0.0 b (0.20)	4.0 ± 0.7 c (0.40)	81.5 ± 1.8 d (2.25)	2.75	9	1
F-value	3.54	8.03	41.81	-	-	-
Pr > F	0.009	0.0001	0.0001	-	-	-

* Based on mean of four replications of 10 observations recorded on ten plants at weekly intervals starting from 50 DAS; ** Based on mean of four replications of data collected at 113 DAS for plant extract; and 114 for the mixture and recommended pesticides; *** Based on mean of 10 observations recorded on two rows of twenty five plants at weekly intervals starting from 50 days after sowing (not statistically analysed); **** From data collected at 114 DAS on six plants (not statistically analysed).

-Figures in parentheses are arcsin√(x/100) values (x being percentages).

-Values in columns followed by the same letter are not significantly different at P> 0.05 by Student Newman and Keuls test.

When using the number of damaged bolls and number of bolls on the plant terminal area (20 cm) as their evaluation criteria for treatment efficacy, the farmers ranked the SP treatment first, followed by Neem-SP and Kaya-SP.

The analysis of the destructive sampling of bolls made by the local research agents revealed

that the synthetic pesticides treatment alone, and the combination of synthetic pesticides with Neem, had significantly more non-damaged bolls (about 80%) than the control (40%), while the other treatments ranged between 50% and 70%.

Effect of pesticide spraying on bollworm larvae

The damage by bollworms on the plant was recorded at 85 DAS i.e. more than a month after the emergence of the first flower buds. Four species of bollworms were identified and grouped in three categories depending on their feeding habit: *Sylepta derogata* F. larva, which feeds on vegetative parts; and *Earias sp.*, *Helicoverpa armigera* (Hübner), *Cryptophlebia leucotreta* (Meyrick) and *Pectinophora gossypiella* (Saunders) larvae, which feed on bolls. Each larva of the first two species is capable of damaging several bolls, while each larva of *C. leucotreta* and *P. gossypiella* damage only one.

The botanical pesticides Neem, *Khaya*, and *Hyptis*, and their mixtures with synthetic pesticides, as well as synthetic pesticides alone, suppressed the *S. derogata* larval population, under the economic threshold level (ETL) determined by Silvie (2001) and CRA-CF (2003) (Table 3).

All treatments with botanicals, and the mixtures of botanicals with synthetic pesticides,

Table 3 Larval populations of bollworms in cotton in comparison with the economic threshold level (ETL).

Treatments	<i>Sylepta derogata</i>		<i>Earias spp./ Helicoverpa armigera</i>		<i>Cryptophlebia leucotreta/ Pectinophora gossypiella</i>	
	Average no./plant*	No. over ETL**	Average no./ plant*	No. over ETL**	Average no./ plant*	No. over ETL**
Control	0.51 ± 0.04 a	0.01	0.54 ± 0.02 a	0.29	0.47 ± 0.08 a	0.22
Hyptis	0.20 ± 0.07 b	-0.30	0.30 ± 0.06 bc	0.05	0.29 ± 0.01 b	0.04
Kaya	0.26 ± 0.06 b	-0.24	0.27 ± 0.03 bc	0.02	0.29 ± 0.03 b	0.04
Neem	0.26 ± 0.03 b	-0.24	0.37 ± 0.05 b	0.12	0.32 ± 0.01 b	0.07
Hyptis-SP	0.14 ± 0.03 b	-0.36	0.11 ± 0.02 d	-0.14	0.05 ± 0.01 c	-0.20
Kaya-SP	0.12 ± 0.06 b	-0.38	0.21 ± 0.05 cd	-0.04	0.11 ± 0.04 c	-0.14
Neem-SP	0.19 ± 0.06 b	-0.31	0.15 ± 0.00 cd	-0.10	0.11 ± 0.01 c	-0.14
SP	0.09 ± 0.04 b	-0.41	0.12 ± 0.01 d	-0.13	0.11 ± 0.01 c	-0.14
F-value	5.6		12.34		17.05	
Pr > F	0.0006		0.0001		0.0001	

* Mean per plant ± SE (computed from four replications of 10 observations on 10 plants at weekly intervals starting from 50 DAS).

** 0.5 for *S. derogata* (20 larvae/40 plants/ha); 0.25 for *E. insulana*, *H. armigera*, and *C. leucotreta* (10 larvae/40 plants/ha) (CRA-CF, 2003; Silvie, 2001).

- Means in columns followed by the same letter are not significantly different at P> 0.05 by Student Newman and Keuls test.

and the synthetic pesticides alone, lowered significantly the incidence of all bollworm species compared to the control. The mixtures of botanicals and synthetic pesticides, and the synthetic pesticides alone, seem to suppress the different bollworm species better than botanicals pesticides alone. In the untreated plot the bollworm population rate surpassed the ETL (0.29 for *Earias* spp. and *H. armigera*, and 0.22 for *C. leucotreta* and *P. gossypiella*). In all plots treated with mixtures of botanicals and synthetic pesticides, and with the synthetic pesticides alone, the population was below the ETL.

The results of the destructive sampling of the green boll carried out by the local research assistants were similar to those mentioned above. All treatments lowered the larval population of the bollworm in comparison to the control (Figure 1 A-F).

Effect of pesticides on predators

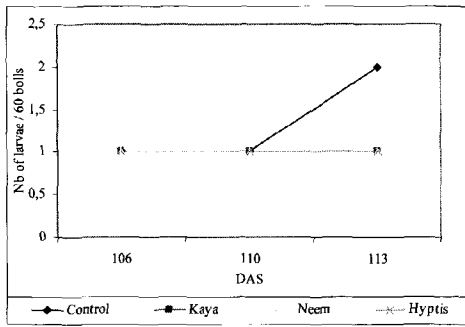
A number of potential natural enemies of bollworms were collected from the field. Ants, ladybird beetles, and spiders were the groups present in a large enough number to be analysed. Three coccinellid species (both adults and larvae), *Cheilomenes vicina* (Mulsant), *C. propinqua* (Mulsant) and *C. lunata* (Fabricius), were repeatedly observed within the fields. Among the collected ants we identified three different genera: i) *Camponotus* spp.: *Camponotus maculatus* (Fabricius), *C. sericeus* (Fabricius), *C. acvapimensis* Mayr, *C. flavomarginatus* (Mayr); ii) *Lepisiota* spp.; iii) *Dorylus bürmeisteri* (Shuckard). The spiders collected were not identified.

All treatments, except Neem, lowered significantly the population of ants, coccinellids, and spiders when compared to the control (Table 4).

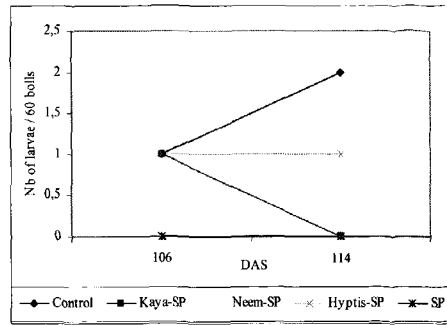
Cost and benefits of the pesticide applications

The highest yield of 2.27 t/ha was realised in the plots treated with one of the mixtures, Neem combined with the synthetic pesticides (Neem-SP), and this was significantly higher than the yields obtained in the other treatments. It was followed by 1.84 t/ha realised in plots treated with synthetic pesticides (SP), which was statistically similar to the yields realised in plots treated with Kaya-SP and Hyptis-SP (1.77 and 1.54 t/ha respectively) (Table 5). However, the yield obtained in plots treated with Hyptis- SP was not significantly different from the one obtained in the untreated plot (1.13 t/ha).

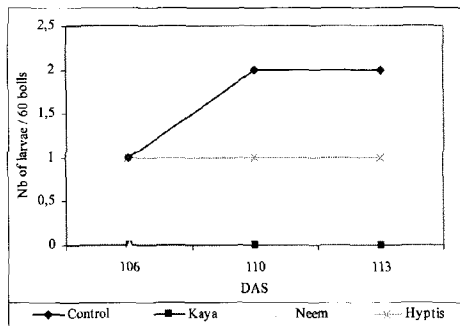
The plots treated with the mixture of Neem and synthetic pesticides had the highest Incremental Cost Benefit Ratio (ICBR), viz. 1:5.4. It was followed by the treatment of the mixture, synthetic pesticides combined with Kaya (1:2.7), and by the synthetic pesticides used alone (1:1.9). The costs of applying Neem alone were higher than the benefits obtained, the ICBR being 1:-1.82.



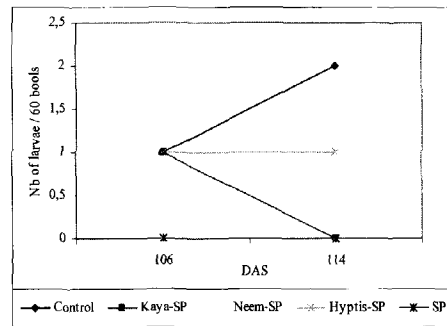
A



D



B



E

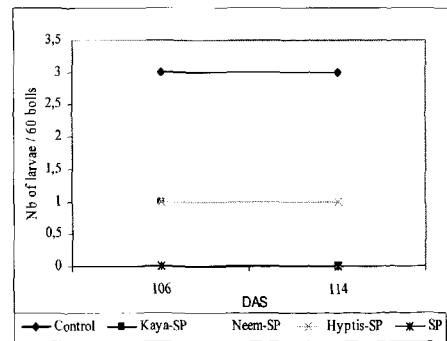
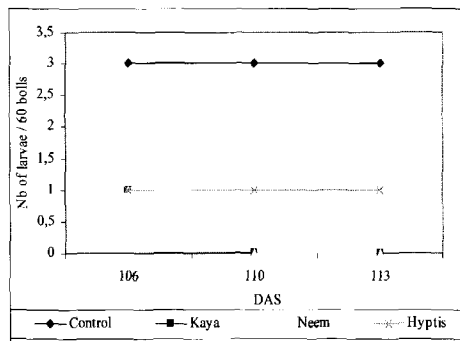


Figure 1. Effect of plant extract alone and in combination with synthetic pesticides on larval populations of: *Helicoverpa armigera* (A resp. D), *Earias* spp. (B resp. E) and, *Cryptophlebia leucotreta* (C resp. F).

Table 4. The effect of botanical and synthetic pesticides alone and in combination on different predators in cotton fields.

Treatments	Ants	Coccinellids	Spiders
	Mean no. of adults / plant *		
Control	4.3 ± 0.1 a (0.72)	0.9 ± 0.1 a (0.27)	0.4 ± 0.0 a (0.14)
Hyptis	3.0 ± 0.1 b (0.60)	0.3 ± 0.0 b (0.11)	0.2 ± 0.0 b (0.07)
Kaya	3.0 ± 0.1 b (0.60)	0.2 ± 0.1 b (0.07)	0.2 ± 0.0 b (0.07) b
Neem	4.1 ± 0.1 a (0.70)	0.7 ± 0.1 a (0.23)	0.3 ± 0.0 a (0.11)
Hyptis-SP	0.1 ± 0.0 d (0.04)	0.2 ± 0.1 b (0.07)	0.2 ± 0.0 b (0.07)
Kaya-SP	0.0 ± 0.0 e (0.00)	0.1 ± 0.0 b (0.04)	0.2 ± 0.0 b (0.07)
Neem-SP	1.4 ± 0.1 c (0.37)	0.2 ± 0.1 b (0.07)	0.2 ± 0.0 b (0.07)
SP	0.2 ± 0.0 d (0.07)	0.1 ± 0.0 b (0.04)	0.1 ± 0.0 c (0.04)
F-value	489.67	16.31	18.54
Pr > F	0.0001	0.0001	0.0001

* Mean per plant ± SE (computed from four replications of 10 observations on 10 plants at weekly intervals starting from 50 DAS).

- Figures in parentheses are $\text{Log}_{10}(X + 1)$ (X being number of insects).

- Means in columns followed by the same letter are not significantly different at $P > 0.05$ by Student Newman and Keuls test.

Discussion

The intensive use of synthetic pesticides in cotton has severe drawbacks (van den Berg, 1993; Ton et al., 2000). The motivating factor for farmers to grow cotton is the cash return and the opportunity to improve their livelihoods (Sinzogan et al., 2004).

This research sought to identify an efficacious pesticide, which would be both cost-effective and reduce the impact on health and the environment. It also aimed to develop stakeholders' confidence in the effectiveness of endogenous technology (Chapter 6). In fact, the selection of entry points that are relevant from farmers' perspectives is critical for the success of any integrated pest or crop management intervention (Morse and Buhler 1997; van Huis and Meerman 1997; Meir and Williamson 2005). Therefore, we focused on reducing the dependence on external inputs and lowering production costs (Williamson et al., 2005), taking into account that pesticide treatments constitute 30-40% of the production costs (Ton, 2001, Sinzogan et al., 2006).

All the treatments demonstrated an efficacy in reducing populations of the key bollworm species *Earias* spp., *H. armigera*, *P. gossypiella*, and *C. leucotreta* when compared to the control. However, the botanicals (Neem, Kaya and Hyptis) themselves did not lower populations below the economic threshold levels established for the three key bollworm species. The economic analysis of costs and benefit using these ETLs showed a negative result for the Neem and Hyptis treatments and a neutral one for the Kaya treatment. These results confirm the validity of the economic threshold level (Silvie, 2001; CRA-CF, 2003).

The three botanical pesticides did not reduce the number of damaged bolls and squares, and in this respect they did not differ from the untreated control. A number of authors have found a lower efficacy for Neem when compared to synthetic pesticides (Samuthiravelu and David, 1990; Dhawan and Simwat, 1993; Bharpoda et al., 2000; Jeyakumar and Gupta, 2000; Patel and Vyas, 2000; Sarode et al., 2000; Rawale et al., 2002). Neem (azadirachtin) is reported to be a fitness reducer and oviposition deterrent to bollworms only when consumed in large quantities (Schmutterer, 1990; Gahukar, 2000; Ma et al., 2000).

Concerning the botanical *H. suaveolens*, Raja et al. (2005) found in the laboratory an antifeedant and an ovicidal effect on *Spodoptera litura* F. and *H. armigera*. We have found no references on the effectiveness of the *K. senegalensis* on cotton pests. Our results indicate that the recommended synthetic pesticide, followed by the Neem seed extract mixed with half the dose of recommended pesticides was the most effective in reducing the incidence of bollworms, when assessed by researchers, local research assistants and farmers. This finding is in accordance with the results obtained by Samuthiravelu and David, (1990); Dhawan and Simwat (1993); Sarode et al. (2000); and Bharpoda et al. (2000). However, the highest yield (2.27 t/ha) was recorded in the plots sprayed with a Neem seed extract mixed with half the dose of the recommended pesticides. This result could be explained by the fact that we only took bollworms into account, for the reason that these are considered by both cotton researchers in Benin and the local farmers as the most important pests (Youdeowei, 2001; INRAB 2002; OBEPAB, 2002; Ton, 2002; Sinzogan et al., 2004). According to Ton (2002), below an average rainfall of 1,000 mm per year (the drier zones where we did our experiments), the key species to monitor are: American bollworm (*H. armigera*), Spiny bollworm (*Earias* spp.), and Sudan bollworm (*Diparopsis* spp.), assuming that other pests are controlled by natural enemies. However, heavy pesticide applications in farmers' fields, especially the use of pesticides like endosulfan at the beginning of the cotton crop growing season, may have destroyed the natural enemy complex normally present in natural agro-ecosystems. Secondary pests like sucking insects become then important and we assume that those insects, when using the mixture of Neem and synthetic pesticides were controlled concurrently with the bollworms, thus allowing

Table 5. Effect of botanical pesticides, synthetic pesticides (SP) and combinations on cotton yields, in relation to pesticide costs, labour costs (to grind plant material), and the incremental cost-benefit ratio (ICBR).

Treatments	Pesticide quantity and labour per ha		Cost (Euro/ha)		Yield (T/ha)	Yield increase over control Euro/ha	Incremental benefit B-A	ICBR (B-A)/A	Rank	
	Quantity (D +kg)*	Labour (M/day)	Insecticide	Labour Total (A)						T/ha
Neem-SP	Half D + 36	3	46.1	5.1	51.2	1.14	330.6	279.4	1:5.4	1
SP	Full D + 0	0	70.5	0	70.5	1.84 b	205.9	135.4	1:1.9	3
Kaya-SP	Half D + 150	9	35.3	15.3	50.6	1.77 b	185.6	135.0	1:2.7	2
Hyptis-SP	Half D + 225	12	35.3	20.4	55.7	1.54 bc	118.9	63.2	1:1.1	4
Kaya	0 + 300	18	"	30.6	30.6	1.26 c	37.7	7.1	1:0.2	5
Hyptis	0 + 450	24	"	40.8	40.8	1.19 c	17.4	-23.4	1:-0.6	6
Neem	0 + 72	6	21.6	10.2	31.8	1.04 c	-26.1	-57.9	1:-1.8	7
Control	"	"	"	"	"	1.13 c	"	"	"	"

* Quantity (D +kg) = total quantity of [synthetic pesticide (D) + plant extract (kg)] used per ha through the crop season.

- Values in columns followed by the same letter are not different ($P > 0.05$) - M/day = man/day - D= dose.

Note: 1. 1 man/day cost 1.7 Euro.

2. Full dose in standard programme cost 70.5 Euro.

3. 1kg Neem seed cost 0.3 Euro.

4. Market sale cost of cottonseed based on pooled data of three years is 0.29 Euro/kg.

5. 1 Euro = 655 CFA.

the higher yield obtained in these plots (Chapter 5). Ascher et al. (1996) and Gahukar (2000) found that when plant-derived products or biocides such as Neem are combined with synthetic pesticides, cotton insects are better controlled, suggesting a synergistic effect. We presume that the antifeedant effect of Neem provokes a higher mobility of the insect when searching for food. This exposes them more to the synthetic pesticide, and that this effect does not occur in treatments without the Neem component. The botanicals act as a stress factor increasing the vulnerability of the pest insects to other sources of mortality (Murray et al., 1993; Trisiyono and Whalon, 1999).

All the pesticides used, except Neem, had a toxic effect on the predators (Table 4). The synthetic pesticides, also in the mixtures with the botanicals, are not selective in their mode of action (Matthews, 1989; Ton, 1998; Stoll, 2002). Many authors have found Neem-derived products to be harmless against cotton pests predators (Mansour et al., 1986; Natarajan, 1990; Schmutterer, 1990; Spollen and Isman, 1996; Van de Veire et al., 1996; Wazunj et al., 1996).

In our experimental fields, ants were present in higher number than any other group of predatory insects, although three species of coccinellids (*Cheilomenes propinqua*, *C. vicina*, and *C. lunata*) and spiders (not identified) were commonly observed. *Camponotus* spp. was the most numerous ant genus found and three species were identified. This genus has been referred to by Van den Berg and Cock (1993) as a predator of *H. armigera* in Kenya. The Dorilinae subfamily, *Dorylus* spp. was also quite abundant within our experimental fields. The Dorilinae, or driver ants, are well-known predators of lepidopterous larvae in Kenya and their nests, as a conservation practice, can be easily transferred to crop fields (Stoll, 2002). Ant foraging activity can also be enhanced by providing alternative food sources such as floral exudates of other plants (Cherry et al., 2003). Artificial mixtures of water and sugar or molasses also can be sprayed over the fields. These solutions in addition have been shown to attract other natural enemies, such as Coccinellidae, *Chrysoperla* sp. and *Orius* spp. (Stoll, 2002). The mixture of Neem with synthetic pesticides was shown to have a toxic effect on predators and therefore should not be recommended whenever the conservation of natural enemies is required for control purposes.

Based on the economic analysis, the learning group concluded that use of the synthetic pesticide alone was not the most economical (even when environmental, ecological and health costs are not considered). From among all the treatments evaluated, the Neem seed extract mixed with half the dose of recommended pesticides was the most cost effective.

Another question to be asked is whether a Neem mixture would be an acceptable alternative to the farmers in terms of availability and the amount of labour involved. This was not studied.

Finally, when considering botanicals alone and in combination with pesticides the following points also arise: 1. except for Neem, all the products used were harmful to the

natural enemies; and 2. the spraying was carried out on a prophylactic basis, and not as needed. Neem appears to be harmless against natural enemies and therefore can be incorporated into an Integrated Pest Management (IPM) strategy. The use of selective pesticides like *Bacillus thuringiensis* also would conserve the natural enemies at the beginning of the season, allowing the natural enemies to build up. Later in the season a mixture of Neem and synthetic pesticides could be applied, when and only when economic thresholds are reached. Such an IPM strategy is more labour intensive, and requires investment by farmers in learning to recognise the insect complex, and scouting by using the economic threshold concept, while at the same time taking into account the presence of natural enemies.

The way in which this study was conducted increased the participating farmers' confidence in their endogenous technology. The encounter among the learning group members allowed the introduction of cost-effective alternative to the recommended practice of synthetic pesticides.

5

Use of entomopathogenic, botanical and synthetic pesticides to manage cotton pests in Benin

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Abstract

In order to develop a sustainable cotton pest management strategy under the ecological conditions of northern Benin the field bio-efficacy of the entomopathogenic formulations of *Bacillus thuringiensis* (Bt) and *Saccaropolyspora spinosa* (Spinosad), and of the mixture of *Azadirachta indica* (Neem) plant extract with half the recommended dose of synthetic pesticides, was evaluated with farmers. The Bt pesticide and the Neem combined with reduced dosages of synthetic pesticides treatments were applied using an economic threshold level (ETL). The treatments were compared to the standard recommended package of the full dose of synthetic pesticides and to a control with no pesticide application. By using ETLs it was possible to reduce the number of applications from six to four by only applying half the quantity of active ingredients. Compared to the standard recommended package of synthetic pesticides the ETL treatments proved to be less harmful for predators like ants, spiders and coccinellids. When Neem was mixed with half the dose of the recommended pesticides the effect on bollworms was equally effective as the recommended package of synthetic pesticides. It was also most effective in protecting bolls against heteropterous insects. The mixture of Neem and synthetic pesticides using ETLs resulted in the highest incremental cost benefit ratio, viz. 1:7.1. As the treatments were carried out and evaluated with farmers, the chance of best practices being accepted by them increases.

Keywords: cotton, insect pests, entomopathogen, Neem, synthetic pesticides, economic threshold, Benin

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Introduction

The major biological constraint to cotton production in West Africa is the damage caused by insect pests (Ton, 2002; Katary, 2003). The conventional strategy for controlling these pests is based on synthetic pesticides (Ochou et al., 1998; Eveleens, 2004) that have economic, human health, and environmental repercussions (Wesseling et al. 2001; Fenske, 2002). There is a high risk of falling into the trap of the pesticide treadmill (Castella, 1999), because pests develop resistance to pesticides (Martin et al., 2000; Ochou and Martin, 2002; Katary, 2003) which also destroy the natural enemies of the pests, leading to pest resurgence and secondary pest outbreaks.

Farmers' margins for making a profit from cotton in Benin recently have been reduced as the price of pesticides has increased (Williamson, 2003; Sinzogan et al., 2006) and the producers' price for cotton has decreased (from 200 CFA/kg in 2000 to 185 CFA/kg in 2006). Some farmers therefore neglect the cotton crop, leading to low yields and bad quality of the produce. Others have abandoned cotton production altogether (Matthess et al., 2005). Maintaining high levels of productivity and profitability while reducing pesticide costs then becomes a challenge. Perrin (1997) called for an integrated pest management (IPM) approach, which he defined as "*An adaptable range of pest control methods, which is cost effective whilst being environmentally acceptable and sustainable*". However, farmers are reluctant to adopt IPM. Farmers' problems are not well appreciated nor the ecological specificity of insect-plant interactions. IPM must be driven by farmers' needs and build on farmers' conceptualised knowledge. *What farmers don't know can't help them* (Bentley, 1989).

In Benin, calendar spraying of synthetic pesticides is recommended by the Cotton Research Institute "*Centre de Recherche Agricole Coton et Fibres*" (CRA-CF). They propose a total of six applications per season at 2-weekly intervals, starting 45 days after planting (the first two applications using a simple insecticide such as Endosulfan and the four subsequent ones using a mixture of many different insecticides). Endosulfan is classified by WHO as moderately hazardous (WHO, 2005), and is recommended by CRA-CF as an early season insecticide. This certainly destroys the complex of natural enemies normally present in untreated agroecosystems.

During a study in the Northern region of Benin (Sinzogan et al., 2004) it was found that farmers had developed a technology in which they halved the dose of the recommended pesticides by mixing the dose with plant extracts. Such mixtures of botanicals with synthetic pesticides proved to be more economical than when using only the full dose of synthetic pesticides (Chapter 4). However, this technology as practised by the farmers still has some drawbacks: i) it does not conserve natural enemies; and ii) the number of applications may be

unnecessary, as decisions to spray are based on the calendar and not on economic thresholds.

When a complex of insects pests is involved, it is unlikely that a single control method would be able to provide an acceptable solution to all insect problems (Reddy & Manjunatha, 2000). Would it be possible to integrate the botanical/synthetic pesticides mixture into an IPM approach? And would it be possible to conserve as much as possible the natural enemies? The possibilities to be considered are: i) using an economic threshold level (Silvie et al., 2001; Naranjo, 2002 & 2003; CRA-CF, 2003); ii) using selective insecticides that would not harm the natural enemies, viz. those based on *Bacillus thuringiensis* (Bt)(Patel and Vyas, 2000; Jeyakumar and Gupta, 2002; Zia-ur-Rehman et al., 2002), or on the actinomycete soil bacterium *Saccaropolyspora spinosa* (Spinosad) (Ma et al., 2000; Mensah, 2002; NOSB-TAP, 2002). Such selective pesticides could be used early in the season when there is less pressure from bollworms, and this would allow natural enemies to build up and control other pests (Wilson et al., 1998; Naranjo, 2002 & 2003). However, with a higher density of pest populations, in particular bollworms later in the season, probably at least a few rounds of synthetic pesticides would still be required (Jeyakumar and Gupta, 2002).

This paper is not intended to demonstrate a novel method of cotton pest control. Rather, it is an attempt to evaluate how locally available alternative control measures, such as Neem seed extract mixed with half the dose of the recommended pesticides (Bharpoda et al., 2000; Sarode et al., 2000; Chapter 4), and selective pesticides such as Bt and Spinosad, could be combined to get “a best mix of control tactics for a given pest problem in comparison with yield, profit and safety of alternative mixes” (Kenmore et al., 1985). The IPM emphasis is on reducing the dependence on broad-spectrum pesticides such as Endosulfan, on lowering the concentration of synthetic pesticides by mixing them with botanicals, and relying more on the action of natural enemies by using selective pesticides such as Bt or Spinosad. Under field conditions we tested different combinations of Neem mixed with reduced dosages of synthetic pesticides, and application of Bt pesticide using an ETL, in order to develop a more sustainable cotton pest management strategy under the conditions of northern Benin.

Materials and methods

The experiment was carried out in 2005 in the village of Gounin (northern part of Benin). The botanical used was Neem of which the seed extract was mixed with half the dose of specific pesticides recommended by CRA-CF.

The experiment was a ‘researcher-managed and farmer-implemented’ trial in which researchers planned the trial while farmers were encouraged to carry out their farming operations

in the normal way, allowing the researcher to evaluate how the treatment performed under current farm management (Stroud & Kirkby, 2000).

Experimental design

Five treatments, described in Table 1, were replicated four times in a randomised block design. Strips of 20 m wild vegetation separated the experimental plots of 25 x 20 m (500 m²). Plants were spaced 0.8 m between rows and 0.4 m within rows, giving 3,264 plants per plot. A 100 m strip of wild vegetation separated the plots of the treatment of the standard recommended programme, in which only synthetic pesticides were used, from the other treatment plots in order to limit the effects of contamination.

Table 2 shows the pesticides and dosages used in the different treatments, which were designed to control specific pests. Plots were sprayed with a ULV knapsack sprayer, using EC formulations calibrated at 10 L/ha.

Table 1 Description, aim and assumption of different treatments used to control cotton pests in Benin.

Treatments	Description	Aim	Assumption
Control	No insecticides	Comparison	-
Standard	SP (2-weekly applications) starting at 45 DAE	Comparison	-
T1	Bt using ETLs by weekly scouting from 30 DAE onwards	Bollworm control (save n.e.)	Bollworms are the only problem
T2	Bt using ETLs; weekly scouting from 30 to 70 DAE After 70 DAE using ETLs by weekly scouting: - MP/Neem (only when bollworms reach ETL) - SP/Neem (when pests other than bollworms reach ETL)	Bollworm control (save n.e. early in season)	Bollworms important early in season
		Bollworm control (save n.e.)	Bt not effective anymore
		Control of all pests	All pests important
T3	ETLs by weekly scouting from 30 DAE onwards: - MP/Neem (only when bollworms reach ETL) - SP/Neem (when other pest reach ETL)	Bollworm control (save n.e.) Control of all pests	Bt not effective against bollworms MP not effective against other pests

DAE: Days after emergence; Neem= Seed extract; MP= Micro-Pesticide Spinosad; SP= Synthetic pesticide; MP/Neem= Mixture of MP and Neem; SP/Neem= Mixture of SP and Neem; n.e.=natural enemies.

Table 2. Pesticides and dosages used in different treatments to control specific pests in cotton when economic threshold levels (ETL) were reached (see Table 1 for explanation of the treatments).

Treatments	Scouting/calendar spraying or ETL	Active ingredient (g/L)	Quantity per ha per spray	Target pest
Control	Weekly (30-115 DAE)			
Standard programme	Weekly (30-115 DAE)/ - (45, 59 DAE)	- Endosulfan (350) ¹	2 L	All cotton insects
	- (73, 101, 115 DAE)	- [Cyperméthrine (72), Acétamipride (16), Triazophos (300)] ²	0.5 L	All cotton insects
	- (87 DAE)	- Spinosad (48) ³		
	Weekly (30-115 DAE)/ ETL basis	- Bt aizawai, 15.000 IU/ mg	0.1 L 1 kg	Bollworms Bollworms
T2	Weekly (30- 70 DAE)/ ETL basis	- Bt aizawai, 15.000 IU/ mg	1 kg	Bollworms
	Weekly (70-115 DAE)/ ETL basis	- [Cyperméthrine (72), Acétamipride (16), Triazophos (300)]+ Neem	0.25 L + 6 kg	All cotton insects
		- Spinosad (48) + Neem	0.05 L + 6 kg	Bollworms
T3	Weekly (30-115 DAE)/ ETL basis	- [Cyperméthrine (72), Acétamipride (16), Triazophos (300)]+ Neem	0.25 L + 6 kg	All cotton insects
		- Spinosad (48) + Neem	0.05 L + 6 kg	Bollworms

Commercial names: ¹ Thionex 350 EC; ² Conquest Plus 388 EC; ³ Laser 480 SC; DAE: Days after emergence; Neem= Seed extract; IU= International Unit.

The sampling procedure, economic thresholds, and pesticides dosage

Weekly scouting for insect pests started at 30 days after emergence (DAE). The sampling procedure and action threshold used were adapted from those previously described by Silvie et al. (2001) and CRA-CF (2003.) (Table 3).

The method of three diagonal transects with five points was used in order to sample insect populations in the plots. Four plants per point, a total of 20 plants per plot, were sampled. On each plant, fruiting sites were inspected for bollworms, and the upper leaves were checked for leaf-eating caterpillars and aphids.

Table 3. Scouting procedure and threshold level of different cotton insect pest species in Benin.

Insects pest species	Scouting procedure	Economic Threshold level/20 plants
Cotton bollworm: <i>Helicoverpa armigera</i>	Examine buds, flowers and bolls of one plant and count larvae	3 larvae
Other bollworms: <i>Earias sp.</i> , <i>Cryptophlebia leucotreta</i> , <i>Diparopsis watersi</i> , <i>Pectinophora gossypiella</i>	Examine whole plant (buds, flowers, and bolls) and record number of larvae	5 larvae
Leafworm: <i>Spodoptera littoralis</i>	Count number of plants with damaged leaves or with larvae	5 plants with either leaf injury or larvae/
Aphid: <i>Aphis gossypii</i>	Examine five fully developed top leaves of plant. The plant is considered infested when aphids are encountered on one leaf	8 plants infested
Mite: <i>Polyphagotarsonemus latus</i>	Examine five fully developed top leaves of the plant. The plant is considered infested with mites on one leaf	1 to 2 plants infested

¹ Adapted from Silvie et al. (2001), and CRA-CF (2003)

Data collection

Adults, nymphs or larvae of cotton bollworms, aphids, mites, and heteropterous insects were counted on the sampled plants. Only those visible were counted (Van den Berg, 1993). Beneficial arthropods were sampled using a beat sheet method (Scholz et al., 2001). This was done as follows. A white cloth sheet of 2 m wide was placed on the ground below the plants to be sampled and was stretched up to the adjacent row. A 0.3 to 1 m section of plants was shaken six times vigorously with a stick, working from the top to the base of the crop canopy, causing insects and spiders to fall from the plants onto the sheet. The insects and spiders on the sheet were recorded and unknown species were collected for identification at IITA in Cotonou, Benin, and at the Laboratory of Entomology of Wageningen University in the Netherlands. The number of healthy, and bollworm damaged flower buds and bolls were recorded.

In order to record the damage caused by *Nezara viridula* (F.) (Heteroptera: Pentatomidae),

and *Dysdercus völkerei* (Schmidt) (Heteroptera: Pyrrhocoridae) for which no ETL had been established, five bolls were collected on each of 20 randomly selected plants at the start of boll development (from 85 to 92 DAE); and at the peak of the bolling period (100 to 107 DAE) (Worou, 2004; Garcia, 2005). The sampling was always done the day before spraying, and one week after spraying. The number of healthy as well as bolls damaged by heteropterous insects (rotten bolls) was counted.

Cottonseeds were harvested on November 4 and 19 in an area of 10 x 10 m² from the middle of the plot in order to avoid border effects.

Data analysis

The sampling data were pooled per plot. Transformations ($\text{Arcsin}\sqrt{X}$, x = percentage damage; and $\text{Log}_{10} [x+1]$, x = number of insects) were used to achieve normality and homoscedasticity before analysis. Statistical analysis was made using the SAS version 8 software (SAS Institute, 1999).

The incremental cost benefit ratio (ICBR) (Sarode et al., 2000) for each treatment was based on data on current year costs of the pesticides (excluding application costs), labour (to prepare the botanical pesticides), and the price to producer of the cottonseed. The farmers estimated the labour price for preparing the botanical pesticides.

Results

Economic damage threshold

Bollworms - except *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) - reached the economic threshold most frequently (Table 4), and most often (8 times) in the control, and least often (3 times) in the plots where the standard recommended practices were followed. Each time the economic threshold level was reached the appropriate trial practice was followed (Table 5). The infestation by the mite *Polyphagotarsonemus latus* (Banks) (Acarina: Tarsonemidae) and the aphid *Aphis gossypii* Glover (Heteroptera: Aphididae) did not reach the threshold except in the treatment when Bt was used (T1); in all the other (need-based) treatments (T2, T3) the threshold was reached once, and in the standard programme even twice (Table 4).

Endosulfan (1.4 kg/ha) was used only in the standard recommended package (Table 5). All treatments succeeded in lowering the total number of applications and the amount of active ingredient compared to the standard package with Endosulfan. In comparison to this package the amount of active ingredient in the mixture of synthetics (Cypermethrin, Acetamipride, Triazophos) was decreased by 66 % when Bt was applied early in the season (T2), as well as when the SP/Neem mixture (T3) was used.

Table 4. Number of occasions when the number of bollworm pests or sucking pests reached or exceeded the thresholds for each treatment in cotton in Benin. (See Table 1 for explanation of the treatments)

Different ETL types	T1	T2	T3	Standard programme	Control
Cotton bollworm (<i>Helicoverpa armigera</i>)	0	0	0	0	0
Other Bollworms (<i>Earias sp.</i> , <i>Cryptophlebia leucotreta</i> , <i>Diparopsis watersi</i> , <i>Pectinophora gossypiella</i>)	6	4	4	3	8
Leafworm (<i>Spodoptera littoralis</i>)	0	0	0	0	0
Aphids (<i>Aphis gossypii</i>)	0	1	1	2	0
Mites (<i>Polyphargotarsonemus latus</i>)	0	1	1	2	1

Table 5. Type of pesticide applied at which day after plant emergence (DAE) and quantity of active ingredients of the pesticides used in several treatments to control cotton pests in Benin. (See Table 1 for explanation of treatments).

Treatments	Pesticides applied		Targeted insects	Active ingredients (g/ha)
	Type	Application dates (DAE)		
Standard programme	- Endosulfan	45/59	- All	- Endosulfan (1400);
	- SP	73/101/115	- All	- Cypermethrine (108); Acétamipride (24) Triazophos (450)
	- MP	87	- All-	- Spinosad (4.8)
T 1	- Bt	60/74/81/88/102/109	Bollworms	Bt aizawai, 90x 10 ⁹ IU
T2	- Bt	60	Bollworms	- Bt aizawai, 15 x 10 ⁹ IU
	- SP/Neem	74/109	All pest	- Cypermethrine (36); Acétamipride (8); Triazophos (150); Azadirachtin (-)
	- MP/Neem	88	Bollworms	- Spinosad (2.4); Azadirachtin (-)
T3	- MP/Neem	60/88	Bollworms	- Spinosad (4.8); Azadirachtin (-)
	- SP/Neem	74/109	All pests	- Cypermethrine (36); Acétamipride (8); Triazophos (150); Azadirachtin (-)

MP= Micro-Pesticide Spinosad; SP= Synthetic pesticide; Neem= Seed extract; MP/Neem= Mixture of MP and Neem; SP/Neem= Mixture of SP and Neem; IU= International Unit.

The amount of active ingredients applied of the myco-pesticide Spinosad was reduced to half when Bt was used early in the season.

Pest damage

Pest damage on the cotton plants, that exceeded the ETLs, was recorded at 60 DAE, which is the moment when the highest numbers of buds are present. Many cotton pests were recorded including those targeted for ETL (*H. armigera*, *Earias sp.*, *Cryptophlebia leucotreta* (Meyrick) (Lepidoptera: Tortricidae), *Diparopsis watersi* (Rothschild) (Lepidoptera: Noctuidae),

Pectinophora gossypiella (Saunders) (Lepidoptera: Gelechiidae), *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae, *P. latus*, and *A. gossypii*), and those not targeted for ETL (*N. viridula*, and *D. völkerei*).

All the treatments reduced significantly the damage to the reproductive organs caused by bollworms compared to the control (Table 6). The Bt treatment alone was less effective in

Table 6. Effect of different treatments on bud and boll damage in cotton caused by bollworms and heteropterous insects. (see table 1 for explanation of treatments).

Treatments	Bollworm Damage		Heteropterous insect damaged bolls (% ± SE)**
	Buds (% ± SE)*	Bolls (% ± SE)*	
Control	11.2 ± 2.7 a (0.67)	14.7 ± 0.9 a (0.79)	66.0 ± 4.0 a (1.9)
T1	4.5 ± 1.1 b (0.42)	5.0 ± 0.5 b (0.45)	39.5 ± 1.4 b (1.35)
T2	4.7 ± 0.2 b (0.44)	2.5 ± 0.5 c (0.31)	4.5 ± 0.8 d (0.42)
T3	4.2 ± 0.2 b (0.41)	2.2 ± 0.4 c (0.30)	3.0 ± 1.2 d (0.35)
Standard programme	1.2 ± 0.2 c (0.22)	2.2 ± 0.4 c (0.30)	18.0 ± 3.7 c (0.86)
CV	19.83	14.32	17.00
Pr > F	0.000	0.000	0.000

* Based on mean of 13 observations recorded on 20 plants at weekly interval starting from 30 days after sowing.

** Based on mean of four observations on 400 collected bolls each at the day before, and one week after spraying during bolling period.

- Figures in parentheses are $\arcsin\sqrt{x/100}$ values (x being percentages).

- Values in columns followed by the same letter are not significantly different (P > 0.05).

reducing boll damage, than the other treatments. The standard package performed best in terms of bud damage, which was reduced more than in the treatments that included assessment of the economic thresholds.

All treatments significantly reduced the boll damage caused by heteropterous insects compared to the untreated control. The treatments including Neem (T2, T3) were significantly more effective in reducing boll damage than the other treatments. The standard recommended practice, which resulted in 18 % of damaged bolls, was less effective than the treatments including Neem but more effective than the control. The use of Bt insecticide alone (T1), with 40% bolls damaged, was better than the control but less effective than the other treatments.

Impact on beneficial arthropods

A number of cotton pests' natural enemies were collected from the field. The most important complexes were:

i) aphid and mite generalist predators including one syrphid species *Ischiodon aegyptius* (Wiedemann) (Diptera: Syrphidae), and two genera of Coccinellidae comprising five species (*Cheilomenes vicina* (Mulsant) (Coleoptera: Coccinellidae), *C. propinqua* (Mulsant), *C. lunata* (Fabricius), and *C. sulphurea* (Olivier), *Exochomus troberti* (Mulsant) (Coleoptera: Coccinellidae)); ii) bollworms predators including four genera of Formicidae comprising six species (*Camponotus maculatus* (Fabricius) (Hymenoptera: Formicidae), *C. sericeus* (Fabricius), *C. acvapimensis* Mayr, *C. flavomarginatus* (Mayr), *Lepisiota* sp., *Dorylus bürmeisteri* (Shuckard) (Hymenoptera: Formicidae)), and one solitary wasp species (*Polistes marginalis* F. (Hymenoptera: Vespidae)); iii) *D. völkeri* predator *Pseudophonoctonus* sp.. However only ants, ladybird beetles, and spiders were present in numbers large enough to be analysed statistically.

Table 7. Effect of different treatments on different predators in cotton fields in Benin (see table 1 for explanation of treatments).

Treatments	Average number of adults / plant *		
	Ants	Coccinellids	Predatory spiders
Control	0.84 ± 0.1 a (0.26)	0.43 ± 0.0 a (0.15)	0.44 ± 0.1 b (0.15)
T1	0.75 ± 0.1 a (0.24)	0.38 ± 0.0 a (0.13)	0.58 ± 0.0 a (0.19)
T2	0.81 ± 0.0 a (0.25)	0.40 ± 0.0 a (0.14)	0.40 ± 0.0 b (0.14)
T3	0.77 ± 0.0 a (0.24)	0.33 ± 0.0 a (0.12)	0.38 ± 0.0 b (0.13)
Standard programme	0.22 ± 0.0 b (0.08)	0.13 ± 0.0 b (0.05)	0.13 ± 0.0 c (0.05)
CV	20.97	20.80	20.89
Pr > F	0.000	0.001	0.000

* Mean per plant ± SE of 13 observations recorded on 20 plants at weekly interval starting from 30 days after sowing.

- Figures in parentheses are $\text{Log}_{10}(X+1)$ values (X being number of insects).

- Values in columns followed by the same letter are not different ($P > 0.05$).

Bt pesticide used alone (T1), or used early in the season (T2), or the use of Neem and the mixture of synthetic pesticides (T3), proved to be significantly less harmful to the population of ants and coccinellids than the standard recommended practice (Table 7). The plots that were treated only with Bt insecticide (T1) had significantly more spiders than the control plots.

Table 8. Effect of different control strategies on cotton yield, insecticide and labour costs (to grind plant material), and incremental cost-benefit ratio (ICBR) (see table 1 for explanation of treatments).

Treatments	Pesticide quantity and labour per ha			Cost (Euro/ha)	Yield (kg/ha)	Yield increase over control (T/ha)		Incremental benefit B-A	ICBR (B-A)/A	Rank	
	Quantity (No + kg + kg)*	Labour (M/day)	Insecticide			Labour	Total A				kg/ha
Standard programme	6 + 0 + 0	0	70.8	0	70.8	1,206 a	706.	204.7	133.9	1:1.9	2
T1	0 + 6 + 0	0	393	0	393	787 b	287	83.2	-309.8	1:-0.8	4
T2	3 + 1 + 18	1.5	88.6	2.5	91.1	1,231 a	731	212.0	120.9	1:1.3	3
T3	4 + 0 + 24	2	30.8	3.3	34.1	1,459 c	959	278.1	244.0	1:7.1	1
Control	"	0	"	"	"	500 d	"	"	"	"	"

* Quantity (No + kg + kg) = [number of synthetic insecticide spray + Bt pesticide (kg) + plant extract (kg)] per ha through the crop season
 - Values in columns followed by the same letter are not different ($P > 0.05$) - M/day = man/day

Note: 1. 1 man/day cost 1.7 Euro

2. One spray in standard programme cost 11.8 Euro and in the strategies it cost 5.9 Euro

3. 1 kg Neem seed cost 0.3 Euro

4. 1 kg Bt. insecticide cost 65.5 Euro

5. Market sale cost of cottonseed is 0.29 Euro

6. 1 Euro = 655 CFA

Cost and benefits of the strategies

The highest yield of 1,459 kg /ha was realised in plots treated with the SP/Neem mixture (T3) and this was significantly higher than the yields obtained in the other treatments. It was followed by 1,231 kg /ha obtained by using Bt insecticide applied early in the season (T2) and the standard recommended package (1,206 kg/ha). The yield obtained with the use of Bt insecticide only (T1) (787 kg/ha) was significantly higher than the control (500 kg/ha) but significantly less than the other treatments.

The mixture of Neem and synthetic pesticides (T3) provided the highest incremental cost benefit ratio (ICBR) viz. 1:7.1, followed by the standard recommended package (1:1.9) (Table 8). The costs of applying only Bt pesticide were higher than the benefits obtained, the ICBR being 1:-0.8.

Discussion

Economic thresholds and calendar spraying

The standard package recommended by the government resulted in six applications of pesticides. By using treatments based on economic thresholds (except the one in which only Bt was used) it was possible to reduce the number of applications to four while the quantity of active ingredients was cut by at least 50 percent (Table 5). These economic threshold treatments reduced the damage by bollworms on the reproductive organs of the cotton plant, and in particular on the bolls, equally well as the recommended package. The action thresholds were effective in reducing the number of applications, as has been found also by other authors (Ochou et al., 1998; Bharpoda et al., 2000; Silvie, 2001, Naranjo et al., 2002).

However, in comparison to the simple regime of calendar spraying, would a farmer be willing to invest in the learning and the extra labour required by the use of economic thresholds? Farmers would need to recognize the different insects, to scout, and to learn the economic threshold concept, while at the same time taking into account the natural enemies actually present in their fields.

In Benin the experience has been that control strategies based on a mix of calendar spraying of half the dose of recommended pesticides and economic thresholds, the so called "*Lutte Etagée Ciblée*" (LEC), has not been fully or widely adopted by farmers (Sinzogan et al., 2004). The reasons for the non-adoption, according to Kuklinski & Borgemeister (2002) and Sinzogan et al. (2006), are: i) longstanding and sole reliance on insecticide calendar spraying, as recommended by the national research institute; ii) the opening of bolls, recommended as a destructive sampling method for establishing whether the economic threshold is reached, is

a practice most farmers are unlikely to accept (under the calendar-based treatments using half dose of the recommended pesticide the extra scouting to justify further more spraying was not considered necessary); and iii) pesticides suppliers refusing to deliver the specific pesticides required for LEC. A project funded by the French Development Agency aimed to spread the LEC method to cover 50,000 ha in five years. The project included the training of trainers for scouting and developed a wooden peg-board method to record the number of plants reaching the ETL (Sylvie, 2001; CRA-CF, 2003).

The control strategy we proposed relies entirely on economic thresholds, as a way of saving natural enemies and reducing the number of applications and the release into the environment of the active ingredients in the synthetic pesticides. Its impact does not depend on the simple promotion and diffusion of the method for it, and can work only if farmers understand the basic principles of what is proposed.

To be effective it would be necessary for farmers to learn and discover the behaviour of pest complexes in their own fields, and to develop their ability to experiment, to draw conclusions, and to take sound decisions (Deugd et al., 1998; de Jager et al., 1999; Chapter 6). Instead of using only flipcharts, field days, and visits (PAN, 2000), farmers would have to be actively involved in local research activities.

Farmer can be assisted to learn about natural enemies by discovery learning, using an insect zoo (see Chapter 6) enabling them to understand the secondary pest outbreak effect of early season pesticide applications. Given adequate support for learning, we have shown in another paper that farmers in the Gounin case were willing to avoid the recommended calendar-based package of synthetic pesticides (Chapter 6).

Effect of Bt insecticide

The use of Bt alone (T1) led to six spray applications, less effective in controlling bollworms than the other treatments, and the costs were higher than the benefits obtained. According to White et al. (1999) and Zia-Ur-Rehman et al. (2002) two reasons could explain the lack of efficiency of Bt formulations in the field. The first is of a physical nature and has to do with solar light and temperatures beyond 50°C, conditions that seem to degrade the protein of the bacterium. The second reason brought forward is a biological one. The success of foliar applications of the Bt pesticide seems to depend on the population density, the larval life stage composition, the species composition, and the presence of natural enemies. According to Johnson et al. (1993) when moderate to high infestations of *Helicoverpa virescens* occur, Bt pesticide is generally not recommended. The failure of Bt pesticide in the control of bollworms in the setting of our study could therefore be explained by: i) the bollworms' ETL having been set too high for the Bt

formulation (as the ETL used was set for recommended pesticides); ii) the period (10:00- 13:00 hours) when the Bt formulation was applied is a period with a lot of sunshine and heat.

Value of using Neem

The strategy of including mixtures of Neem with half the dose of the recommended pesticides was as equally effective in protecting bolls against bollworms as the recommended package, and more effective than the rest of the treatments in protecting bolls against heteropterous insects. The synergistic effect of Neem and the synthetic pesticides was reported in Chapter 4. It may well provide an explanation to the higher yield obtained in plots sprayed with this mixture. Heteropterous insect adults perforate the boll to reach the seed preferred for feeding. The wound provoked by the adults allows fungi, especially *Nematospora gossypii*, and bacteria to penetrate and rot the boll (Bruinsman, 1987). Less rotten bolls were found in the plots treated with the Neem mixture. What is the mode of action of this mixture? This was not studied. However, Ascher et al. (1996) and Gahukar (2000) found that when plant-derived products or biocides such as Neem are combined with synthetic pesticides a synergistic effect occurs. The antifeedant effect and repellent effect of Neem may deter the boll feeders from feeding, prompting higher mobility and thus exposing them more to the synthetic pesticides and making them more vulnerable to their effects (Murray et al., 1993; Trisiyono & Whalon, 1999). In addition, Neem extract has been shown to inhibit the germination of the spores and mycelium development of many genera of fungi (Jeyarajan et al., 1987; Parmar and Dutta, 1987; Kale and Holey, 1994; Bambawale et al., 1995; Thakur et al., 1995), thereby avoiding the boll rotting caused by 'opportunistic' fungi.

Saving natural enemies

The broad-spectrum pesticides used in the standard programme caused a significant reduction in the number of predatory species (ants, spiders and coccinellids). The effect was time- and dose- dependent. The standard package, by starting with two applications of Endosulfan early in the season, had the most negative effect compared to the treatments that started applications later, that used selective pesticides (e.g. the Bt application alone), and applied a lower quantity of active ingredients. A number of studies have documented the negative impact of broad spectrum pesticides on the beneficial arthropods in cotton fields (Mizell & Schiffhauer, 1990; Ma et al., 2000; Mensah, 2002).

Secondary pests like *A. gossypii* and mites had low population densities. The ETLs were almost not reached in the control and in the treatment in which Bt was applied alone. When the mixture of Neem and synthetic pesticides was used the threshold was reached only once and when the standard package was used it reached it even twice indicating a resurgence/

outbreak effect of the secondary pest. The selective pesticide and/or delay of the early season applications of synthetic pesticides used in the economic threshold treatment permitted natural enemies to develop, thereby keeping aphid and mite populations low. The negative relationship between early season insecticide application and predator populations, leading to an outbreak of secondary pests, has been reported previously for mites (Wilson et al., 1998); aphids (Kuklinski and Borgmeister, 2002); and whitefly, (Naranjo et al., 2002 & 2003). The first pesticide applications in the different treatments that use economic thresholds was made at 60 DAE and only with harmless pesticides: i.e. Bt pesticide (Patel & Vyas, 2000; Jeyakumar & Gupta, 2002; Zia-ur-Rehman et al., 2002); and Spinosad (Ma et al., 2000; Mensah, 2002; NOSB-TAP, 2002). The synthetic pesticides (pyrethroids) that disrupted the predator population build up (Ma et al., 2000) were applied first at 74 DAE.

The sampling revealed a low density of *H. armigera*. This could be because of the replacement in Benin of pyrethroids by Endosulfan, a strategy recommended by Forrester et al. (1993) to manage pyrethroid resistance in *H. armigera* (Katary, 2003; Martin et al., 2003 & 2005). The maintenance of this key pest below the ETL may explain the successful control of other bollworms by our treatments. Indeed, often, the only effective and reliable means available to control high population of *Helicoverpa* spp. are broad-spectrum pesticides (i.e. Endosulfan, thiodicarb, methomyl), which are detrimental to predators (Forrester et al., 1993; Simpson et al., 1996).

Conclusion

The use of mixtures of Neem with synthetic pesticides using economic thresholds seems an important alternative pest management strategy compared to the standard recommended practice. The strategy that proved capable of controlling the pests adequately, achieved the best yields, and was economically the most interesting - and probably would also be capable of limiting the risks of development of resistance to pesticides. Developed with the involvement of farmers, it has a higher chance of becoming a common farmer practice if farmers are supported to learn the ETL technique (Chapter 6).

6

Co-researching with a Stakeholder Learning Group: experiences in pest control technology development with cotton farmers in Benin

Sinzogan, A.A.C., J. Jiggins, D.K. Kossou, S. Vodouhè, and A. van Huis.

Abstract

This paper describes an approach to agricultural technology development in which researchers, farmers and extensionists learn together how to best manage cotton pests in a sustainable manner. The process described is iterative with each repetition serving to maximise the knowledge available at any time to support decision-making by those in the learning group. A framework is developed for bringing scientific and local knowledge systems together to support the identification and adoption of more sustainable pest management practices. The next challenge is how to expand the benefits of a locally successful approach, to more people more quickly, whilst maintaining active farmer involvement.

Keywords: Co-research, Stakeholder, Learning, Pest control, Cotton, Benin.

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Introduction

The “Transfer of Technology” (ToT) model of innovation (also referred to as a top-down linear approach) has been widely used in Sub-Saharan Africa (SSA). It is characterised by research conducted in privileged conditions, high input packages, and top-down extension. It met with success in the uniform and controlled conditions of irrigated or industrial agriculture, although even in these conditions, the sustainability of the solutions is open to question. In the more complex, diverse and risk-prone rain-fed agriculture of much of SSA the ToT model does not work well (Chambers, 1983; Stoop, 2002). In the ToT model, the research process itself discriminates against resource-poor farmers (Chambers and Jiggins, 1986; Horne et al., 2000) and they have been reluctant to adopt the technologies developed by formal research (Mutimba, 1997). The CRIG (Cocoa Research Institute of Ghana), for example, courageously admits that farmers have adopted only 3.5 to 7 per cent of the technologies it has developed (Donkor et al., cited by Ayenor et al., 2004). The Cotton Research Institute of Benin, CRA-CF (*Centre de Recherche Agricole Coton et Fibre*) has indicated that farmers do not respect the institute’s recommendations, such as the volume of pesticides quantities to be applied to protect the cotton crop (CRA-CF 2002). The ToT approach formerly was widely used in cotton extension in Benin; however, from 1990 the cotton sector has been subject to reform processes, and publicly-provided training and supervision, two of the most important elements in the implementation of the ToT approach, have been largely dismantled.

Various attempts have been made to take account of farmers’ perspectives, knowledge, and experience (Bawden et al., 1985; Chambers and Jiggins, 1986). Research, technology, extension, education, and users are recognised as forming elements of an agricultural information system (Roling, 1988) that has to work in concert if impacts larger than that of ToT are to be achieved (Allen, 2001). More emphasis in these models is given to the social organization of innovation networks i.e. it is recognised that an effective agricultural innovation system requires a multitude of organisational and institutional changes. Some of these relate to the participation and empowerment of farmers as actors informed by their own knowledge and information system (Engel, 1997). A sustainable cotton pest management strategy, for instance, in this perspective means creating a ‘social space’ in which scientists and farmers can interact to develop a control system that works and will be accepted by farmers.

A participatory diagnostic study of cotton production constraints and opportunities in Benin, identified a clear need: the inadequate knowledge and skills of farmers concerning pest management strategies. The diagnostic study allowed the conventional research process itself to come into question. It suggested that an approach that pre-defines the variables to investigate and that do not take into account the need of farmers leads to frustration of researchers and

extension agents concerning the non-adoption of their 'solutions' (Sinzogan et al., 2004). The encounter between farmers and researchers during the diagnostic study initiated the actors' collaboration in a participatory learning and technology development process that linked local and external knowledge systems (Sinzogan et al., 2004). These processes have begun to produce a wealth of shared knowledge that is not only relevant to, but also owned by communities in which the farmer participants live (Vos, 2004). One begins to see innovation emerging from the 'cradle' of local networks (Houkonnou, 2001). This article reports on and analyses this experience.

According to Vos (2004), three challenges have to be addressed: i) *how can communities better identify, understand, value and broaden local knowledge generation processes?* ii) *How can external knowledge be made more relevant, easier to evaluate and more accessible to local contexts and needs?* and iii) *How can local innovation enrich external processes concerned with the generation of knowledge?* Our hypothesis was that these challenges in the cotton sector in Benin could be overcome through establishing a 'learning platform' or 'stakeholder learning group' (SLG) in which actors collaborate in participatory, experiment-based agricultural technology development, linked to the farmers' needs and the dynamic of local pest ecologies. By involving stakeholders in the early stages of technology development we expected a better targeting of technologies; greater sense of local ownership; economically securer livelihoods; reduced time between research initiation and adoption; increased rate and pace of adoption; greater impact on farmers' human and social capital and joint experimentation and sharing of innovations (Knox and Lilja, 2004). We return to these criteria in the discussion.

This article briefly reviews the key terms used, then describes the SLG and its learning cycle. The subsequent section presents the key results of the on-farm experiments in terms of the learning cycle. The 'question of knowledge' is discussed throughout in terms of the origin of technology developed and research methodology, the role and motivation of SLG actors, and the problems of participation.

Theoretical concepts

Farmers' knowledge / Indigenous knowledge

Farmers' knowledge has been defined as "The body of knowledge which results from the interaction between indigenous and scientific knowledge that continuously adapts to changes in environment, socio-cultural and politico-economic conditions" (Van Mele, 2000). Indigenous knowledge according to Warren (1987) is: "local knowledge that is unique to a given culture or society". Rajasekaran (1993) offers "the systematic body of knowledge acquired by local people through the accumulation of experiences, informal experiments, and intimate understanding of

the environment in a given culture". Thrupp (1989) suggests "Insight and adaptive skills of farmers often derived from many years of experiences and which have co-evolved with the local environment". This article follows these definitions.

Learning and learning process

Our starting proposition is that learning involves reflecting on experience to identify how a situation or future actions could be improved and then using knowledge to actually make improvements (IAC, 2004). Learning activities can occur at various levels, including: individual, group based, and within society. Learning involves using the lessons learned to inform future actions, which in turn provide the experiential basis for another cycle of learning. Our interest centres on how learning processes, thus outlined, contribute to and work with farmers' and others' knowledge so as to constitute practices that are perceived as improvements.

In the transfer of technology model, learning is supposed to happen through a linear flow of information. However, "*Technology usually changes as knowledge products change through the knowledge system, and that farmers 'reinvent' technologies before incorporating them in their production system*" (Schoubroeck, 1999; Bartlett, 2004). Kolb (1984) has developed this idea as 'experiential learning' referring also to 'learning by doing' or 'discovery learning' as forms of experiential learning.

Experiential learning theory is useful in the design of innovation processes in rural settings as we are usually dealing with adults, who are involved in substantive activities such as farming and other livelihood activities. In this context, learning is immediately connected to the diversity of human interests and changes in professional practice. Leeuwis and van den Ban (2004) suggest that it is because of the immediate relation with practice that Kolb's (1984) model of "experiential learning" is widely used as a basis for organising communication for innovation. Johnson and Johnson (1987), cited by Guera (2003), describe as follows the experiential learning principles that contribute to the sustainability of innovation:

- *Effective experiential learning will affect the learner's cognitive structures (action theories), attitudes, values, and behavioural patterns.*
- *People will believe more in knowledge they have discovered themselves than in knowledge presented by others.*
- *It is easier to change a person's action theories, attitudes, and behavioural patterns in a group context than in an individual context.*

Farmer participatory research

Research could be defined as a careful study or investigation carried out in order to discover a new fact or information. Okali et al. (1994) suggest that research is a more or less deliberate and

systematic process that proceeds through three general stages: i) *identification of opportunities (more commonly referred to as problems or constraints)*; ii) *identification of ideas or options*; and iii) *testing and/or adaptation of the ideas and options*. Farmer participatory research (FPR) (Cohen and Uphoff, 1977) thus can be described as an approach that encourages farmers to engage in experiments in their own fields so that they can learn, adopt new technologies and spread them to other farmers. The researcher here acts as facilitator of the interaction between farmers and other actors, who closely work together from the initial design of the research project to data gathering, analysis, final conclusions, and follow-up actions. This article takes the view that FPR can be considered to be a framework for organising direct interaction between the formal agricultural research system and farmers' own informal research, a framework which excludes research implemented by farmers or researchers alone and includes the possibility of farmers and researchers being involved at any or all points along a continuum of participation (Sanginga et al., 2001; Horton and Prain, 1988; Farrington and Martin, 1988).

The Stakeholder Learning Group

Innovations in pest management have been identified as a pertinent research priority in the cotton sector in Benin (Kossou et al., 2004). At one specific site in Gounin village (Borgou department, northern part of Benin), farmers considered pest problems to be the primary cause of low cotton yields (Sinzogan et al., 2004), and showed eagerness to interact with scientists concerning the development of their knowledge, perceptions, and practices in pest management. Such enthusiasm has been identified as a prerequisite for the development of a participatory technology development programme (PAN, 2000). Therefore, Gounin village was chosen for the development of a 'learning platform' formed around a Stakeholder Learning Group (SLG). The objective was to facilitate the actors' collaboration in participatory development of experiment-based cotton pest management technology.

Following a diagnostic survey, in December 2003 the author of this thesis acted as the facilitator of a group meeting, attended by farmers, the 'local research agent' (LRA), and the local extension officer, in order to validate the results of the survey. During the meeting, it was agreed that a 'stakeholder learning group' (SLG) should be formed to test and discuss pest management options based on on-farm experiments. Farmers were asked to volunteer, based on their interest in working on pest problems. Fifteen farmers together with two LRAs, the extension officer, author of this thesis (acting both as researcher and facilitator), formed the learning group. Five farmers subsequently left for diverse reasons, principally, sickness, migration, and time constraints. The effective learning group thus constituted 10 farmers, 2 LRAs from the cotton research institute, one extension worker, and the first author.

The ten farmers are very diverse. They are from two different ethnies: *Batonou* (dominant ethnie), and *Yom* (migrants). They are also from two different farmers' organisation, GV-FUPRO (belonging to the main organisational network in the cotton sector), and GP-FENAPRA (that is associated with a 'break-away' network) (Sinzogan et al., 2006.). Eight members are men, and most of them are opinion leaders and quite well educated. The SLG members have appointed a (male) president and his deputy, and a (male) secretary.

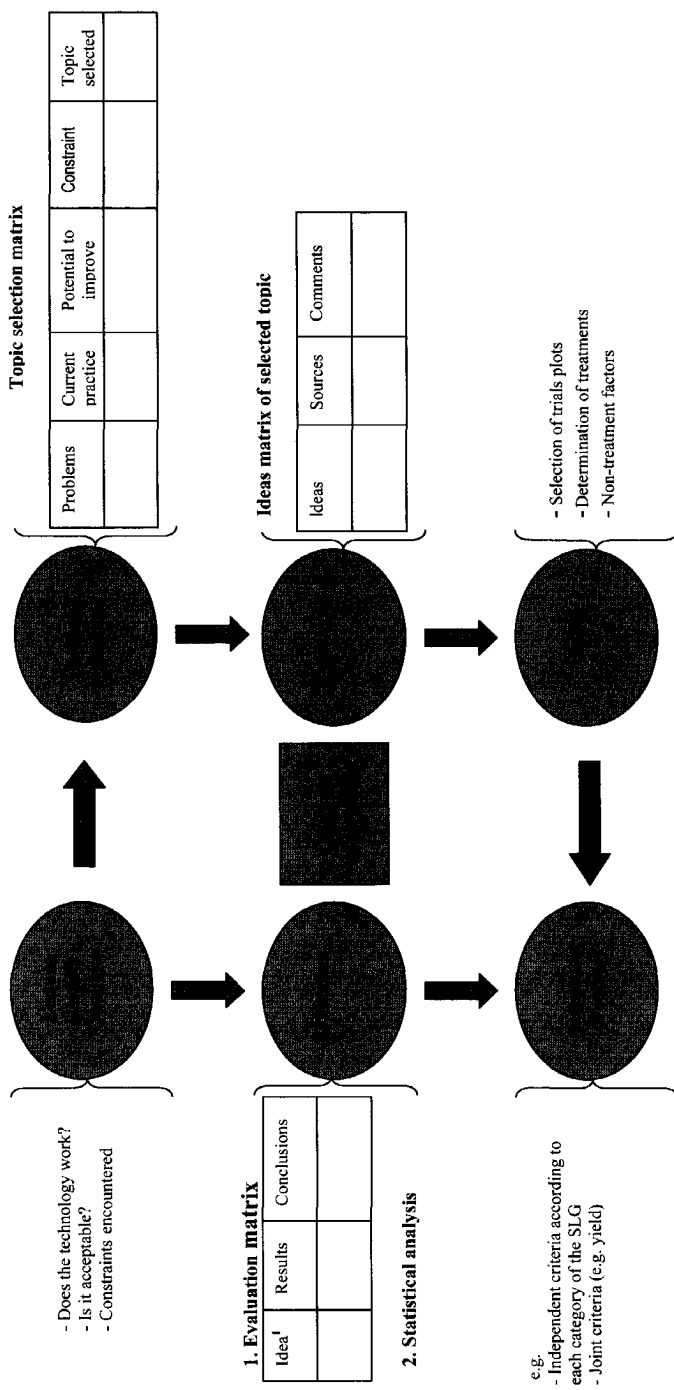
According to a preliminary stakeholder analysis, in general the motivation of the farmer members' to join the group was to improve cotton pest control. They were interested to 'try out things'. Also they wanted to be able to translate their needs into research topics. The local research agents joined because they were interested in the results of the pest control option tested and in the improvement of research practices and recommendations. The extension worker joined because his task was to assist the farmers. He had to be able to respond to everything that was worrying the farmer. Hence, he also wanted to know something about alternative pest controls.

The group agreed to meet weekly on Fridays, the day when normally farmers carry out community work in the village. The villagers considered the experimentations to be community work and therefore that it was appropriate for the farmer members of the learning group to meet on that day and to be exempted from other community work.

Process of design and implementation of the on-farm experiment

The design of the process drew heavily on an analysis of farmer field research experience from Indonesia (see Van den Berg et al., 2001). The learning cycle (Figure 1) that emerged had six steps: potential solution (topic selection); hypothesis; design; assessment; evaluation; and lessons learned. It resembles an experiential learning cycle, adapted for use in on-farm experimentation.

Topic selection in this instance was developed on the basis of the researcher's previous diagnostic study (Sinzogan et al., 2004). Farmers had identified the main cause of the low yield in the cotton crop as poor pest control and had suggested a number of potential solutions as priority areas for further investigation. The potential solutions were screened systematically by the researcher on the basis of the scientific literature, and then critically reviewed in detail with the SLG. Those considered by the SLG as the most promising options were selected for trial. The SLG then constructed an Ideas Matrix (see figure 1) based on asking what exactly the SLG members wanted to find out (the hypothesis), framed by the question: "*What possible influences will the topic of the study have on the crop, the ecosystem, and the socio-economic aspects?*" (Van den Berg et al., 2001). Then the specific source of each idea was recorded. Finally, each



¹ From the Idea matrix.
 Source: Adapted from Van den Berg (2001).

Figure 1. Participatory on-farm experiment-based learning cycle.

idea was discussed in terms of its reliability, relevance to the local situation, and the need to test it.

The ideas that the SLG agreed needed to be tested in relation to each option selected were recorded and formed the basis of the design of the experiments. The experimental design that emerged incorporated the SLG's response to practical questions such as: *will the experiment be located in a farmer's own field or in a common field?* The different treatments, an activity plan including a time schedule, the materials required, and the negotiation of responsibilities as well as the design of the monitoring and documentation system, also were collectively discussed and agreed. The hypothesis and design steps, that took place over five SLG meetings, were now complete. The next step, called the assessment process, used the Ideas Matrix to determine what should be observed, how, and where, at every stage of each experiment. Each stakeholder category, supported by the facilitator, decided their own assessment criteria. Some criteria (e.g. yield, economic return) were found to be common to all the stakeholders in the learning group. The experiments were then laid out, initially based on the researcher-designed protocol. The adaptations that were made subsequently are discussed under each of the two cases that will be presented later. As the crop season proceeded, the next round of discussions focussed on evaluation. The researchers and the LRAs agreed to use statistical analysis whereas farmers decided to use an Evaluation Matrix, which was constructed by adding the results of the experiments to the Ideas Matrix.

Discussion of the results of the experiment, and analysis of the lessons learned, completed the learning cycle. Some basic conclusions were drawn, related to questions such as: does the technology work? Is it acceptable? The constraints encountered in the learning cycle were identified. New questions also emerged, which served to close the first cycle and open the door to another.

Results

The Ideas Matrix (Table 1) lists the SLG's ideas concerning how the problem of low yield might be overcome, and the researchable topics related to these. This section tracks the subsequent SLG processes by means of two case studies, that represent different types of on-farm experiment. The first describes an assessment by the SLG of an indigenous pest control method that was already used by a few farmer members of the SLG. The second case describes an integration of the result (Neem mixture with half dose of the recommended synthetic pesticides) of the first case into an integrated control method proposed by the researcher. The method had not been tested before by researchers on-station. The two cases have been selected because of their interdependence, i.e. for showing how a learning cycle can accommodate new ideas for

Table 1. Topic Selection Matrix.

Cause of low yield	Current practices	Potential to improve	Constraints	Selected topic
Pests (bollworms)	Calendar spray of synthetic pesticides	-Mixture of local insecticide plant and half dose of recommended pesticide -Crop habitat manipulation (cotton/cereal intercropping) to enhance biological control	-Availability of insecticide plants; lack of labour; environmental impact of synthetic pesticides -Use of synthetic pesticide around food crops forbidden; lack of labour	-Participatory evaluation of synthetic and botanical insecticide mixtures for cotton bollworm control (Case I)* -Effect of strip-cropping of maize (an alternative host plant for bollworms); luring bollworms away from cotton
Delay in cottonseed payment	Conventional network of organisations	Non-conformist network; changing production system	Institutional trap, leading to indebtedness	Stakeholders analysis and actor perspectives on organisational arrangements in cotton sector
Low price of produce	Conventional network of organisations	Lower input cost	Input sector liberalised (input subsidies suppressed)	
Lack of labour	No practice	Higher labour efficiency	Labour cost	

- Case I procedure in italic.

* Case II was developed after the results of Case I.

Source: group discussion with the learning group, N'dali, January 2004.

research as these emerge from the learning process. The complexity of the first, in terms of its acceptability to farmers, led to another hypothesis, which constituted the second case. Both cases show how farmers' knowledge was sought and applied in all stages of the co-researching process.

Case I: Testing an endogenous technology

The idea of mixing synthetic with botanical pesticides was discovered during the diagnostic study as an alternative pest control method that was used already by a few farmers in the community.

They had taken the initiative to mix half the dose of the recommended pesticide (including Endosulfan) with a local pesticide plant (*Kaya senegalensis*) to control cotton bollworms that had become resistant to the active ingredient, a pyrethroid, in the synthetic pesticide. They also disliked using the synthetic pesticide because of increased health risks, and the high costs involved. The learning group was strongly motivated to test this technology, given what they heard about the pioneer farmers' experiences.

Selection of specific ideas

The SLG specified what exactly they wanted to find out by testing this method (Table 2). Their main idea was to test whether the mixture better controlled bollworms than either the botanical or synthetic pesticides alone. However, because changing one aspect of the agro-ecosystem may influence several other variables, either directly or indirectly, the SLG members were concerned also to learn about the side effects, and the cost effectiveness of the mixture technology. The researchers and LRAs in particular were keen to include these points. They here acted as challengers of farmers' endogenous technology claims.

Table 2. Specific ideas tested concerning mixture technology and the perceptions of different Stakeholder Learning Group members.

Ideas to be tested	Source of Ideas	SLG members' opinion about ideas
Using botanicals mixed with chemicals to control bollworms better	-Farmers' perception -Publications	Not everyone is convinced: needs to be tested locally
Botanicals mixed with chemicals reduce input cost	-Farmers	Yes, but to what extent?
Botanicals mixed with chemicals are less hazardous to environment	-Researcher	Needs to be observed: how?
Botanicals mixed with chemicals cause bollworm resistance	-Cotton research institute representative	Difficult to test. Could be tested at laboratory and results shared with learning group

Source: group discussion with learning group, N'dali, March 2004.

Experiment design and assessment

Only two farmers in the learning group already used mixed applications of *K. senegalensis* with synthetic pesticides to control bollworms. Some other farmer members suggested adding to the experiment, Neem (*Azadirachta indica*), a plant with toxic or repellent properties that they also knew through their own experience. The farmers were supported by one of the researchers, who proposed also to include *Hyptis suaveolens*, a plant that he had learned was a toxic and repellent plant through his previous experience in cowpea pest management. The group finally agreed to compare eight treatments: 1) no pesticide (control); 2) recommended synthetic pesticide (SP); 3) Neem seed extract (Neem); 4) *Hyptis* leaf extract (Hyptis); 5) *Khaya* bark extract (Kaya); and three treatments involving the above mentioned botanicals plus half the dose of the recommended synthetic pesticides, i.e. 6) Neem-SP; 7) Hyptis-SP; and 8). Kaya-SP.

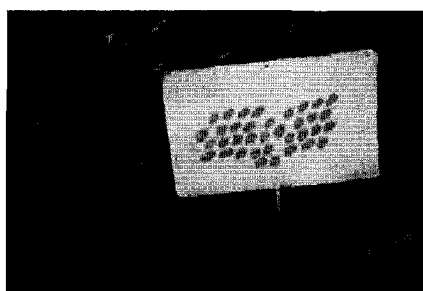
The lay out of the trials proposed by the researchers was the commonly used scientific block design. The other SLG members were briefed on the reason why researchers considered it necessary to use blocks in the experiment. The blocks at first were allocated to the fields of each of four farmers members of the group (one block per member), and the farmers agreed to report their findings to other members of the community during a monthly platform meeting. However, the farmers on reflection insisted that all farmer members of the learning group should be able to test the technology. Thus it was agreed finally to locate the experiment in a common field.

The question then arose: which field? Farmers first proposed a plot that was not suitable (not easily accessible and with bad soil quality). They claimed, "*if the experiment would succeed on that field it would succeed in any field!*"; the researchers argued rather "*if they want to compare the result with their own practices they need a plot that has the same type of soil that they would normally use, and then an already ploughed plot would be better*". Farmers decided - after further consultation - to provide the SLG with three hectares of an already ploughed field that belonged to the secretary of the group.

The researchers' guidance on the lay-out of the blocks concerning replication, control plot, and space between plots were the main points on which the farmers' judgement was hesitant and difficult to influence. They thought that the proposed unit plot of 20 x 20 m was too big and that they would not have enough space and time for their own farming. They agreed to 10 x 10m, which also was accepted by LRAs. The replications were reduced to four, instead of the six originally proposed by the researchers.

They did not agree with the researcher on the space to be left in between the plots. They proposed instead to grow maize in between, as they could not understand why ploughed land would be left unplanted only to see it become infested by weeds. However, all the group members in the end were convinced to leave the space unplanted, after receiving an explanation of the drift effect of spray products and also of the fact that maize is also an alternative host

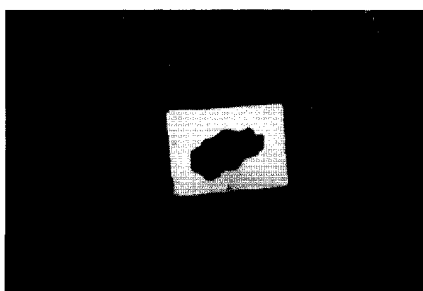
plant for bollworms, which makes maize less suitable for inclusion in the design. The concept of the control plot also met some opposition. Farmers thought that the cotton plant would never produce a single boll without any treatment. But they agreed finally to establish a control plot, as a case where the SLG would not intervene at all. The control plot became known as the discussion plot because the group used it as the main reference for discussion. The farmers later said: *by comparing the other results with the results of the control we can be sure that the difference is due to the product sprayed*. In order to identify each plot the LRA proposed to number the plots; farmers accepted the principle but proposed to use also a visualisation tool (Figure 2) permitting everyone to recognize the treatment applied to each plot.



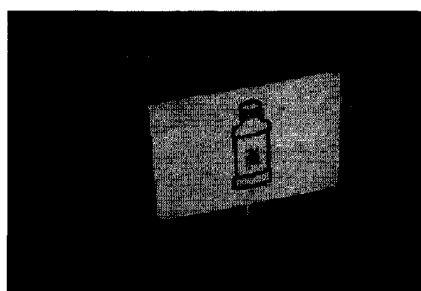
Neem



Hyptis-SP



Kaya



SP-full dose

SP= Synthetic pesticides.

Figure 2. Visual tools used to identify experimental plot.

The responsibilities for the management of the crop and the operations during the growing season were discussed in the group (Table 3). The researchers and LRAs agreed to give their input on topics such as the set up of the experiment, criteria for evaluation, as well as their expertise in identifying insects.

Table 3. Allocation of responsibilities for the main operations and management of the experiment to control cotton bollworm by application of a mixture technology.

Field operations	Implementers
Land preparation	Researcher/ LRA /farmers
Layout of experiment	Researcher/ LRA /farmers
Planting	LRA and farmers
Thinning	LRA and farmers
Weeding	LRA and farmer
Insecticide application	Researcher/ LRA /farmers
Data collection	Researcher/ LRA /farmers
Harvesting	Researcher/ LRA /farmers

LRA = Local Research Agent.

Source: group discussion with the learning group, N'dali, April 2004.

Each stakeholder category in the SLG developed its own assessment criteria and its own method of data collection (Table 4).

Table 4. Assessment criteria of the different categories of members of the Stakeholder Learning Group.

Parameters	SLG categories		
	Farmer	LRA	Researcher
Repetition in space	Not important	Important (4 replicates)	Important (4 replicates)
Repetition in time	Weekly observations	Periodic	Weekly observations
Sampling materials	2 rows of 20 m per plot	5 plants per plot	10 plants per plot
Sampling methods	-Fixed row (4 th & 7 th) -Inspection of the whole row -Non destructive sampling	-Randomly selected plants -Collection of bolls -Destructive sampling	-Fixed plants -Inspection of the whole plant -Non destructive sampling
Variables	-Damaged squares, and bolls -Number of healthy bolls on terminal 20 cm of plant -Yield	-Damaged bolls -Yield	-Damaged squares, and bolls -Larval incidence -Density natural enemies -Yield

LRA: Local Research Agent; SLG: Stakeholder learning Group.

Source: group discussion with the learning group, N'dali, June 2004.

The researchers collected data such as the number of insects (adults or larvae) and damage to the reproductive organs of the plants. The LRAs were especially concerned to assess the damage to the reproductive organs of the plants (boll) while farmers in addition to the damage on the cotton plant were keen to assess the number of healthy bolls at the top of the plant. The farmers claimed that “*when the crop canopy is well developed (80 Days After Sowing –DAE– onward)*

the protection of the top of the plant by the pesticide is less effective (the coverage of the product is low) and by counting the number of bolls at the top we will have an idea about whether the product penetrated the crop canopy”.

Farmers collected data on the whole fourth and seventh rows of the plot. Researchers used a fixed number of plants for data collection while the LRAs used destructive sampling methods. Both the researcher and the LRAs collected data from all replicated plots. The farmers thought that even the four replications were too much to monitor completely. They therefore chose in each block two different treatments such that all eight treatments were covered.

At the end of each data collection session – which occurred 17 times during the growing season – a one hour group discussion was carried out to review the data collection methods and the criteria used, such as presence and number of natural enemies, and the data records. At the end of the crop season the group compared the different data and together assessed the yield.

Evaluation and lessons learned

The results of the evaluation and lessons learned are reported in detail in Chapter 4. In this chapter we present the main conclusions only.

Farmers ranked first the SP-full dose treatment followed by the Neem-SP treatment as the treatments that best controlled bollworms. The LRA found that statistical analysis of the healthy reproductive organs of the plants (boll) ranked the following treatments as best: SP-full dose and Neem-SP; all other treatments except the control treatment were ranked 2nd, and the control treatment as 3rd.

The main conclusion of the researchers was that SP-full dose treatment and Neem-SP treatment were the best treatments for bollworm control considering bollworm numbers and plant damage (Chapter 4). All treatments (excepted the Neem alone) were found to lower the population of predators significantly, compared to the control.

The highest yield of 2.27 t /ha was realised in the Neem-SP treatment plots, and this was significantly higher than the yields obtained in the plot with SP alone, which in turn was significantly higher than the yields in the other treatment plots and the control plot. The plots treated with Neem-SP, also incurred the best incremental cost to benefit ratio (ICBR), viz. 1:5.4, followed by those treated with Kaya-SP (1:2.7) and SP- full dose (1:1.9) (Chapter 4), indicating that Neem-SP was the most attractive treatment not only in terms of yield but also economically.

During the group meeting held at the end of the crop season to compare the treatment data collected by each stakeholder category, and the yield data, the first question raised after analysing the results indicated above was why the highest yield of 2.27 t/ha was realised in the Neem-SP treatment. The group expected, given the results, that the yield from the Neem-SP treatment

and SP-full dose treatment should have been similar. The first explanation proposed by all the members of the group was that the result was a chance outcome that must be confirmed in the next crop season. But the researcher shared with the group another reason that could explain the result. The highest yield recorded in the plots sprayed with Neem-SP could be explained by the fact that we only took bollworms into account, for the reason that these are considered by both cotton researchers in Benin and the local farmers as the most important pests (Youdewei, 2001; Ton, 2002; Sinzogan et al., 2004), assuming that other pests are controlled by natural enemies. However, heavy pesticide applications in farmers' fields, especially the use of pesticides like Endosulfan at the beginning of the cotton crop growing season, may have destroyed the natural enemy complex normally present in natural agro-ecosystems. Secondary pests like sucking insects become then important and we assume that those insects, when using the mixture of Neem and synthetic pesticides, were controlled concurrently with the bollworms, thus allowing the higher yield obtained in these plots. The group decided to repeat the mixture experiment in the next (2005) season. It was also agreed to integrate the best mixture (i.e. the Neem mixture) into a management regime that preserves at the beginning of the crop season the natural enemies of the cotton pest. These two topics were selected for the next crop season's experiments, thus starting the learning cycle anew.

Case II: Testing a technology proposed by the researcher

Case II takes up the story where Case I left off. When considering the experiment on the botanicals in combination with synthetic pesticides the following concerns were expressed in the SLG: i) the mixture does not conserve natural enemies; and ii) the number of applications may be too high as decisions to spray are based on the calendar and not on economic thresholds. The idea behind the management regime then proposed by the researcher was to reduce the number of applications and the quantity of active ingredient applied by using a threshold (density level of insects above which a control method is applied), with the aim to save costs and to conserve the natural enemies (especially during the first phase of the growing season). These natural enemies not only control the target pest (bollworms), but also secondary pests such as mites and aphids (*A. gossypii*). This meant replacing the routine use of Endosulfan as the first two treatments in the conventional calendar-based programme, by the use of selective pesticides (*Bacillus thuringiensis* (Bt) or Spinosad) on a need basis i.e. whenever the number of bollworms exceeded a predetermined level that would result in economic loss (the Economic Threshold Level or ETL) (Silvie, 2001; CRA-CF, 2003). Later in the season, whenever bollworms exceeded a predetermined ETL, the Neem mixture (Neem seed extract mixed with half the dose of recommended insecticide) would be used (Chapter 4).

The proposed technology was analysed using the Ideas Matrix (Table 5). It was not

intended to demonstrate a novel method of cotton pest control. Rather, it was an attempt to evaluate how the available control options such as Neem seed extract mixed with half the dose of recommended insecticides (Samuthiravelu and David 1990, Dhawan and Simwat 1993, Sarode et al. 2000, Bharpoda et al. 2000), and Bt (Patel and Vyas 2000, Jeyakumar and Gupta 2002, Zia-ur-Rehman et al. 2002) or Spinosad (Ma et al. 2000, Mensah, 2002, NOSB-TAP 2002), could be best used practically and in an integrated manner to control cotton pests.

Table 5. Specific ideas tested concerning IPM strategies and the perceptions of different SLG members, Case II.

Ideas to be tested (IPM strategies: integrating selective pesticides, Neem mixture and action threshold)	Source of ideas	What needs to be done
Conserve natural enemies better	Researchers	Observation of natural enemies
Control cotton pests better	Researchers	(Not everyone is convinced) Test locally
More cost-effective	SLG members	Evaluate

Source: group discussion with the learning group, N'dali, March 2005.

Experiment design and assessment

Two options for the experimental design were discussed with the SLG, and also with other farmers and scientists. The first option was a randomised block design (laid out in the same field), which would allow statistical analysis of the data. Such a design usually generates reliable results; however, it bears the risk that the recommended standard practice of using synthetic pesticides including Endosulfan early in the season would contaminate those plots aimed at conserving natural enemies. The second option was to take a “more ecological” approach, which strictly avoids the interaction between the plots using synthetic chemical treatments and the plots aiming to conserve natural enemies, by allocating the treatment blocks to different farms. This design, however, carries the risk of biasing statistical analysis. In discussion with scientists they stressed the need for the results to be statistically sound. Also they were concerned that using different farms for the replication would increase variation. It also would not avoid the risk of contamination with pesticides from neighbouring farms that practised the regime of calendar-based spraying. They suggested that, as much as possible, a big space should be left between plots in a block design in order to reduce the effects of pesticide contamination. The discussions of the SLG then were opened to the whole village, and at that meeting the focus was mainly on the second (i.e. the more ecological approach) experimental design option. The researchers asked to locate the experiment in a field that would not be surrounded by fields treated with synthetic pesticides. According to villagers, however, it would be difficult to implement such an experiment, because all the farmers in the surrounding area applied synthetic pesticides. The other members of the SLG also warned the researchers of the risk that even if farmers

accepted in public not to spray in the fields around the experiment, there could be no guarantee that spraying would not occur. The first author's previous experience in the organic cotton production area indeed had been that contracting a conventional farmer not to spray around the experimental plot, was not successful. The discussion at the village meeting finally led to the following solution: the farmers undertook not to plant cotton in the fields surrounding the experimental field with the randomised design. The chief of the village offered four ha for the experiment and the owners of the three ha on each side promised to sow this area with crops other than cotton. The treatment with the calendar-based spraying of synthetic pesticides would be separated from the other treatments.

The final experimental lay-out thus looked like this: a randomised design located in a common field with large bush row spaces (10 m) between the replicated plots, and a non-cotton crop sown over three ha. on each side of the experiment. The following treatments were applied:

- 1) control crop without pesticide spraying;
- 2) IPM strategy No. 1: Bt insecticide applied on an ETL basis starting from 30 DAE onward;
- 3) IPM strategy No. 2: Bt insecticide applied on an ETL basis, from 30 to 70 DAE then in the following period a mixture of Neem seed extract with $\frac{1}{2}$ dose of the recommended pesticides applied on an ETL basis;
- 4) IPM strategy No. 3: Neem seed extract in combination with a $\frac{1}{2}$ dose of recommended pesticides used on ETL basis starting from 30 DAE onward; and
- 5) calendar spraying with the recommended insecticides, located in a farmer's field. In order to limit the disruption of the experimental environment by the synthetic chemical treatment, the last treatment was isolated from the others by a bush space of 100 m.

Following the learning during Case I it was now easier to reach consensus about the replications, the allocation of the control plot, the inter plot space, the identification of the plots, responsibilities for management, implementation, and for data collection. In order to create an ecological unit of a plot necessary for populations of natural enemies to build up, the experimental unit was enlarged to 20 x 25 m without much disagreement.

It was also proposed to use an "insect zoo" as a didactic tool for helping the SLG to understand the importance of natural enemies and the negative impact of early insecticide spraying on those natural enemies. The coccinellids (lady bird beetles) were chosen as an example. Two insect zoo cages were set in one replicated plot per treatment. One cage included two plants with aphids and a certain number of coccinellid larvae, and the other one included two plants with aphids only. The aphid incidence were scored as 1 = number of aphids <10; 2 = number of aphids \geq 10; 3 = number of aphids \geq 20. The cages were supplied with a number of

coccinellid larvae that corresponded to the aphid incidence, viz. 2 larvae per 10 aphids. Both cages were sprayed according to the treatment of the plot. The evolution of the aphid and coccinellid populations was compared within treatments and among treatments.

The evaluation

Based on the discussions of a meeting (N'dali, October, 2005) held to review the results of the field experiments, the IPM strategies were identified as having a relative efficacy. In addition to being financially attractive to the farmers (with the exception of the use of Bt insecticide only) most of the IPM options were felt to be less risky with regard to health and the environment. However, the IPM management strategies were associated with a different level of risk in the production of seed cotton and it was suggested that care was needed in implementing the management strategies at farm level.

Secondary pests like aphids and mites were observed to have low population densities in the Bt treatment and control plots. The ETLs were not reached in the control and in the Bt treatment. However, when the mixture of Neem and synthetic pesticides was used the ETL for secondary pests was reached once and twice when the standard package was used. This indicates a resurgence/outbreak of secondary pests. The use of the selective pesticides (Bt and Spinosad), and/or the delay in the early season applications of synthetic pesticides when the economic thresholds were applied, permitted natural enemies to develop, keeping aphid and mite populations low. The insect zoos also demonstrated this result. After four sprays the coccinellid population was nil in the standard package treatment while the aphid population increased; in contrast, the aphid population was nil in the control plot while the coccinellid larvae were able to develop into pupae and adults (Table 6).

Table 6. Results of Insect Zoo observations of the effect of Coccinellidae on the incidence of aphids in cages in cotton.

Treatments ¹	Before first spray				After two sprays				After four sprays			
	Aphid incidence ²		No. of coccinellids ³		Aphid incidence		No. of coccinellids		Aphid incidence		No. of coccinellids	
	+ C	- C	L	N/A	+ C	- C	L	N/A	+ C	- C	L	N/A
Control	2	2	4	0	1	3	3	1	0	3	3	1
Standard programme (SP)	2	3	4	0	0	0	0	1	2	2	0	1
T1	2	2	4	0	0	3	2	1	0	3	1	2
T2	3	2	6	0	1	4	3	2	1	4	1	4
T3	2	2	4	0	0	2	2	2	0	3	0	4

¹ For the explanation of treatments (SP, T1-T3) see text.

² Aphid incidence in cage with (+ C) and without (- C) coccinellids.

³ Number of coccinellid larvae (L) and 'nymphs or adults' (N/A).

Source: Authors' survey, September, 2005.

However, the natural enemy populations, which were composed essentially by generalist predators, did not succeed in controlling the bollworms. The population density of the bollworms observed in the control reached the ETL several times.

A number of the strategies, including mixtures of Neem with half the dose of the recommended synthetic pesticides, were as effective in protecting bolls against bollworms as the recommended package, and more effective than the rest of the treatments in protecting the bolls against heteropterous insects.

This synergistic effect of Neem and the synthetic pesticides has been reported in chapter 4. It may provide an explanation for the higher yield obtained in plots sprayed with this mixture and validates the same synergistic effect result observed in Case I.

In all, the use of the Neem mixture combined with threshold-based spraying action was found to be an important option for integrated pest management in cotton. It also limits the risks of development of resistance to insecticides. By developing these options through the involvement of farmers, the farmers gained a better knowledge of crop protection and the farming community found the threshold concept to be of interest.

Learning forum

A learning forum was designed as a two-day workshop (December 27-28) organised by the SLG with the participation of the Gounin village community, the farmer organisations' representatives, senior members of the cotton research institute, as well as extension workers. It was held to review with the community and the professionals the results obtained and the ways forward. Each category of the SLG presented what he had learned through the two co-researching seasons. The SLG members showed themselves to be confident in the Neem-SP mixture and its use in an economic threshold management regime, since it saved natural enemies and reduced the number of applications and active ingredients of synthetic pesticides. The SLG members were also aware that the efficacy of the technology did not depend on simple promotion and diffusion of the method. They were well aware that it could work only if farmers understand the basic principles of what is proposed and that all farmers of the community should be involved to avoid the risks of contamination from full dose treatments of synthetics. For that reason they suggested that more farmers should have an opportunity to learn and discover, to develop their ability to experiment and to draw conclusions, and to take sound decisions. The forum mandated the farmer members of the SLG and the extensionist to keep records of the experiments and to make these available to the community members and, during the Friday community work sessions, to explain to any other farmers on request the practices followed by the SLG. The farmers' organisation representatives were willing to find a way of scaling-out this technology and management regime and had already informed farmers about the advantages through a

farmers' newspaper (Weziza, 2006). However, the forum was concerned about the availability of Neem raw material.

Analysis and Discussion

How technologies arise

The cases reported here present a situation in which a learning group jointly assessed: i) an existing local technology identified during an exploratory phase of study that was championed by a few of the farmer members of the group; and ii) an integration of a local technology into an IPM control method proposed by a researcher.

The idea of mixing botanicals with synthetic pesticides (i) was prompted by evidence, that farmers themselves observed pyrethroïd resistance among key cotton pests, the increased environmental and health risk, and the higher costs incurred by use of synthetic pesticides. The initiative taken by farmers to mix half the dose of the recommended pesticide with a local insecticide plant to fight against cotton bollworms could be seen as an endogenous technology (Van Mele, 2000). The precise origin of the technology can no longer be established. One might speak perhaps of blending local, external and scientific elements (Leeuwis, 2004).

Despite farmers' knowledgeable and expertise, they may at times lack the insight or tools to draw appropriate and sufficiently accurate inference. This may be especially so when phenomena are difficult to observe either because of their inherent characteristics, small size (sorghum midge), cryptic behaviours (stem borers), spatial distance (migration of insects), or temporal lags (e.g. build up of natural enemies) (Leeuwis, 2004). Leeuwis (2004) concluded that there is then scope for sharing learning and an expansion of farmers' knowledge through interaction with scientist and extensionist around field experiments. This was the expected role of the learning group and IPM strategy experiment, in the sense that farmer had shown how they dealt with "what" and "how" but had not been able to tackle the all-important "why" question. The iteration of the learning cycle over a second season showed that learning had taken place concerning the negotiation of an effective research design and implementation protocol, incorporating the ideas, interests, and concerns of stakeholders who conventionally would act in isolation.

As understood here, "innovation" is no longer to be seen as a product of individual genius working in isolation. It is no longer only a thing. "Innovation" emerges from people's interaction (Guera, 2003) and their interaction with their environment. Technology in this perspective serves to intermediate relationships. As Leeuwis (2004) puts it "*When starting from the assumption that innovation is a collective process, other key processes come to mind...this include social learning, conflict resolution and negotiation*".

As relationships become stabilised around the innovation process – as in the learning group

– new institutional arrangements and rules come into being that may sustain the innovative momentum.

Methodological lessons

Question of valorisation

The search for an arrangement by which scientists and farmers can interact to develop a control system that works, that will be accepted by farmers, and that develops stakeholders' confidence in the effectiveness of endogenous technology, did not prove easy. Both farmers and scientists were involved in determining the research agenda. The main researcher was involved not only as scientist but also as facilitator of the learning group's researching process. This facilitation included sharing with farmers key elements of the scientific method, such as replication and control, through both negotiation and action; offering ideas, information and access to technology; and helping the farmers to establish contacts with a wider circle of expertise. It also, importantly, involved assisting the members of the learning group to experience iterative 'learning cycles'.

The involvement of the farmers from the identification of the topic to the phase of experimentation deserves particular attention (Deugd et al., 1998; de Jager et al., 1999). Our methodology distinguishes itself from approaches that neither valorise endogenous knowledge nor implicates farmers in the development of the research axes (Kossou et al., 2004). Throughout the process described in this chapter, our relation with the producers and the extensionists was that of a partnership. The research design, assessment criteria, the role of each member, were negotiated with the learning group. What emerged was an improved design and implementation process, from which all members of the SLG learned. Bentley (2002), and Meir (2005) have recognized the advantages of such partnerships. These authors have shown empirically that smallholder farmers are more minded to appreciate and accept technical innovations in a setting that valorises local knowledge as well as scientists' information.

The process of co-researching

The process of co-researching can result in radical changes in farmers' mental maps of their role in the process of technology generation and diffusion. Braun and Hocdé (2000) noted that through involvement in a co-researching programme, farmers could realise in explicit, public procedures that they are capable of experimenting, offering solutions, communicating and transmitting technological options to others. These effects were experienced also among the farmers of the SLG, as they became empowered as decision-makers.

The potential for conflict between the scientists' understanding of what could guarantee the rigour of the research and the farmers' wishes is noticeable in the two cases presented.

Farmers' concepts of a valid experimental process have been shown to differ from those of the formal researchers. For example, the farmers in Gounin did not limit what they conceive as experimentation to plots specifically designated for that purpose and, while the notion of a "control" is clearly not alien to them, they perceive less need than the researchers to control for variables in an environment which is as familiar (and predictable) to them as it is unfamiliar (and apparently unpredictable) to the outsiders. Nevertheless, it has been shown that a balance can be achieved between these two points of view that still produces reliable results. The resultant reduction in the number of control plots and comparative trials greatly reduced the research management time both on the part of the facilitator and on the part of farmers. This in turn gave more scope for discussing with farmers matters such as trial record keeping, alternative layouts, and appropriate procedures, and for giving training in these areas as required.

Innovation in the two cases reported required a change in the relation among the stakeholders. The distinguishing feature in the innovation processes discussed was the systematic collaboration, constituted in and through the SLG. The SLG was not sufficient to ensure innovation but innovation needs this platform around which fruitful relationships can form.

Learning and knowing

Overall, the two experiences presented draw upon the concepts of Freire and Fals Borda (Braun and Hocdé, 2000) that reject passive knowledge banking in favour of active knowledge acquisition and generation. Other concepts, which have been mapped on to these two case studies from earlier participatory research experiences, include the interaction of processes, the cycling of action¹ and reflection², and the importance of 'learning lessons' as keys to ensuring the effectiveness of the on-farm learning cycle. *Learning become knowing through acting in a domain of existence* (Maturana and Varela, 1992). The results of the experiments were constructed knowledge in the sense that they were the outcome of a number of decisions and selective incorporation of previous experience, ideas and beliefs (Arce and Long, 1987). The success of the SLG experience as a process of co-researching is evident in the fact that the farmers have learned more about insect ecologies in their own fields and the options for crop protection and that they have been able to draw their own conclusions out of the experience. The essential factor in strengthening farmer innovation capacity would appear to be that it is not technology *per se* that is a constraint but rather the institutional barriers that prevent the

¹ Action refers to processes such as planning, experimentation and evaluation (Braun and Hocdé, 2000)

² Reflection refers to processes such as analysing results and also extracting what has been learned from the process itself (Braun and Hocdé, 2000).

construction of methodological processes that support experimentation and learning (Braun and Hoddé, 2000).

Role and motivation of learning group actors

During the process of innovation the role of each actor depends on the one hand on the actor's knowledge and perceptions and on the other hand on the actor's influence over decision-making (Van den Ban, 1994). In the process of co-researching presented in this article, farmers and scientists were jointly involved in determining research agendas. Nevertheless, each stakeholder category in the SLG used their own assessment criteria and own method of data collection. The exchange among actors created a richer picture of the agro-ecology and the effects of different management interventions, as well as allowed agreement on the results to be more easily reached. However, it appears sometimes that what one actor finds relevant and efficient is regarded as less relevant or efficient by another. For example, a strip-cropping experiment reported by Garcia Saez (2005) was judged efficient by the producers whereas the results were seen as statistically uninteresting by the researchers.

One of the strongest motivations of the farmers to join and remain in the learning group was the "search for knowledge" or the "curiosity of discovering". This might seem to relegate the farmers to a position only of that of learner. In reality, the base idea of the co-researching process was to think and act together, so that a convergent evolution of both scientific and endogenous knowledge would allow an interactive synergy to develop among the actors. By structuring communication as a social process in the space for learning created by the institutional innovation of the SLG, the actors became complicit in problem analysis, development of solutions, and the creation of the space for innovation. However, some farmer members of the SLG are not yet convinced of their role in the co-researching system. According to our post-experiment interviews with the SLG members, only 60% of the members recognise that they also have contributed knowledge to the other actors in the co-researching process.

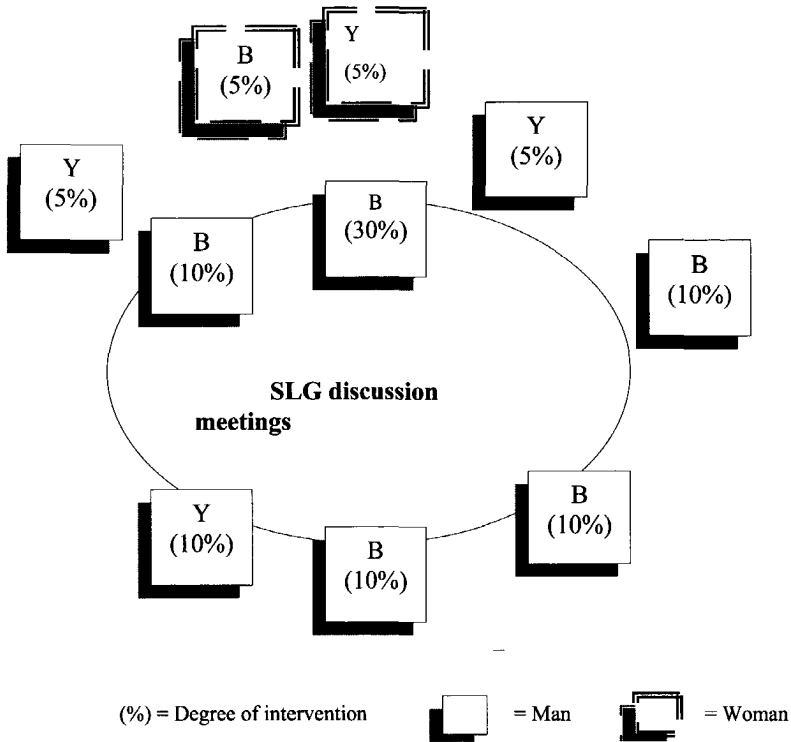
Questions of participation: empowerment

"Empowerment means individuals acquiring the power to think and act freely, exercise choice, and to fulfil their potential as full and equal members of society" (DFID, 2000). In principle, farmers' participation in agricultural research and extension offers potential to improve the effectiveness and efficiency of these empowerment processes. Participation can help break the mentality of dependence and can promote self-awareness among people to control their own problems (Elias, 2004). A dialogue between one of the older farmers of the SLG and one of the LRAs offers a clear illustration. The farmer claimed: *"In my life time I never had seen that! We as farmers teaching researchers and extensionists about our practices. Instead of coming*

to ask whether we have done the scouting or spraying, the extensionist and LRA sit with us and experiment with us, and ask about what we did and so we learn together”. And the LRA replied: “I also never thought that farmers had enough knowledge to develop technology such as the mixture one! I was surprised that they have their own assessment criteria that sound scientific. I realised that some of your recommendations, like early application of pesticide, have adverse effects and that could be demonstrated simply and convince everyone. I think we have to do these types of exercises often in order to learn from each other”.

However, there is real chance that the participation becomes token or symbolic. In the cases of co-researching reported here, the obstacles to participation that were experienced were embedded in farmers’ cultural identities and/or were a facet of the divergence of interests, or directly linked to the professional identity of each category of actor.

The ten farmers of the learning group were from two different ethnies, *Batonou* and *Yom*, who were equally represented in the SLG. However, the ethnies *Batonou* is the dominant group.



Source: Authors’ survey of 12 SLG meetings.

Figure 3. Social relationships and intensity of intervention of Stakeholder Learning Group (SLG) male and female members of the Yom (Y) and Batonou (B) ethnic group in Gounin village in Benin.

This social difference means for example that it is difficult for a *Batonou* to consider true and convincing an argument developed by the *Yom*, who are migrants. Another social difference observed in this region is inequalities between the sexes. These two phenomena inspired the researcher to record and evaluate the number of times each member of the group “took the word” in order to make a proposition or advance an argument in the SLG meetings. After each meeting, a diagram was constructed that translated schematically the position of each member in terms of these speech events (Figure 3). The members did not have a constant position from meeting to meeting but the pattern of speech events was consistent, and these have been aggregated in Figure 3. We observed that the members did not participate to the same degree and that this pattern was consistent with cultural expectation. The women often stood back from the group, because in the *Batonou* society, women do not sit in the same place or argue with a man. It would be appropriate to search for some means to go beyond these cultural patterns, without creating frustration within the group, to promote a fuller and more equal involvement by all members in such groups.

Concluding comments

This study reports the results of a co-researching experience with a stakeholder learning group for cotton pest control technology development. It has provided insight into farmers’ capability and needs concerning an innovation process. Involvement of stakeholders in the co-researching process appears to be essential if sustainable pest management issues are to be identified in a changing institutional and ecological environment. The challenge is to provide the learning environments which enable all those involved to develop a more holistic perspective, within which they can make their particular contribution (Bawden et al., 1985).

A co-researching approach such as that described here evolved around the cycling of action and reflection. Each repetition served to maximise the knowledge available at any time to support decision-making by those in the learning group.

Through time, as those involved cooperated to develop the necessary knowledge and knowledge-based tools, new issues were raised and the process expanded.

The approach provided science with the opportunity to learn from local actors endowed with endogenous knowledge acquired through the accumulation of experiences, informal experiments, and intimate understanding of the environment in a given culture. It allowed scientists to obtain a better feeling for how their research field fits into the total system, and provided an appreciation of farmers’ management concerns and issues.

At the same time, the formal involvement of local actors in the programme helped these actors to realise that they are capable of experimenting, offering solutions, communicating

and transmitting technological options to others. Farmers acquired greater technical expertise, building on both collective local knowledge and an associated scientific awareness of their particular environment.

This empowered the farmers of Gounin, as they became the main decision-makers. Although such a co-researching undertaking may not be able to offer definitive solutions to such elusive issues as sustainable pest management, it can begin to offer a variety of knowledge-based methodologies and tools and possible courses of action to enable the community to make better-informed decisions.

7

General discussion:

Collaborative Development of Crop Protection- the case of Integrated Pest Management in the Cotton Sector in Benin

Antonio A.C. Sinzogan

Introduction

This thesis has addressed the technical and organisational problems of crop protection in the cotton sector in Benin. It has analysed why technical alternatives to farmers' current dependence on purchased synthetic insecticides is necessary if cotton is to remain a worthwhile crop for farmers, and if the cotton sector is to regain the efficiency needed to compete in today's markets. It has shown that a number of alternatives are viable and that one at least gives substantial advantages over farmers' current practices. It has also explored the role of a local learning group in identifying and testing such alternatives, and in bringing the best performing option into wider use, thereby bringing into question the conventional R&D pathway. This chapter summarises the main findings and assesses them in the light of the original objectives of the study. A reflection on the lessons learned from the broader perspective of research design and practice, and in terms of how the scope for local innovation might be fostered on a wider scale, concludes this chapter.

Objectives

Over the last decade, the economic sustainability of the cotton industry in Benin has been questioned. Declining productivity and an increasing production cost are affecting the production system. Low yield caused by pests and socio-economic problems have been identified as the main problems facing cotton producers (Sinzogan et al., 2004), leading to low income, as cotton produces the main revenue for households in the cotton-growing areas of Benin. This thesis

presents a problem-oriented research inquiry into how to produce cotton in a sustainable manner without compromising public health and the environment, while increasing private and public returns to investment in pest management.

The study's main objectives were to:

- i) develop and apply a methodology for improving existing pest management technologies, or for testing new pest management options that might help cotton farmers to get adequate returns to investment;
- ii) and place the methodology in a multi-actor learning process that seeks to create the institutional space for sustainable innovation.

A preliminary literature review was carried out at Wageningen University (WU), The Netherlands, and “*Université d'Abomey Calavi*” (UAC), Benin. A technographic study, a diagnostic study, field experimentation, and stakeholder interviews were carried out in Benin, complemented by taxonomic studies at the Entomological Laboratory, WUR and the Museum of the International Institute of Tropical Agriculture. The main research site in Benin was the village of Gounin, in the municipality of N'dali, in the northern cotton zone, where collaborative field trials were carried out together with members of a multi-stakeholder Learning Group during the 2003-2004 and 2004-2005 cotton growing seasons. The field experiment data were analysed by means of statistical analysis using SAS software version 8 and economic analysis tools. Stakeholder interviews with key actors in the cotton sector also were carried out in order to develop deeper insight into the organisational linkages that constrain the cotton sector reform process; these were analysed by means of stakeholder analysis and participatory diagramming. The results of the diagnostic study and stakeholder analysis have been published (Sinzogan et al., 2004; Sinzogan et al., 2006); the results of the field experiments (Chapter 4 and 5) have been submitted for publication; and the analysis of the technology development processes constituted by the Learning Group is in preparation (Chapter 6). These studies and articles form the main body of the thesis.

Main Findings

The study generated findings on a range of alternative methods for controlling economically significant cotton pests, principally by means of the integration of different pest control methods such as the use of botanicals, entomopathogens, and the reduction of the number of sprays and synthetic active ingredients using action thresholds. The study also demonstrated a methodology for conducting site-specific, ecologically-informed research for development (R4D), that created the institutional potential to sustain innovation. The notable features of the methodology were:

using a perspective relevant to farmers as the entry point, developing control methods in the context of a multi-stakeholder learning alliance, and altering the boundaries and conditions that affect the space for change.

The identification of farmers' problems, needs, and opportunities (chapter 2) showed that the motivating factor for farmers to grow cotton is the potential cash return and the opportunity to improve their livelihoods. The diagnostic study also identified a lack of basic pest management knowledge and skills among the farmers surveyed (Chapter 2). It also showed that farmers were not following the pest management recommendations of researchers, neither for the conventional spraying regime nor for the so-called LEC system that has potential to substantially reduce the amount of synthetic chemicals used, and the study thus allowed the conventional research process itself to come into question. A stakeholder analysis (Chapter 3) assessed the prime actors influencing farmers' knowledge and revealed that in order to become successful and effective partners, farmers would need to be assisted to change their production system, to release their dependence on production credit and pesticide inputs (Vos, 2004).

The Stakeholder Learning Group (SLG) was established to facilitate the actors' collaboration in participatory development of experiment-based cotton pest management technology. Entry points that are relevant from farmers' perspectives have been shown to be critical for the success of any integrated pest or crop management intervention (Van Huis and Meerman, 1997; Meir and Williamson 2005). The SLG focused on reducing the dependence on external inputs and lowering production costs (Williamson et al., 2005), taking into account that pesticide treatments constitute 30-40% of the production costs (Ton, 2001, Sinzogan et al., 2006). The study of *what useful abiotic and biotic relationships can be constructed?* and *what can technically make a difference?* (Chapter 4 and 5) thus sought to identify an efficacious pesticide management strategy, which would be both cost-effective and reduce the impact on health and the environment, while developing stakeholders' confidence in the effectiveness of endogenous technology (Chapter 6).

With respect to the surveys and experimentation it appear that farmers were very clear about the constraints limiting their production. They appreciated very much the interacting with scientists concerning the development of their knowledge, perception, and practices in pest management. Despite farmers' longstanding use of synthetic pesticides they used an endogenous technology: mixture of botanicals and synthetic pesticides. The success of the technology seems to be based on the synergetic control action of Neem and synthetic pesticides (Chapter 4 & 5).

A challenging aspect regarding the whole research was the collaboration with stakeholders in the design of field experiments. Farmers' concepts of a valid experimental process have been shown to differ from those of the formal researchers (Chapter 6). It appears sometimes that what one actor finds relevant and efficient is regarded as less relevant or efficient by another. For

example, a strip-cropping experiment with another SLG, reported by Saez Garcia (2005) was judged efficient by the producers whereas the results were seen as statistically uninteresting by the researchers. Moreover, the quantity and quality of participation in the various information exchange and reflection events - both of which are critical components of success in participatory research (Vernooy and Mc Dougall, 2003) - was very difficult to sustain throughout the two growing seasons in which the field experiments took place.

We also experienced a turnover among the SLG members a few weeks after its foundation. Sickness, migration, and time constraints were the publicly stated reasons for non-participation. However, more informal discussions revealed that the initial rush of enthusiasm experienced at the diagnostic meetings and feedback meeting dissipated as people realised in more detail what might be required of them as members of an SLG. Other obstacles to participation that were experienced in the SLG were embedded in farmers' cultural identities as members of two different ethnies, *Batonou* and *Yom*, and to the inequalities between the sexes (Chapter 6)

Discussion

There is a particular problem brought about by the promotion of synthetic insecticides in the cotton crop, that is, it tends to erode valuable indigenous knowledge on pest management (Atteh, 1984). Further, it positions farmers as the passive recipients of predetermined technical prescriptions. None the less, an endogenous technology (Van Mele, 2000) consisting of mixing botanicals with synthetic pesticides was identified during the exploratory phase of the study (Chapter 2), indicating that knowledge development was continuing within the farming community. The endogenous technology was prompted by evidence, that farmers themselves had observed, of pyrethroid resistance among key cotton pests, that their experiments with mixtures of synthetics and extracts of local plants seemed to deliver some benefits, as well as by their awareness of the increased environmental and health risk and the higher costs incurred by use of synthetic pesticides. As a result of these findings, three botanical extracts with known bio-efficacy against cotton bollworms -viz. *Azadirachta indica* seed extract, *Hyptis suaveolens* leaf extract, and *Kaya senegalensis* bark extract, applied either alone or in combination with half the dose of the recommended pesticides (including Endosulfan), were assessed and compared to the full dose of the recommended pesticides, in field experiments designed and implemented by the SLG.

Based on an economic analysis of the results, the SLG concluded that use of the synthetic pesticide alone was not the most economical (even when environmental, ecological and health costs are not considered). From among all the treatments evaluated, the Neem seed extract mixed with half the dose of recommended pesticides was found to be the most cost-effective.

The SLG attempted to evaluate how available alternative control measures such as Neem seed extract mixed with half the dose of the recommended pesticides (Bharpoda et al., 2000; Sarode et al., 2000; Chapter 4), and selective pesticides such as Bt and Spinosad, could be combined to get “a *best mix of control tactics for a given pest problem in comparison with yield, profit and safety of alternative mixes*” (Kenmore et al., 1985). The results showed (Chapter 5) that a reduced number of sprays (except in the case of the use of Bt pesticide only), and reduction in the active ingredient applied, based on an action threshold, are enough to protect the cotton plant against the bollworms, compared to the conventional treatment regime (calendar-based application of six sprays of synthetic chemicals, using more active ingredients). The incidence of the bollworms on the reproductive organs, in particular on the boll, was reduced to a significant degree by the experimental treatments compared to the conventional treatment. Action thresholds were shown to be effective and did not lead to excessive spraying (Ochou et al., 1998; Bharpoda et al., 2000; Silvie et al., 2001, Naranjo et al., 2002), while also offering considerable cost saving.

The study thus allowed the conventional insecticide recommendations also to come into question. However, the stakeholder analysis revealed the organisational interests that perpetuate the promotion of the conventional system and block any shift toward promotion of lower dose treatments (chapter 3). The study thus has been forced also to consider the development of R4D pathways that might enable cotton farmers themselves, together with other local actors, to lead a transition toward more profitable crop protection practices.

It was recognised that a change from the conventional research recommendations for cotton pest management to an integrated pest management approach is an innovation which could re-direct cotton production to a more ‘ecologically sound’ path. This kind of shift requires a complex learning process that can take a number of years, and typically involves a wider range of actors than farmers alone (Roling and Jiggins, 1998). Because of the involvement of actors who need to work together in developing such innovations, the idea of a ‘establishing a ‘learning platform’ or ‘stakeholder learning group’ was pursued. Local actors were facilitated to collaborate in participatory, experiment-based agricultural technology development: a ‘co-researching approach’ (Chapter 6) that has provided opportunities also to study the process through participant observation and before-and after-surveys (Vos, 2004).

The developmental purpose of this research was to facilitate learning towards sustainable cotton pest management. The results of the experiments were constructed knowledge in the sense that they were the outcome of a number of decisions and selective incorporation of previous experience, ideas and beliefs. This placed the main researcher in a three-fold role: as one of the sources of ideas and expertise available to the SLG; as a facilitator of the multi-stakeholder experiential learning process constituted with and through the SLG; and as a researcher with a

personal stake in the outcomes of the surveys, field trials, and SLG process. The first two roles included providing tools for guiding farmers to use the right methods, and to introduce basic principles for enriching content and understanding. If used correctly, these tools and principles bring forward the potential skills, creativity and knowledge of the group of the participating farmers (Van den Berg et al., 2001). One thing I have learned and believe is important for the “*success*” of this kind of research is the confidence and mutual respect that developed over the time. This was gained through regular practice and through direct involvement in field studies. In addition, the claim from the very beginning that I did not have preconceived answers but that I was willing to work with those who wanted to try out alternative options, building knowledge together by joining local and scientific knowledge, was also essential (Bentley and Andrews, 1991; Trutmann et al., 1996). The third role has required also careful and systematic documentation of the process.

These multiple roles at times caused some problems, like being part of the group as a researcher and at the same time documenting the interaction between different members of the group.

The main lessons that might be drawn from attempting to conduct an SLG from this position of multiple role-playing are as follows:

1. collaborative, user-oriented technology development is an art that requires both discipline and experience if it is to deliver robust results;
2. the advantages are that such processes create an “innovation space”.

The experiences presented in this thesis also posed considerable personal and professional challenges to the main researcher. The advantages that the researcher brought to the complexity of his roles were his training in agronomy and entomology, and his previous experience as a facilitator of a Cowpea Farmer Field School. However, he had to embark on a steep learning curve through the opportunities offered by the CoS project, in order to deepen his understanding of social, organisational and institutional processes, and his ability to work with and analyse these critically.

A number of lessons can be drawn from this aspect of the experience:

1. it is easier to develop a multi-disciplinary competence as a member of a team of other researchers, with whom both specific skills and meta-level understanding can be developed;
2. field-based training is essential in the development of competence in research-for-development.

Smits and Kuhlman (2004) argue the end of the linear model of innovation, as over-reliant

on expert problem definition and technology transfer. They suggest five functions of innovation systems:

- i. management of interfaces;
- ii. construction and organisation of new systems of relationships;
- iii. providing a platform for learning and experimenting;
- iv. providing an infrastructure for (market-oriented) strategic intelligence;
- v. stimulating demand articulation, strategy development and visioning.

How well did the study presented in this thesis develop these functions? The study concentrated on functions iii and v, whilst deepening stakeholders' appreciation of i, ii, and iv. The expectation was that by opening the potential for releasing farmers from their pesticide dependency, organised cotton farmers themselves can begin to manage these three functions in ways that more neatly meet their own interests. Certainly this study has shown that as long as the currently most influential actors in the cotton industry continue to serve their own narrow interests in terms of functions i, ii, and v, rather than those of the cotton industry as whole, innovation in the cotton sector will be constrained, with continuing loss of efficiency and competitiveness.

Impact of co-researching with SLG on its members' livelihoods

This section is partially extracted from the results of an on going evaluation of the outcomes of the co-researching approach used by the Benin CoS students. It was requested by the Benin CoS team and conducted by two independent researchers i.e. not involved in the implementation of the SLG.

The CoS project's long-term aim is to improve the livelihoods of the rural population. This thesis describes a *pest problem research process* that has development as its primary aim: - i.e. *research for development* (Ashby, 2003). The implication is that: "... *it is to be judged by its impact on the livelihoods of people, rather than by intermediate outputs such as successful solution of a research problem...*" (Mettrick, 1993). It follows that the impacts of the co-research with cotton farmers in Gounin village should be expected to go much beyond improvements in the management of cotton pests, to include social organisation and human capital developments i.e. they should be expected to initiate processes of capacity building that lead to the participants' *empowerment* (Bartlett, 2004). Evaluation is therefore needed to appreciate the broader effects that might result from the SLG experience, and that captures farmers' own appreciation of these values. A study thus was initiated by the Benin CoS researchers of the impacts of their work in terms of human and social capital effects.

The study framework draws on the definition of sustainable livelihoods (SL) formulated by DFID (2003): “*A livelihood is a combination of the resources and capabilities people have, and the decision and action they undertake, in order to make a living and attain their goals and aspiration. A livelihood is sustainable when people can cope with and recover from different stresses and shocks and can maintain or enhance their capabilities and assets both now and in the future, while not undermining the natural resource base*”. The SL framework guides farmers in conceptualising change over time in their overall livelihood in order to capture their own perceptions of the impact of the intervention (Mancini, 2006). It is constructed around five capitals briefly described below; the capitals on which the SLG activities might be expected to have immediate direct impact are given in bold font:

- Human capital: assets related mainly to knowledge, skills, practices of individual and family members, and their health.
- Social capital: assets related to relationships, contacts, and networks, formal and informal group or social organisations people belong to and from which they can obtain various opportunities and benefit.
- Natural capital, - assets related to the natural resources base (land, biodiversity, etc.).
- Financial capital: - assets related to financial resources that people have and used as cash.
- Material capital: comprising housing, basic infrastructures such as transport, water and energy supply systems etc., and equipment (including household equipment).

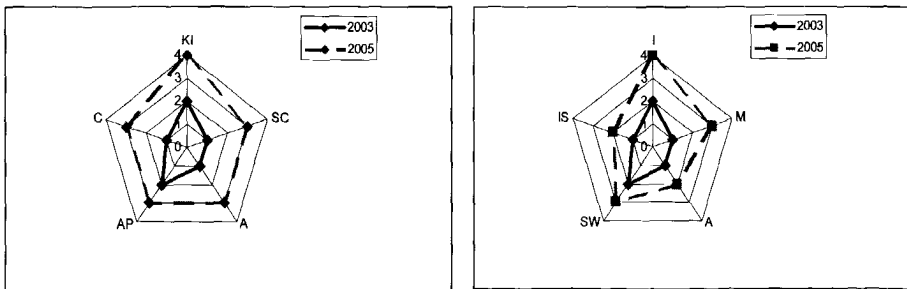
In brief, the purpose was to examine the impact of the SLG in terms of two dimensions of the overall SL framework. The elements of the human and social capitals meaningful to the respondents (the farmer members of the learning groups) were first elicited during group interviews conducted by the two independent researchers (Table 1). Secondly, the respondents each rated their own stocks of the assets they had identified for each capital, for the baseline year 2003 (SLG starting year) and impact year 2005, on a 0-5 scale, with the zero value (no stocks). The median values of the scores of the group members for the baseline and impact year were calculated. The researchers used these values to construct ‘Spider diagrams’ on poster sheets, in order to visualise the changes over time in the asset stock. Thereafter any changes made visible between the two references years were discussed with the respondents. The data presented here are those generated by the participatory evaluation process conducted with the Gounin-based SLG. Analysis is in progress of data from the complete study, conducted with the three other learning groups established in the course of the CoS project in Benin, and from a control group that was included for comparison. The data from the Gounin SLG case have been further processed, using parametric and non-parametric statistical analysis (see Sinzogan et al., in prep.).

Table 1. Categories and elements of responses identified under the two capitals (Human and Social)

Human capital	Social capital
Knowledge & information on: <ul style="list-style-type: none"> - Pest - Mixing pesticides - Natural enemies - Appreciation of pest damage - Evaluation criteria 	Interaction <ul style="list-style-type: none"> - Joint programme with researchers, extensionists and local research agents - Visiting other groups like organic cotton producers
Skill of communication <ul style="list-style-type: none"> - Share idea with others - Listen to others (including women) 	Membership <ul style="list-style-type: none"> - Mixed group (tribe, gender, age, and producer organization)
Attitude <ul style="list-style-type: none"> - Innovative (test ideas in their own field) - Respect for knowledge - Accommodative 	Attitude <ul style="list-style-type: none"> - Trust - Responsibilities - Solidarity
Agricultural Practice <ul style="list-style-type: none"> - Using mixed pesticides at small scale - Visiting field to evaluate damage before spray - Strip-cropping 	Social work <ul style="list-style-type: none"> - SLG considerate as community work - Feed back to the community
Contact	Institutional support

Source:Livelihood survey, N’dali, 10-2005

The preliminary results of the analysis are as follow. The SLG farmers perceived that their human and social capitals had increased (Figure 1). They described their personal growth primarily in terms of knowledge, communication skills, and changes in their attitude to their participation in the learning platform. The increase in human capital was perceived in terms of



a

b

Key: KI = knowledge & information, SC = skills of communication, A = attitude, AP = agricultural practices, C = contact, I = integration, M = membership, SW= social work, IS = institutional support

Figure 1 Farmers’ perceptions of change in their capital stocks recorded between baseline year (2003) and impact year (2005): human capital (a) and social capital (b).

new knowledge acquired and the establishment of new contacts.

They described changes in social capital in terms of the new relationships established among the farmers, local research agent, extensionist, and formal researchers, their increasing confidence in the endogenous technology, an increased appreciation of the value of and potential for innovation, and in their own communication skills.

The contribution of this study is, beyond these specifics of what farmers' valued, that it helps to establish the inner validity of the "co-researching with SLG" approach. We have shown that, from the SLG farmers' own point of view, the co-researching experience yielded important gains beyond the development of technology. In their view it has improved their human assets, comprising leadership, knowledge, management skills and capacity to innovate, and social capital assets, comprising relationships based on explicit norms and on trust, embodied in a new social organisation (Tripp, 2006).

Gains in these capitals appear to be important in bringing about technical change in agriculture. Low- external input technology (such as some forms of IPM) is, indeed, information-intensive and hence it becomes important to ask where farmers might be expected to get information and to what extent local networks (e.g. the farmer-extensionist-local research agent relationship) might facilitate the flow of indigenous knowledge, scientific principles, or attitudes regarding pest management (Tripp, 2006). Forster and Rosenzweig (1995) find in India for adoption of new varieties that 'farmers with good, expansive and experienced neighbours are significantly more profitable than those with inexperienced neighbours'.

A study using a comparable technique with cotton IPM FFS farmers and a control sample in India (Mancini, 2006), and with similar SLG groups in Benin, dealing with weed management (Vissoh, 2006) and soil fertility (Saidou, 2006), have recorded similar gains in social and human capitals as a result of group-based experiential learning experiences. However, it should be noted that in the reported cases the recall process for base year values may have introduced a bias, and that the indicators of social capital are largely surrogate and indirect (Bebbington, 1999). Caution must be exercised therefore in interpreting the results (Tripp, 2006).

Concluding reflections on the co-researching approach

Entry point

The choice to work on cotton pest management followed the process approach advocated by Røling, (2004). The topic of cotton pest management was a *pre-analytical choice* (The notion of pre-analytical choices refers to the choices that are made before embarking upon research project (Røling et al., 2004)) guided and informed by technographic studies (Richard, 2001) that had revealed an urgent need for further improvements in pest management practices and

the existence of a large range of alternative pest management technology options (Kossou et al., 2004), and by the previous professional and personal experience of the author. Moreover, a starting assumption was that, in order to be effective, research for development must work on farming problems as identified by the farmers within the social, political, economic and cultural context they live in - which is also the one in which they must take decisions that ultimately affect their survival (Lee, 2002). Following the pre-analytical choice a diagnostic study (Sinzogan et al., 2004) was conducted that helped to bring farmer's perceptions, needs, knowledge, cultural inclination, and enthusiasm into focus when defining research problems. The technographic and diagnostic studies provided legitimacy for the choice of research domain and research location and pointed to the options for the next steps in building a collaborative research process. They also helped to decompose the general category of 'cotton farmers' into identities meaningful for selection of whom to work with, with awareness of the social network implications of the choices made. This kind of explicitness has consequences for the potential for institutionalisation and scaling-up.

If the technographic study is a new concept, diagnostic studies are not, but what seems different in the CoS approach is how farmers were effectively involved in the identification of the problems and how their knowledge was taken into consideration in the definition and design of the study. The diagnostic study allowed researchers together with the beneficiaries of the research results to set a common agenda in a complementary way.

A question to be asked is whether the nature of the causes of the main problem identified, the reasons why these causes have persisted, and the local opportunities to cope with these in a different way, could be fully understood in the short period during which the diagnostic study lasted. My own experience suggests that the objective of bringing out farmers' needs, knowledge, etc. may not be achieved if a diagnostic study is treated as a 'stand alone' study. But the co-researching process, as conceived in the CoS approach, is a dynamic process that allows flexibility and adaptation. The diagnostic study served as a preliminary step, to put relevant problems on the agenda for further inquiry and action. In fact, it was during the diagnostic phase that a platform began to emerge on which stakeholders could interact in order to engage in joint learning. So the shared understanding of the identified problem and the opportunity to act co-evolved, with specific activities adjusted to the needs and opportunities that arose. Here we find that an important distinction can be made between the design of one-off events (such as a stand-alone workshop or a diagnostic study) and a learning process (Blackmore, 2002).

Study design and technology developed

The set of elements in the co-researching process that seem to be essential in designing a learning path for SLG members includes;

- participatory diagnostic exploration to bring in focus farmers' needs, knowledge, opportunities, etc. when defining the problem to be researched;
- building a learning platform, that can be viewed as a means to learn about the human, social, and technical processes in sustainable cotton pest management. The technical aspects include: selection of the technical options to be tested, design of the experiments, review and assessment of progress, and interpretation of the results;
- design and testing of improved technologies and management options;
- development and practise of collaborative and experiential learning procedures that promote and sustain innovation processes
- collective and individual decisions about what to do with the results that take the shared learning process back into the wider institutional realm of social action, by means of a learning forum, that reviewed the role of the community and its institutions and further developed and promoted the options chosen.

The co-researching process described and analysed in this thesis should not be seen as a discovery of a new methodology so much as an adaptation and application of an existing methodology. It can be considered as an attempt to discover how R4D could be better organised to serve farmers' needs.

The specific structure adopted was the SLG. Local stakeholders were encouraged to engage jointly in a *learning alliance* to experiment/adapt existing technology or new technology. The SLG from the start was thought to be relevant to low external-input strategies (as in the case addressed in this thesis) (Pretty, 1995). The experience indeed has shown that the combined knowledge of the different stakeholder categories can help in thrashing out the problems associated with the application of low external-input pest management. The perceptions contributed by the various stakeholders challenged also the idea of exclusive technical expertise and privileged technology development capacity. Farmers showed they had more to contribute than as passive "recipients" (Schoubroeck, 1999). In addition, the SLG's work, followed by the learning forum, served to build and rebuild local institutional capacity (Tripp, 2006). The study also showed that the participants did recognise and value the shared activity, the opportunity to learn from each other, and the development of critical thinking: skills. We can identify this experience in retrospect as a form of *social learning* (Woodhill and Roling, 1998). However, we also note this kind of process and the activities associated with it take time – a real cost for all participants. Moreover, we note that those farmers with time to invest in group membership were not the poorest members of the farming community. Were the interests of the poorest met by the technology option approved by the community? Will the option now spread to others?

The cost-effective IPM strategy resulting from a learning cycles that was spread over two growing seasons relies entirely on a mixture of lower doses of broad-spectrum synthetic

pesticides and Neem, applied on the basis of economic action thresholds. This strategy was shown to save natural enemies, and reduce the number of applications and the release into the environment of the active ingredients in the synthetic pesticides. Its impact does not depend on the simple promotion and diffusion of the method. It can work on a larger scale only if farmers understand the basic principles of what is proposed. To be effective it would be necessary for farmers to learn and discover the behaviour of pest complexes in their own fields, and to develop their ability to experiment and to draw conclusions and to take sound decisions (Deugd et al., 1998; de Jager et al., 1999). In addition all farmers of the community ideally would need to be involved to avoid the risks of contamination from the use of the recommended broad-spectrum synthetic chemicals. Another issue that deserves consideration is the availability of Neem seeds. Promoting the commercial manufacture of these products by farmers or village enterprises would encourage the widespread use of alternative pest control products.

In hindsight, the cost-effective strategy discovered by the SLG and described in chapter 5 resulted in the development of a technology that is applicable only in a certain social configuration. The conclusions of the experimental research cannot be integrated directly into the solution of the problem. The results of the experimental research must pass through knowledge integration into what has been called soft design. For the sake of the argument, Schoubroeck (1999) labels such a construct as "*socio-technological*" knowledge. This study has shown that reducing the external input, and avoiding the use of broad-spectrum pesticides like Endosulfan especially earlier in the season and by using the mixture technology developed with the SLG could bring about sustainable cotton pest management. But this study indicates that larger scale adoption will work out only if the community is well organised and carries out a village-wide non broad-spectrum pesticide application and relies on threshold control. Without outside assistance most cotton growing communities will not be able to do this.

Implication for R&D and policy

Implications for R&D policy related to cotton crop protection

The evidence that reducing the external input, and avoiding the use of broad-spectrum pesticides is cost-effective, demonstrates that technical alternatives to farmers' current dependence on purchased synthetic insecticides are possible. The current recommended level of pesticides has been shown to be unnecessary and determined by issues others than sustaining production. Policy and the interests of powerful organisational actors sustain the official recommendation and gravely compromises the cotton sector's ability to deliver the level of efficiency needed to compete in today's markets.

Policy change is required at both national and international levels if cotton is to remain

a valuable crop for farmers in Benin. Policies have to promote more effective crop protection strategies that support sustainable development without sacrificing productivity. The search for this strategy must be centred on entry points relevant from farmers' perspectives (e.g. cash returns) and local learning groups engaged in identifying and testing such alternatives and in bringing the best performing option into wider use. This does not mean that all fundamental and applied scientists should be working with farmers. But if the strategies, the approach, and reflections formulated in this thesis could be built into cotton crop protection policy and programme development the outcomes could be considerably enhance cotton futures.

Implication for research policy

Our research can be seen as problem-oriented research i.e. focussing on problems which are not structured or delimited according to disciplinary categories. Constructing and fostering the natural and social science interface (*inter-disciplinarity*) and involving non-academic stakeholders, especially farmers (*trans-disciplinarity*) (Van Huis et al., 2006) made the realisation of this research possible. Researchers in this tradition have to play multiple roles. The implication is that researchers have to be trained to develop their inter-disciplinary or/and trans-disciplinary capacity; such opportunities are still lacking in our university and research organisations. So the challenge for universities and research institutes is to institutionalise interdisciplinary training programmes, and to allow, facilitate, fund and stimulate interactive research.

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Summary

Over the last decade the economic sustainability of the cotton industry in Benin has been questioned. Declining productivity and increasing production costs are affecting the entire system.

Low yield caused by pests and socio-economic problems have been identified as the main problems facing cotton producers, leading to low household incomes, as cotton is the main source of money throughout the cotton growing zones.

This study's twofold research focus thus was: to develop and apply a methodology for improving existing pest management technologies, or for testing new pest management options that might help cotton farmers escape the credit trap; and to place the methodology in a multi-actor learning process that seeks to create the institutional space for sustainable innovation.

To achieve these objectives an interactive approach with path-dependent steps was adopted. These path-dependent steps included a technographic study, a diagnostic study, and an interactive design of a system that works and is acceptable. The interactive design involved a series of agricultural research activities and process interventions that constituted the co-learning pathway, created the space for innovation, and institutionalised new relationships.

The present thesis thus offers material of wide interest because it explores research that is responsive to farmers' problems by constructing and fostering the natural and social science interface (*inter-disciplinarity*), and by involving non-academic stakeholders, especially farmers (*trans-disciplinarity*). The study can be seen as empirical outcome of an emergent, adaptive, interactive process constituted in the relationship between scientists and non-academic stakeholders: i.e. a *co-researching process of research-for-development*.

The set of elements in the co-researching process, that seem to be essential in designing a learning path, includes:

- participatory diagnostic exploration to bring in focus farmers' needs, knowledge, opportunities, etc. when defining the research problem;
- building a learning platform that can be viewed as a means to learn about the process in sustainable cotton pest management, including selecting the technical options to be tested, designing the experiments, reviewing and assessing progress, and interpreting the results;
- design and testing of improved technologies and management options;
- development and practise of collaborative and experiential learning that promotes and

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- sustains innovation processes;
- a learning forum, to review with the community and R&D institutions the results obtained and the ways forward.

The first chapter of the thesis gives a brief description of the general context of cotton production and the industry. It describes the research problems and the study focus addressed and provides an overview of the thesis chapters.

Chapter 2 diagnoses cotton production constraints and opportunities in order to bring into focus, in the definition of the research problem, farmers' own perceptions and needs. The chapter provides legitimacy for the choice of research domain and research location and points out the options for the next steps in the collaborative research process.

An agreement was made with the farmers that some of their constraints, such as delayed cottonseed payment, low producer price, and the difficulty of obtaining inputs (related to distribution and price), would be investigated through an analysis of actor linkages within the cotton sector.

Chapter 3 takes up this issue. Stakeholder analysis revealed that the reforms undertaken since 1990 to improve efficiency, formally speaking could be expected to lead to a harmonised system. But the analysis also showed how stakeholders' conflicting interests and personal strategies, more or less bound to networks organised as alliances, subvert the aim of the reform and have led to a further, unplanned re-structuring. As things stand now, the cotton industry encompasses the conventional network and a break-away network of stakeholders. In both, the primary stakeholders are the producers. They are directly affected by any change, but they have little power or influence. The analysis concludes that neither the reform process nor the unplanned re-structuring have been favourable to producers. We argue that unless cotton farmers are assisted to bring about a change in their production system, to release their dependence on production credit and pesticide inputs, they cannot be effective industry partners.

IPM options form the technological focus of the work reported in this thesis. The technical work was complemented by deliberate effort to construct a sustainable *research for development* (R4D) process that could institutionalise local problem-solving capacity. This R4D process was constructed around the formation of a *learning alliance* (or Stakeholder Learning Group- SLG), composed of farmers, local research agent, a national researcher (the author of this thesis - playing a varying role as scientist and as facilitator), and local extension workers, who together selected the technical options to be tested, designed the experiments, reviewed and assessed progress, and interpreted the results, over two cotton-growing seasons.

Chapter 4 describes a participatory assessment by the SLG of an indigenous pest control method already used by a few farmer members of the SLG. The bio-efficacy of various plants extracts viz., *Azadirachta indica*, *Kaya senegalensis*, and *Hyptis suaveolens*, either alone or in

combination with half the recommended dose of synthetic pesticides, was studied in order to find a more sustainable strategy for the management of bollworms. Applications of either the full recommended dose of the synthetic pesticides or the combination with a neem seed extract (6 kg/ha) were found to be most effective in reducing bollworm incidence and damage. Both treatments gave the highest yields of cottonseed, with the latter proving to be also the most cost effective. All the pesticides used, except neem alone, had a toxic effect on bollworm predators. The technology, as practised by the farmers, was shown still to have some drawbacks: i) it did not conserve natural enemies; and ii) the number of applications may be unnecessarily too high because decisions to spray were based on the calendar and not on economic thresholds. The following questions arose: would it be possible to integrate the botanical/synthetic pesticides mixture into an IPM approach? And would it be possible to conserve as much as possible the natural enemies?

Chapter 5 evaluates how locally available alternative control measures, such as neem seed extract mixed with half the dose of the recommended pesticides and entomopathogenic formulations of *Bacillus thuringiensis* (Bt) and *Saccaropolyspora spinosa* (Spinosad), could be combined to get “a best mix of control tactics for a given pest problem in comparison with yield, profit and safety of alternative mixes”. The chapter emphasises reducing the dependence on broad-spectrum pesticides such as Endosulfan, on lowering the concentration of synthetic pesticides by mixing them with botanicals, and relying more on the action of natural enemies by using selective pesticides such as Bt or Spinosad. Treatments using the Bt pesticide, and the neem combined with reduced dosages of synthetic pesticides, were applied using an economic threshold level (ETL) to trigger applications. The treatments were compared to the standard recommended package of the full dose of synthetic pesticides and to a control with no pesticide application. By using ETLs it was possible to reduce the number of applications from six to four and to apply half the quantity of active ingredients. Compared to the standard recommended package of synthetic pesticides the ETL treatments proved to be less harmful for predators like ants, spiders and coccinellids. When neem was mixed with half the dose of the recommended pesticides the effect on bollworms was equally effective as the recommended package of synthetic pesticides. It was also most effective in protecting bolls against heteropterous insects. The mixture of neem and synthetic pesticides using ETLs resulted in the highest incremental cost benefit ratio, viz. 1:7.1.

The research activities described in chapters 4 and 5 positioned the SLG as a ‘learning platform’. The diagnostic studies from the beginning had allowed the conventional approaches to agricultural technology development process themselves to come into question.

Chapter 6 describes and analyses the alternative approach adopted in this study. The process was iterative with each repetition serving to maximise the knowledge available at any

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time to support decision-making by those in the learning group. A framework was developed for bringing scientific and local knowledge systems together to support the identification and adoption of more sustainable pest management practices. The challenge that remains is how to expand the benefits of a locally successful approach, to more people more quickly, whilst maintaining active farmer involvement.

In summary, the thesis shows that the current level of pesticide use in cotton cultivation in Benin is unnecessary and harmful to insect ecologies that can be better managed to sustain the cotton crop. Sustainable cotton pest management could be carried out with low external-input technologies. But these will only work at the strategic level if the community is well organised and agrees to carry out a village-wide, non broad-spectrum pesticide application, based on threshold control. Without outside assistance most cotton growing communities will not be able to do so.

The co-researching approach constituted in the SLG, has been shown to have yielded important gains to participants' livelihoods beyond the development of technology, from SLG farmers own point of view. This study (only briefly reported in this thesis) documents farmers' own evaluation of the gains in terms of human capital comprising leadership, knowledge, management skills and capacity to innovate, and social capital comprising relationships of norms and trust embodied in new social organisations.

Résumé (Summary in French)

Depuis une décennie le contexte économique de production du coton devient hostile aux paysans, le prix de cession des intrants devenant de plus en plus chère. Au lieu de s'améliorer, le système évolue en se dégradant. Le paiement du coton aux producteurs accuse beaucoup de retard, les pesticides sont mal utilisés, des résistances d'insectes apparaissent spécialement la résistance d'*Helicoverpa armigera* au pyrethrenoïde. Il en résulte un faible taux moyen de rendement inférieur à une tonne à l'hectare. Dans ce contexte la production du coton devient économiquement risquée. Beaucoup de producteurs abandonnent la culture. Dans les champs les paysans ne respectent plus les recommandations de la recherche. Il s'ensuit une chute drastique de la production globale de 450000 tonnes en 2003 à 190000 tonnes en 2005.

Le système de production du coton suit le système classique de "pesticide treadmill" au sein duquel une forte liaison avec l'utilisation des pesticides marche très bien au début pendant plusieurs années puis se montre à la fin très désastreuse. Une fois au sein du système, le paysan se retrouve face à une spirale d'évolution du prix des pesticides; une évolution croissante des problèmes de ravageurs; et de faible rendement. Ce qui entraîne de faibles revenus et donc une production non économique. Cependant, les producteurs comme recours à l'utilisation des pesticides n'utilisent pas les méthodes de contrôles alternatives développées par la science qui sont pourtant moins coûteuses, moins dangereuses mais qui nécessitent un apprentissage intense. Quelles sont alors les conditions d'une innovation technologique et institutionnelle -en terme de coût-efficacité, de durabilité et de persistance?

La double objectif de cette étude était donc de: développer et d'appliquer une méthodologie pour améliorer les technologies de gestion des ravageurs déjà existantes, ou pour essayer de nouvelles options de gestion des ravageurs afin d'aider les producteurs du coton à éviter les pièges de crédit; et de placer la méthodologie dans un système d'apprentissage de 'multi-acteurs' en vue de créer l'espace institutionnel pour une innovation durable.

Pour atteindre cet objectif, une approche interactive avec des étapes inter-dépendantes a été adoptée. Ces étapes inter-dépendantes incluent: l'étude technographique, l'étude diagnostique, et la conception interactive d'un système qui fonctionne et est acceptable. La conception interactive a impliqué une série d'activités de recherche agricoles et d'interventions qui ont: constitué le processus d'apprentissage, créé l'espace pour l'innovation, et institutionnalisé de nouvelles relations entre les acteurs au niveau local.

La présente étude offre donc un matériel d'intérêt public car elle explore une méthodologie

de recherche qui permet de répondre aux problèmes pratiques des producteurs en combinant les sciences biologiques et les sciences sociales (interdisciplinarité) et en impliquant les acteurs non-académiques en particulier les producteurs (transdisciplinarité). L'étude peut être vue comme un résultat fonctionnel du processus adaptatif et interactif émergent en ce qui concerne les relations entre scientifiques et acteurs non-académiques: c'est à dire le processus de recherche conjointe pour une recherche pour le développement (*Research for Development- R4D*).

Les éléments essentiels de l'approche R4D pouvant permettre l'acquisition durable de connaissance sont :

- Un diagnostic participatif permettant de prendre en compte les besoins et connaissances des producteurs, ainsi que les opportunités lors de la définition des problèmes de recherche;
- Etablissement d'une plate-forme d'apprentissage qui peut être vue comme un moyen pour discuter et échanger au sujet du processus de développement durable des moyens de contrôle des ravageurs. Processus incluant la sélection des options techniques à tester, la conception des expérimentations, l'évaluation des progrès, et l'interprétation des résultats.
- Conception et test des technologies améliorées et options de gestion des ravageurs
- Développement et pratique d'un apprentissage conjoint par expérience qui promeut et soutient le processus d'innovation.
- Un forum de discussion, pour échanger avec la communauté et les institutions de recherche et de développement les résultats obtenus et la démarche future.

Le premier chapitre de la thèse donne un bref aperçu du contexte général de production et d'organisation de la filière coton. Il décrit les problèmes de recherche et les objectifs de l'étude ainsi qu'il donne une idée des différents chapitres de la thèse.

Le chapitre 2 diagnostique les contraintes et les opportunités de production du coton dans le but de prendre en compte dans la définition des problèmes de recherche la perception et les besoins des producteurs. Ce chapitre donne une sorte de légitimité au choix du lieu et du domaine de recherche. Il discute aussi des étapes futures du processus de recherche conjointe. Il a été retenu avec les producteurs une investigation à travers une étude analytique des acteurs et de leur relation au sein de la filière coton pour mieux comprendre certains de leurs contraintes tel que le retard des paiements de la vente des coton-graines, faible prix aux producteurs, et les difficultés d'obtention des intrants en rapport avec la distribution et le prix élevé.

Le chapitre 3 présente les résultats de cette étude analytique. L'analyse des acteurs révèle que les réformes entreprises depuis 1990 dans la filière pour améliorer son efficacité pouvait théoriquement aboutir à une harmonisation de la filière. Mais l'analyse montre aussi que les conflits d'intérêts et des stratégies personnelles, plus ou moins liés à des réseaux organisés

en alliance, ont affaibli les ambitions de la réforme et ont entraîné une restructuration non planifiée. Actuellement, la filière coton comprend le réseau conventionnel et le réseau des acteurs dissidents. Au sein des deux réseaux, les acteurs primaires sont les producteurs. Ces derniers sont affectés par n'importe quel changement intervenu dans le réseau et ont très peu de pouvoir ou d'influence sur celui-ci. L'analyse conclut que ni la réforme officielle ni celle non planifiée n'ont été favorable aux producteurs. Elle conclut qu'à moins que les producteurs du coton ne soient assistés pour se libérer de la dépendance des crédits et de l'utilisation des pesticides en changeant leur système de production, ils ne pourront pas être de réels partenaires au sein de la filière.

L'approche de lutte intégrée (Integrated Pest Management- IPM) a guidé les travaux techniques décrits dans cette thèse. Ces travaux techniques ont été complétés par un effort délibéré de mise en place d'un processus de R4D qui pourrait institutionnaliser les capacités locales de résolution des problèmes. Ce processus de R4D est construit avec au centre un groupe d'apprentissage conjoint (*Stakeholder Learning Group*- SLG). Ce groupe composé des acteurs locaux à savoir les producteurs, les agents locaux de recherche (représentant la recherche coton et fibre), l'agent local de vulgarisation et un chercheur national (l'auteur de cette thèse) –qui a joué le double rôle de scientifique et de facilitateur, ensemble sélectionnait les options techniques à tester, concevait les expérimentations, évaluait le progrès des expérimentations, et interprétait les résultats durant deux saisons de cultures.

Le chapitre 4 décrit une évaluation participative par le SLG d'une méthode de contrôle endogène déjà pratiquée par quelques producteurs membres du SLG. La bio-efficacité de différents extraits de plants tel que *Azadirachta indica*, *Kaya senegalensis*, et *Hyptis suaveolens*, soit seul ou mélangé avec la moitié de la dose recommandée de pesticides synthétique a été étudié dans l'optique de la recherche de méthode de contrôle durable des chenilles du cotonnier. L'application soit de la pleine dose recommandée de pesticides synthétiques ou du mélange de la demi-dose avec l'extrait de Neem (6kg/ha) ce sont révélés les traitements les plus effectifs dans la réduction de la densité des chenilles du cotonnier et des dommages causés par ces dernières. Les parcelles traitées par ces deux traitements ont enregistré les meilleurs rendements avec en prime le meilleur ratio de coût-bénéfice pour les parcelles traitées par le mélange de la demi-dose avec l'extrait de Neem. Tous les pesticides utilisés exceptés l'extrait de graine de Neem ont eut un effet toxique sur les ennemis naturels prédateurs des chenilles du cotonnier. La technologie de mélange d'extrait botanique et des pesticides synthétiques tel que pratiquée par les producteurs a encore quelques désavantages: i) la technologie ne conserve pas les ennemis naturels; et ii) le nombre d'applications est pourrait être utilement trop élevé parce que la décision d'application est basée sur un calendrier pré-établi et non sur seuil des ravageurs. Ces différentes remarques suscitent les questions suivantes: Est-il possible d'intégrer dans un

système de lutte intégrée la technologie de mélange? Et serait-il possible de conserver autant que possible les ennemis naturels?

Le chapitre 5 évalue comment les alternatives de contrôle localement disponible, comme le mélange de la demi-dose avec l'extrait de Neem et les formulations entomopathogénique de *Bacillus thuringiensis* (Bt) and *Saccaropolyspora spinosa* (Spinosad) pourrait être combiné afin d'avoir «une meilleure intégration des méthodes de contrôle pour un problème donné de ravageurs en comparaison au rendement, au profit et la santé de ceux qui applique ces méthodes». L'étude rapportée dans ce chapitre met l'accent sur: i) la réduction de la dépendance aux pesticides de large-spectrum telque l'Endosulfan; ii) la réduction de la dose des pesticides synthétiques en les mélangeant aux extraits botaniques ; et iii) la préservation des ennemis naturel en utilisant les pesticides sélectives telque le Bt ou le Spinosad. Les traitements utilisant le pesticide Bt et mélange de la demi-dose recommandé de pesticides synthétiques avec l'extrait de Neem sont appliqués en utilisant la méthode de seuil (*Economic Threshold Level-ETL*). Les traitements sont comparés au traitement standard de pleine dose de pesticides synthétiques et au control sans application de pesticides. En utilisant le ETL il était possible de réduire le nombre d'application de six à quatre et de réduire de moitié la quantité de matière active. Comparé au traitement standard, les traitements à base de ETL sont moins toxiques pour les prédateurs telque les fourmis, les araignées, et les coccinelles. L'effet du traitement mélange de la demi-dose recommandé de pesticides synthétiques avec l'extrait de Neem est aussi effective contre les chenilles que le traitement standard de pleine dose de pesticides synthétiques. Ce traitement de mélange était aussi le plus efficace en ce qui concerne la protection des capsules contre les insectes hétéroptères et les parcelles traitées avec ce traitement ont enregistré le meilleur ratio coût-bénéfice, viz. 1:7,1.

Les activités de recherche décrites dans les chapitres 4 et 5 positionnent le SLG comme une plate-forme d'apprentissage. L'approche conventionnelle du processus de développement de technologie a été remise en cause dans l'étude diagnostique.

Le chapitre 6 décrit et analyse l'approche alternative adoptée dans cette thèse. Le processus était itératif avec chaque répétition servant à maximiser les connaissances disponibles pour supporter la prise de décision des apprenant du SLG. Un cadre était développé afin d'intégrer les connaissances scientifiques et endogènes pour supporter l'identification et l'adoption des moyens de contrôle des ravageurs plus durable. La question majeure reste alors comment étendre cet approche réussit au niveau local à plus de localités tout en maintenant la participation active des producteurs.

En conclusion, la thèse a montré que le niveau actuel d'utilisation des pesticides dans le système de production du coton au Bénin est inutile et toxique aux ennemis naturels qui peuvent être mieux géré pour protéger la culture du coton. La gestion durable des ravageurs

peut se faire avec des méthodes alternatives de contrôle respectueuse de l'environnement et moins coûteuses. Mais ceci ne peut être efficace et effectif si la communauté est bien organisée et d'accord de rompre de façon générale et au niveau villageois avec l'utilisation des pesticides de large-spectrum. Sans assistance extérieure, beaucoup de communautés productrices de coton ne pourront pas être capables.

L'approche développée tout au long de cette étude en dehors du développement de technologies alternatives a apporté un plus au bien être des participants de leur propre point de vue. En effet une étude brièvement décrite dans cette thèse a eut a documenté l'auto évaluation des producteurs sur le gain apporté par l'approche développée en terme de capital humain comprenant le leadership, la connaissance, les aptitudes de gestion des cultures et la capacité d'innover et capital social comprenant les normes relationnelles et la confiance dans la nouvelle organisation sociale que prône cette thèse.

Samenvatting (Summary in Dutch)

Gedurende de laatste tien jaar is de economische duurzaamheid van de katoenindustrie in Benin ter discussie komen te staan. Dit heeft te maken met afnemende productiviteit en toenemende productiekosten, die het systeem negatief beïnvloeden. Katoen producenten worden enerzijds geconfronteerd met lage opbrengsten als gevolg van insectenplagen en anderzijds met sociaal-economische problemen. Dit leidt tot lagere inkomsten per huishouding in de gebieden waar katoen wordt geteeld. Het gewas vormt de belangrijkste bron van inkomsten.

Het doel van het onderzoek was het ontwikkelen en toepassen van een methodologie voor het verbeteren van bestaande technieken voor plaagbeheersing en ook het testen van alternatieve mogelijkheden van bestrijding. Dit met het doel om katoenboeren te helpen niet afhankelijk van krediet te laten worden. Bovendien werd getracht de methodologie onderdeel te laten worden van een leerproces met meerdere actoren. Dit was gericht op het creëren van institutionele ruimte om duurzame innovatie te bewerkstelligen.

Om deze doelstellingen te bereiken werd een interactieve en stapsgewijze benadering toegepast. Deze stapsgewijze benadering behelsde een technografisch onderzoek, een diagnostisch onderzoek en het ontwerpen van een interactief systeem dat uitvoerbaar en aanvaardbaar zou zijn. Het interactieve aspect omvatte een serie van landbouwkundige onderzoeksactiviteiten en proces interventies. Dit bestond uit een traject van samen leren, het creëren van ruimte voor het tot stand brengen van innovaties en het institutionaliseren van nieuwe relatie netwerken.

Dit proefschrift bestrijkt een breed interessegebied, omdat onderzocht werd welk type onderzoek aan de problemen van boeren tegemoet zou kunnen komen. Dit werd gedaan door het bewerkstelligen en in stand houden van een interactie tussen de natuur- en sociale wetenschappen (interdisciplinariteit) en door het betrekken van niet-academische belanghebbenden, in het bijzonder boeren, bij het onderzoek (trans-disciplinariteit). Het onderzoek is het empirisch resultaat van een adaptief en interactief proces tussen wetenschappers en niet-academische belanghebbenden. Het was een gezamenlijk onderzoeksproces in het kader van 'onderzoek voor ontwikkeling'.

De volgende onderwerpen bleken in het gezamenlijk onderzoeksproces van cruciaal belang:

- participatief diagnostisch onderzoek bij het definiëren van het onderzoeksprobleem teneinde de behoeften, kennis en mogelijkheden van boeren in kaart te brengen;
- het opzetten van een kennisplatform als middel om het proces van een duurzaam

beheer van katoenplagen te begrijpen, zoals het selecteren van de te testen technische mogelijkheden, het ontwerpen van experimenten, het vaststellen en evalueren van de voortgang van het onderzoek en de interpretatie van de onderzoeksresultaten;

- ontwerpen en testen van verbeterde technologieën om plagen beter te bestrijden;
- ontwikkelen en uitvoeren van gezamenlijk experimenteel leren gericht op het bevorderen en in stand houden van innovatieve processen;
- het opzetten van een 'leer-forum', dat samen met de plaatselijke bevolking en landbouwontwikkelings- en onderzoeksinstituten de verkregen resultaten evalueert en dan de volgende te nemen stappen bepaalt.

Het eerste hoofdstuk van het proefschrift geeft een korte beschrijving van de productie van katoen en de rest van de industrie. Het beschrijft de problemen en de doelen van het onderzoek door een overzicht te geven van de hoofdstukken van het proefschrift.

Hoofdstuk 2 evalueert de knelpunten en de kansen van de katoen productie. Bij het definiëren van het onderzoeksprobleem was het van belang een goed beeld te krijgen van de perceptie van de boeren. Het hoofdstuk geeft een verantwoording voor de keuze van het onderzoeksgebied en somt de mogelijkheden op voor de te nemen vervolgstappen bij het gezamenlijke onderzoeksproces.

Met de boeren werd overeengekomen dat verschillende van hun problemen, zoals de vertraagde betaling voor het katoenzaad, lage prijzen voor het product en de moeilijkheid om inputs te verkrijgen (verband houdende met distributie en prijs) zou worden onderzocht door middel van een analyse van de verbanden en netwerken tussen actoren binnen de katoen sector. In hoofdstuk 3 wordt het resultaat hiervan beschreven. Een analyse bij belanghebbenden bracht aan het licht dat de hervormingen die sinds 1990 waren ingezet om de efficiëntie te verhogen, formeel gesproken hadden moeten leiden tot een harmonieus systeem. Maar de analyse liet zien dat tegengestelde en individuele belangen bij betrokkenen, die min of meer zijn verbonden met georganiseerde netwerkallianties, het doel van de hervorming hebben ondermijnd. Dit heeft geleid tot een zich voortdurende en ongeplande herstructurering. Op dit moment omvat de katoen industrie een conventioneel en een afgescheiden netwerk van belanghebbenden. In beide netwerken zijn de primair belanghebbenden de producenten. Zij ondervinden direct de effecten van iedere verandering, maar hebben zelf weinig macht of invloed. Uit de analyse blijkt dat noch het hervormingsproces noch de ongeplande herstructureringen gunstig zijn geweest voor de producenten. Wij durven te stellen dat katoenboeren alleen effectieve industriële partners kunnen zijn als zij geholpen worden bij het tot stand brengen van een verandering in hun productie systeem en bij het opheffen van hun afhankelijkheid van productie kredieten en het gebruik van pesticiden.

Het vinden van mogelijkheden voor een geïntegreerde bestrijdingsbenadering van plagen

is het technologische doel van het beschreven werk in dit proefschrift. Het technische werk werd aangevuld met een doelgerichte poging om een blijvend proces tot stand te brengen van ‘onderzoek voor ontwikkeling’ welke in staat zou zijn de capaciteit te institutionaliseren om op lokaal niveau oplossingen te vinden. Het proces ‘onderzoek voor ontwikkeling’ werd vormgegeven gedurende twee groeiseizoenen van de katoen rondom een leer alliantie van belanghebbenden bestaande uit boeren, een lokale onderzoeksmedewerker, een nationale onderzoeker (de auteur van dit proefschrift nam afwisselend de rol op zich van wetenschapper en die van bemiddelaar) en voorlichters, die tezamen de te testen technische opties selecteerden, experimenten ontwierpen, zorg droegen voor het vaststellen en evalueren van de voortgang en het interpreteren van de resultaten.

In hoofdstuk 4 wordt een participatieve evaluatie door de ‘Leergroep van Belanghebbenden- (LvB) beschreven van een inheemse plaagbestrijdingsmethode, waar een aantal van de LvB boeren al eerder gebruik van had gemaakt. De bio-werkzaamheid van diverse planten extracten, zijnde *Azadirachta indica* (neem), *Kaya senegalensis* en *Hyptis suaveolens*, alleen gebruikt of in een combinatie met de helft van de aanbevolen dosis synthetische pesticiden, werd bestudeerd teneinde een duurzamere strategie te vinden voor de bestrijding van rupsen die de vruchten aantasten, de zogenaamde ‘bollworms’. Toepassingen van zowel de totaal aanbevolen dosis van synthetische pesticide als van een combinatie van een halve dosis synthetische pesticide met een extract van neem zaden (6 kg/ha) bleken het meest effectief te zijn in het verminderen van het voorkomen van de rups en de schade aan de vruchten. Beide toepassingen leverden de hoogste opbrengsten aan katoen zaad op waarbij de laatst genoemde toepassing ook het gunstigste kostenplaatje opleverde. Alle gebruikte pesticiden, behalve het gebruik van uitsluitend neem, hadden een toxisch effect op de predatoren van de rups. De techniek, zoals door de boeren gebruikt, liet toch wat nadelen zien: i) de natuurlijke vijanden bleven niet gespaard; en ii) het aantal bespuitingen lijkt onnodig hoog te zijn omdat het besluit om te gaan spuiten werd gebaseerd op de kalender en niet op economische schadedrempels. De volgende vragen kwamen naar voren. Zou het mogelijk zijn om het botanisch/synthetische pesticidemengsel te introduceren in een geïntegreerde bestrijdingsbenadering? En zou het haalbaar zijn om de natuurlijke vijanden zo veel mogelijk te sparen?

In hoofdstuk 5 wordt geëvalueerd op welke manier lokaal beschikbare alternatieve bestrijdingsmiddelen, zoals het extract van neem zaden vermengd met de halve dosis van de aanbevolen synthetische pesticiden en het gebruik van entomopathogene formuleringen van *Bacillus thuringiensis* (Bt) en *Saccaropolyspora spinosa* (Spinoad) konden worden gebruikt om het volgende te bereiken: “een beste combinatie van bestrijding van een gegeven plaagprobleem in relatie tot opbrengst, winst en veiligheid van alternatieve combinaties”. In dit hoofdstuk wordt de nadruk gelegd op vermindering van de afhankelijkheid van breed-spectrum

pesticiden zoals Endosulfan, door de concentratie van synthetische pesticiden te verlagen door deze te vermengen met botanische pesticiden en meer te gaan vertrouwen op de activiteit van natuurlijke vijanden door gebruik te maken van selectieve pesticiden zoals Bt of Spinosad. Behandelingen met het Bt pesticide en neem in combinatie met gereduceerde doses synthetische pesticiden werden alleen toegepast als een economisch schadedrempel werd overschreden. De behandelingen werden vergeleken met zowel de standaard aanbevolen hoeveelheid van de volledige dosis van het synthetische pesticide als met een controle waarbij geen pesticiden werden gebruikt. Door gebruik te maken van economische schadedrempels bleek het mogelijk te zijn het aantal bespuitingen terug te brengen van zes naar vier, waarbij slechts de helft van de hoeveelheid actieve ingrediënten van de pesticiden werd gebruikt. Vergeleken met de standaard aanbevolen hoeveelheid synthetische pesticiden bleken bespuitingen waarbij een economische schadedrempel werd gebruikt minder schadelijk te zijn voor predatoren zoals mieren, spinnen en lieveheersbeestjes. Wanneer neem vermengd werd met de halve dosering van de aanbevolen synthetische pesticiden was het effect op de 'bollworms' gelijk aan het gebruik van de totaal aanbevolen hoeveelheid synthetische pesticiden. Daarbij was het ook uitermate effectief voor de bescherming van de katoenvruchten ('bolls') tegen schadelijke wantsen. Het mengsel van neem met de halve hoeveelheid aanbevolen synthetische pesticiden, daarbij gebruik makend van economische schadedrempels, leverde de hoogste kosten-baten verhouding op, te weten 1:7.1.

De onderzoeksactiviteiten beschreven in hoofdstuk 4 en 5 omschrijven de LvB als leerplatform. De diagnostische studie uit de beginfase maakte het mogelijk om de conventionele benaderingen met betrekking tot landbouwkundige technische ontwikkelingsprocessen zelf ter discussie te stellen. Hoofdstuk 6 beschrijft en analyseert de alternatieve benadering, zoals voorgestaan in dit proefschrift. Het proces was voortdurend zelf evaluerend waarbij iedere herhaling tot doel had om op ieder gewenst moment de beschikbare kennis in de leergroep te maximaliseren ter ondersteuning van het besluitvormingsproces. Er werd een stramien ontwikkeld om de wetenschappelijke en lokale kennissystemen samen te brengen ter ondersteuning van het proces van identificatie en aanname van meer duurzame plaagbeheersingsmethoden. Het blijft een uitdaging om de voordelen van een plaatselijk succesvolle benadering op een snelle manier te verbreiden onder meer mensen, terwijl de actieve inbreng van boeren gehandhaafd blijft.

Samenvattend blijkt uit het proefschrift dat het bestaande niveau van pesticide gebruik in de katoenteelt in Benin onnodig hoog is en schadelijk is voor natuurlijke vijanden. Door meer rekening te houden met de ecologie van insecten zou het mogelijk moeten zijn tot een duurzame katoenteelt te komen. Duurzame plaagbeheersing in katoen kan tot stand worden gebracht met weinig van buitenaf geïntroduceerde technologieën. Maar dit zal alleen op strategisch niveau werken wanneer de gemeenschap goed georganiseerd is en bereid is om op dorpsniveau, het

gebruik van breed-spectrum pesticide bespuitingen te vermijden en pesticiden alleen te gebruiken wanneer economische schadedrempels worden overschreden. Zonder hulp van buitenaf zullen de meeste gemeenschappen die katoen verbouwen daartoe niet in staat blijken te zijn.

De aanpak van samen onderzoeken, zoals gedaan in de LvB, heeft laten zien belangrijke voordelen op te kunnen leveren voor het welzijn van de deelnemers aan de leergroep, gezien vanuit hun eigen perspectief en naast de ontwikkeling van de technologie zelf. In dit proefschrift wordt, slechts kort, de evaluatie van de boeren zelf gedocumenteerd ten aanzien van voordelen in de zin van ‘menselijk kapitaal’ zoals leiderschap, kennis, management vaardigheden en het vermogen te innoveren en ‘sociaal kapitaal’ als relaties van normen, waarden en vertrouwen die belichaamd zijn in nieuwe sociale structuren.

Annex: The Convergence of Sciences programme¹

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

¹ 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. *Wageningen Journal of Life Sciences (NJAS)*, 53(3/4): 343-367.

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 farmers, CoS pioneered a new context-method-outcome configuration² 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 NJAS³.

² See R. Pawson and N. Tilley, 1997. *Realistic evaluation*. London: Sage Publications.

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

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 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.

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This work is the fruit also of the excellent cooperation with Gounin village (northern part of Benin) and various cotton stakeholders, especially the farmers. To you I dedicate this thesis.

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Curriculum Vitae

Antonio Alain Coffi SINZOGAN, a native of Benin, was born in Cotonou, Republic of Benin, on June 13, 1969. In 1990, after completing his primary and secondary education, he joined the agronomy school at the Benin state University “*Université Nationale du Benin*”. His major subject in agronomy was in Crop Science and his minor in Economic innovation and communication sciences. During his final study in agronomy he focused on weed problems in cotton and maize. He obtained his Engineer degree in 1996 and worked during the subsequent two years as research assistant. In 1996 he carried out for the Forestry Department of “*Université Nationale du Benin*” an inventory of sacred forests “*Projet forêts sacrées*”, and in 1997 he undertook an environmental study of the hydroelectric dam of ADJARALA for the same department. From 1998 to 2000 he returned to his former department the crop science department to work as a research assistant in the IPM cowpea project in Benin. His work included a diagnostic survey of the project sites; elaboration and execution of on-farm research on cowpea pests, facilitation of a Farmer Field School in IPM-Cowpea, and writing scientific articles. A scholarship from the Netherlands government offered him the opportunity to do his MSc. study in Crop Science-IPM at Wageningen University from 2000 to 2002. His major studies for the MSc. were Entomology and Phythopathology. For his MSc thesis he focused on the use of biological agents and bio-pesticides in the cowpea crop. In November 2002 he was sponsored by the Convergence of Science project, financed by the Dutch government, to carry out an interdisciplinary sandwich PhD. at Wageningen University and *Université Nationale du Benin* in the departments of plant science (Laboratory of Entomology), and innovation and communication studies at both Universities. His PhD. studies were completed on October 20th 2007 with the defense of his thesis on *Facilitating learning toward sustainable cotton pest management in Benin: The interactive design of research for development*.

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List of Publications

Peer-reviewed Journal articles

Sinzogan, A.A.C., J. Jiggins, (To be submitted) Co-researching with Stakeholder Learning Group: experiences in pest control technology development with cotton farmers in Benin.

Sinzogan, A.A.C., D.K. Kossou, E. Akpo, and A. van Huis, (To be submitted). Use of entomopathogenic, botanical and synthetic pesticides to manage cotton pests in Benin.

Sinzogan, A.A.C., D.K. Kossou, P. Atachi, and A. van Huis, 2006 (forth coming). Participatory evaluation of synthetic and botanical pesticides mixtures for cotton bollworm control. *International Journal of Tropical Insect Science*.

Sinzogan, A.A.C., J. Jiggins, S. Vodouhé, D.K. Kossou, E. Totin, and A. van Huis, 2006 (forth coming). Cotton industry institutional linkages in Benin: stakeholder analysis and actor perspectives. *International Journal of Agricultural Sustainability*.

Sinzogan A.A.C., van Huis A., Kossou D.K., Jiggins J., Vodouhé S., 2004. Farmers' knowledge and perception of cotton pests and pest control practices in Benin: Result of Diagnostic study. *Netherlands Journal of Agricultural Science* 52 (3-4): 285-203.

Boeke S.J., **Sinzogan A.A.C.**, de Almeida R.P., de Boer P.W.M., Jeong G., Kossou D.K. and van Loon J.J.A. 2003. Side-effects of cowpea treatment with botanical insecticides on two parasitoids of *callosobruchus maculatus*. *Entomologia Experimentalis et Applicata* 108 : 43-51.

Kossou K. D., Ahanchede A., van Huis A., **Sinzogan A.A.C.** et Djidonou D. 2003. Analyse de l'agro-écosystème: Un outil pour la formulation des composantes d'une lutte intégrée contre les ravageurs du Niébé (*Vigna unguiculata* L.(Walp.) dans la vallée de l'ouémé au sud du Benin. *Annales des sciences Agronomiques du Benin* 5 (2): 173-201.

Books and Monographs

Sinzogan A.A.C. 1996 "Contribution a l'étude de la nuisibilité des mauvaises herbes sur le Maïs (*Zea mays* L.) et le Coton (*Gossypium hirsutum* L.). Thèse d'ingénieur, University of Abomey Calavi, Benin. 61p.

Sokpon N., **Sinzogan A.A.C.** and Houngbo E. 1997 Caractéristiques floristique et socio-économiques de la région du Lac Nangbéto: Monographie des villages Adjaha au Benin et Agbetiko au Togo. Banque Mondiale, 76p.

Sinzogan A.A.C. 2002. Oviposition-deterrent and toxic effects of various botanicals on two parasitoids of Bruchids infesting cowpea” These de Master of Science. Wageningen University, Wageningen, the Netherlands. 34p.

Sinzogan A.A.C. 2003. Participatory diagnosis of cotton production constraints and opportunities in Benin. ‘Convergence of science project’ research design report

Other scientific contributions

Sinzogan A.A.C. 2004. Integrated Pest Management: A review of theory, concepts, principles and approaches paper presented at the 2nd International Scientific Days of Abomey-Calavi University, Benin, October 2004.

Sinzogan A.A.C. 2005. Cotton industry institutional linkages in Benin: stakeholder analysis and actor perspectives, Paper presented at Convergence of Science International Workshop, Cape-Coast, Ghana, October 2005

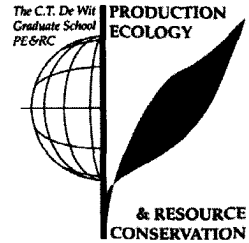
Sinzogan A.A.C. 2006. Participatory evaluation of synthetic and botanical pesticides mixtures for cotton bollworms control, paper presented at Plant-Insect Interaction Group Meeting at the chair Group of Entomology Wageningen University, the Netherlands, Mars 2006

Popular publications

Sinzogan A.A.C. 2005. Video entitled: Voice from the field, farmers’ experience in participatory cotton pest management technology development in Benin, presented at Convergence of Science International Workshop, Cape-Coast, Ghana, October 2005

PE&RC PhD Education Statement Form

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 22 credits (= 32 ECTS = 22 weeks of activities)



Review of Literature (4 credits)

- Integrated pest management: a review of theory, concepts, principles and approaches (2002)

Writing of Project Proposal (4 credits)

- Facilitating learning towards sustainable cotton pest management in Benin (2003)

Post-Graduate Courses (2 credits)

- Multi-stakeholder processes (2005)

Deficiency, Refresh, Brush-up and General Courses (3 credits)

- Introduction to agro-ecology studies (2003)
- Introduction to communication innovation studies (2003)
- Statistical analysis using SAS software (2004)

PhD Discussion Groups (5 credits)

- Six (6) inter country meetings (convergence of science group meeting) of one week (2002/2005)
- Second international scientific day of Benin National University (2004)
- Plant insect - interaction group meeting at the chair group of Entomology (2006)

PE&RC Annual Meetings, Seminars and Introduction Days (0.75 credits)

- Beta-gamma perspective in organic farm systems (seminar) (2003)
- TAD work in progress seminars (every week, 2 meetings attended) (2006)

International Symposia, Workshops and Conferences (3 credits)

- Convergence of sciences CoS proceedings orientation workshop (2002)
- CoS international workshop (one week + oral presentation) (2005)
- II International symposium on agro-ecological livestock production (2004)

Laboratory Training and Working Visits (2 credits)

- Identification of cotton pest insects, Laboratory of entomology/ CRA-CF, Bohicon, Benin (2004)
- Integrated pest and plant management, FAO, Mali (2005)