



## **IITA**

International Institute of Tropical Agriculture  
Projet Lutte Biologique contre les Locustes et les Sauteriaux  
BP. 08-0932 Cotonou, Benin  
tel. 229 35 05 53/35 01 88 fax 229 35 05 56  
IITA-Benin@cgiar.org

# **Potential for Mycopesticide Use in Africa: Socioeconomic Analysis**

*Hugo De Groot*

**LUBILOSA Socioeconomic Working Paper Series No. 98/5**

Paper presented at the LUBILOSA Project Management Committee in Eschborn,  
December 10, 1997

## SUMMARY

Due to a growing dissatisfaction with the heavy and continuing use of chemical pesticides for acridid control, a consortium of donors agreed to finance the search for a biological alternative. In the LUBILOSA programme (Lutte Biologique contre les Locustes et les Sauteriaux) a biopesticide was developed based on the spores of a fungus, *Metarhizium anisopliae (flavoviride) var. acridum*, a natural pathogen of locusts. A production unit was set up, an application technique developed and field test successfully completed. In order to reach the extension stage, it is necessary to check the suitability of the technology to its clients: check for sociological constraints, a positive cost-benefit balance, and the interest of farmers and political decision makers. Four basic tools can be used for this analysis: cost-benefit analysis, study of farmers' perceptions, participatory research, and marketing studies.

This first tool is a comparison of the benefit-cost ratio or the marginal rate of return of the proposed action with those of the possible alternatives. Major benefits of the new technology are reduction of yield loss, gain in animal and human health, and less damage to the environment. Yield loss assessment methods have been developed, but still need to be applied on a larger scale to allow for extrapolation. A study of animal and human health effects of chemical pesticides has been undertaken, and eco-toxicological research give low to no effects on non-target organisms. The production costs at the pilot plant in Cotonou are estimated at \$20/ha, at the standard dose of 100 mg of spores per ha, and application costs have been previously estimated at \$2/ha. The cost of distribution and organization still needs to be assessed. Finally, the new technology needs to be compared to alternatives. The two standard alternatives are no locust control or chemical control, although food aid or an insurance program might be worth consideration.

Instead of calculating which alternative technology has the best cost/benefit ratio, one can also ask the farmers directly what they think about it, in order to diagnose and prioritize problems from a farmers' perspective, and even quantify them. Oral history, participatory rural appraisal (PRA), group discussions and individual discussions can be used. A first PRA around grasshoppers was executed in the Mono region of Benin. The results were promising and the research will continue in Benin, Mali and Niger. More formal surveys can also be very useful. In previous surveys, grasshoppers were reported to be the most important crop pest, but actions against them vary widely, and mycopesticides used in communal actions can play a role in their control.

The best way to see if a new technology is suitable is to test it with farmers. In this, the researcher works closer to reality, farmers' opinions are known immediately and their suggestions incorporated and tested. Farmer participatory trials on *Metarhizium* have been conducted in Mali, Niger and in Benin. In Mali and Niger, the participation was limited to the application of the product by village brigades in demonstration plots. In the future, the participatory work will be expanded to investigate how to organize the village to incorporate the product into grasshopper management. Particular attention should be given to bring the trials as close to reality as possible. Subsidizing certain aspects of the

new technology can solicit strategic behavior of farmers, thus biasing results and leading to faulty recommendations

If a technology is good and adapted, it should sell itself, and the best way to find out is by trying. Marketing studies are necessary to identify possible clients are, and find out their profile, tastes and preferences. It also means bringing the product to the market: public relations and information campaigns, promoting and distribution of the product. In the humid tropics, individual farmers should be targeted, especially for cash crops. In the Sahel, work with institutions such as PVs and NGOs is more likely to be successful. We find a similar need to work with government institutions for locust control in South Africa and in Madagascar. For desert locust, FAO plays a coordinating role.

## 1. INTRODUCTION

The locust plague of 1986-89, the first in many years, was the cause of serious concern and substantial donor activity. While 25.9 million hectares were sprayed with chemical pesticides (Schulten 1990, in Showler 1995) dissatisfaction with the heavy and continuing use of chemical pesticides was growing. A consortium of donors (including the governments of Canada, Switzerland, The Netherlands, Great Britain and initially also the United States), agreed to finance LUBILOSA (Lutte Biologique contre les Locusts et Sauteriaux), a research program initiated in 1989. The project is implemented by a network of collaborators from CABI Biosciences, formerly IIBC (International Institute of Biological Control), IITA (International Institute of Tropical Agriculture), CILSS (Comité Permanent Interetats de Lutte Contre la Secheresse au Sahel) and GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit).

In the initial phase a biopesticide was developed based on the spores of a fungus, *Metarhizium flavoviride*, a natural pathogen of locusts. A production unit was set up to provide spores in sufficient quantities (Jenkins 1994), and an oil-based formulation was developed. In the second phase of the project (1993-1995) field trials were carried out on different locust species in several African countries (Lomer 1997) and production was scaled up (Cherry *et al.* 1999). The results are promising, with mortality rates of 80% or higher, although this mortality is only reached after one to two weeks. The product is easy to store and to apply. The biopesticide turned out to be a technically powerful technology, but its economic viability is still uncertain.

Socioeconomic evaluation of mycopesticides are therefore urgently needed. The final stage of every new technology development is the extension. To achieve this, some basic gaps in our knowledge need to be filled. We need to study if the technology is adapted to its clients: if there are no sociological constraints to its use, if there is a positive cost-benefit balance, and if the farmers and the political decision makers can be interested to take action, plant protection agencies as well as donors.

LUBILOSA has had two socioeconomic consultants (Swanson 1995, Stonehouse 1995) who laid the groundwork and were cautiously optimistic that the technology would be taken up. In 1996, a socioeconomics program started, using four basic tools for the analysis: cost-benefit analysis, study of farmers' perceptions, participatory research, and marketing studies.

## 2. ANALYTICAL FRAMEWORK FOR EVALUATING A NEW TECHNOLOGY

We assume that the people evaluating a new technology are rational decision makers. Everybody tries to maximize their objectives, facing numerous constraints. We do not, however, fully understand the objectives and the elements of the reasoning. Some methods, like cost benefit analysis, offer a first approach. This economic technique quantifies and compares different alternatives. Benefits and costs are given a monetary value, discounted and aggregated. Through several methods, the benefits and costs of different options can be compared, and the alternative with best ratio will determine the technique to be used.

We assume that the end-user, the farmer, compares the benefits and costs of a new technology (mycopesticides) with those of the alternatives (chemicals or no treatment). If there are no other constraints (such as cash or labor) the technology with the highest benefit/cost ratio will be chosen. Not all the benefits are financial: food losses avoided and impact of technology on health are just a few of the non-financial but still economic benefits and costs. To correctly predict the adoption of a new technology, the full picture needs to be drawn and approximately quantified. The element of uncertainty delivers a particular challenge to the analyst. Especially in this last field we observe that individuals do not decide on real probability of costs and benefits, but rather on perceived probabilities. It is therefore of extreme importance to ask about farmers' perceptions and opinions.

We could develop a simple decision making model: a farmer is likely to adopt a new technology if his or her individual extra benefits outweigh the extra cost. Extra benefits usually result from a gain in production. Extra costs do not only include the cost of buying the new technology, but also the extra time needed to apply it and to learn it, and the discomfort (or pleasure) associated with change and uncertainty.

From a society's point of view, the cost-benefit analysis takes into account the whole society, and therefore also the effect of the technology on people other than the farmer, called "externalities" in economic jargon, and include extra costs as well as benefits. Society would be favorable to a technology if the total extra benefits outweigh the total extra costs. One can imagine a case where a technology would not be advantageous to the individual farmer, but would be to the society. A subsidy of the technology would hereby be justified.

But society's decision making also has to take into account the constraints to optimization: budget, infrastructure, human resources, etc., and compare the benefit-cost ratios of possible alternatives within that framework. Of course, a poor country can demand support from a donor, either an institution or a country, to support extra costs. Ideally, the decision making process of both donors and recipients should be the same, but in practice the process does not only depend on the cost-benefit analysis. The major categories of decision makers, bureaucrats and politicians, are also individuals with their own individual objectives and reward structure. A bureaucrat's sense of importance (and

rewards) is often directly related to the size of his department, hence the natural inclination of every bureaucracy to grow, regardless of its benefits to society. Politicians cling to power, in democracies through elections, elsewhere by other means.

So far, we have assumed rational economic decision making. It is important to realize that not all decisions are made rationally, and that economic rationality is not the only rationality. People might be influenced by other factors and arguments. These have to be incorporated into the analysis.

### 3. COST-BENEFIT ANALYSIS

#### 3.1. Specifications

Based on the experience of the LUBILOSA project, the form of the costs and benefits can already be put down in more detail. The loss due to any crop pest can be expressed as a proportion ( $L$ ) of the production, itself expressed by yield ( $Y$ ) by area ( $A$ ). The efficacy of a treatment  $E$  can be expressed as a proportion of that loss, and the production gained from the treatment becomes  $YALE$ . The benefits to the farmer due to the treatment, as compared to not treating, can be obtained by multiplying it by its current price  $p$ .

$$\Delta B_i = Y_i A_i L E p$$

If two treatments are to be compared, say a biological one  $b$  with a chemical one  $c$ , the difference in benefits becomes:

$$\Delta B_i' = Y_i A_i L (E_b - E_c) p$$

The direct extra cost of a treatment to a farmer is determined by the area treated  $A_i'$ , the dose of application  $d$ , the cost of the product  $c$ , and the number of applications  $n$ , in a straightforward formula:

$$\Delta C_i = A_i' c d n$$

The use of chemicals also implies cost to human and animal health  $H$ . Assuming this is not the case for biocontrol, the difference between biological and a chemical treatment becomes, at the individual level:

$$\Delta C_i' = A_i' (c_b d_b n_b - c_c d_c n_c) - H_i \quad \text{where} \quad \begin{cases} d = \text{g / ha} \\ p = \$ / \text{g} \end{cases}$$

The cost  $c$  is the total cost of the technology to the farmer. It includes the price at which he or she buys the product (which includes the production cost, margin for the salesperson and company, and a reduction for a possible subsidy), the application costs (sprayer, batteries, labor), but also the cost of learning a new technology and adjusting to it.

For society as a whole, the externalities are to be included. If compared to not treating, we have first the benefits to the rest of the community from farmers saving their harvest. This translates into a more prosperous community, with a demand for other services (such as trading or artisanal products). This is expressed as a multiplier  $m$  of the income generated by an activity. The use of a new technology also generates a change in economic activity in the farm supply business. This happens in the local production of a new mycopesticide. Again, it is the difference, noted  $\Delta FS$  that matters. The total benefits become:

$$\Delta B = (1 + m) \sum \Delta B_i + \Delta FS$$

If comparing biological control to chemical control, the difference in benefits would be same as for the individual farmer, basically a difference in efficacy. On the farm supply side, the difference with the economic activity from the distribution of an imported chemical pesticide needs to be considered.

$$\Delta B' = (1 + m) \sum Y_i A_i L (E_b - E_c) p + \Delta FS'$$

On the cost side, there are the costs of a possible subsidy, but also the decreased cost in food aid  $F$  (be it by family, private organizations or government), the cost of providing other services  $P$ .

$$\Delta C = \sum \Delta C_i + S - F - P$$

On the cost side, food aid  $F$  and other services provided  $P$  cancel out, but the health and environmental costs on non-users need to be taken into account.

$$\Delta C' = \sum \Delta C_i + (H_b - H_c) + (E_b - E_c)$$

The parameters in these models will be estimated in the following sections to allow for an approximation of where the conditions of the analysis are favorable to the use of Metarhizium, determining hereby the market size.

It should be noted that the technology with the best benefit-cost ratio might be chosen. That option might be not interesting due to constraints, different perceptions or non-rational arguments. Constraints commonly encountered are related to cash and credit availability, human resources or labor shortages, and a lack of equipment or infrastructure. Perceptions also play a major role: people's decisions are based on their expected benefits and costs, and the available information is usually limited. Finally, the decision makers might use non-economic arguments, which translate for example in a preference for certain ways of packaging a product.

### 3.2. Grasshopper types and their distribution

The locusts and grasshoppers causing major economic losses in Africa can be regrouped in four categories: the desert locust, the Sahelian grasshopper complex, the variegated grasshopper, and the brown locust.

The desert locust (*Schistocerca gregaria*) has its habitat in the wadis of the Sahara, where irregular rain falls provide enough humidity for successful breeding and some development of vegetation. At high population densities, desert locust nymphs become gregarious and aggregate to hopper bands, regarded as an international pest, and do substantial damage.

The Senegalese grasshopper (*Oedaleus senegalensis*) is the most important Sahelian grasshopper. Its major area is the Sahel, where it occurs together with a complex of other grasshoppers. In contrast with the sporadic outbreaks of desert locust, they cause major yield losses on millet on a regular basis.

The variegated Grasshopper (*Zonocerus variegatus*) is the only grasshopper pest known in the humid forest zone. It causes damage on most crops, mainly cassava, but also cotton, coffee, and horticultural crops. Over the last years this grasshopper species is spreading northward and its economic impact seems to be increasing

The brown locust (*Locustana pardalina*) is important in southern Africa. For the last 50 years, control operations in the Karoo region of South Africa have successfully contained the pest.

### 3.3. Benefits: Yield loss avoided

Yield losses in subsistence crops are hard to measure, and as a result very few studies have been undertaken. In recent years, several projects have started tackling this problem, but they have had to develop the methodology first. Several have been developed, particularly in Mali (Legg and Togola, 1993; Jago 1993) and Niger (Pantenius and Krall, 1993; Krall *et al.* 1995) (see Wewetzer, Krall and Schulz, 1993 for an overview). These methods are still very labor intensive and have therefore not seen wide scale application. Some general estimates are produced, but always on small samples. In Niger in 1991, total yield loss in millet due to different pests was estimated between 10 and 24%, according to district, while the overall loss due to grasshoppers was estimated at 1,3 % (Pantenius and Krall, 1993; a national sample of 318 fields). The survey was repeated yearly from 1992 to 1994, producing an average national damage level of 1.4% (Kogo and Krall, 1997). Coop *et al.* (1993) give figures of crop losses due to grasshoppers from different regional surveys: 1.5% in Senegal, 21.1 % in Chad, 1.5% in The Gambia, and 21.8% in Mali.

These methods are based on field observations of head damage by trained technicians, and therefore expensive and confined to small samples. All authors stress that grasshopper damage is very variable between villages and between years, which means that large samples are needed.

Given the importance of measuring the benefits of treatment for the economic analysis, LUBILOSA is applying adapted versions of these methods (so they can be used by available PPS agents or farmers) to compare the yields of our treated and control plots in Mali and Niger. For an overall assessment of crop loss due to locusts and grasshoppers, we will also try farmers' estimates and a recall of the last ten years. Equally important is the distribution of damage. We need to know what percentage of the fields are likely to be in what damage category. Proper observation techniques are important because they provide the information on which IPM is based.

In Benin, a crop loss assessment method is being developed to measure losses due to the variegated grasshopper. For cotton they are included in our field trials, while for cassava special on-station trials in cages will be conducted.

### 3.4. Cost of Production

Spores of *Metarhizium* have been produced at IITA-Cotonou since 1991. A scaled-up plant was commissioned in 1996. The major goals of this plant are to produce enough spores for the field tests and to study the possibilities of mass production of spores. A

preliminary economic evaluation was carried out in 1995 and resulted in an estimated break-even cost of \$9-\$15 per treated hectare in function of technology used, demand and geographical region. Over the last few years, the production methods have seen some major changes, and more detailed analysis is now possible.

The investment cost of the Cotonou plant is 56 million FCFA for a production of 37 kg of spores per month. The production cost stands now at 9,900 FCFA (\$17) for the standard application of 100 g/ha. The production system is relatively complex and with many linkages. So far the autoclave and the building are not used at full capacity, but personnel is at their limit and doing a lot of overtime. The production is highly variable, and a number of parameters and relationships still unknown. Although the current plant has still some options for improvement, the system has major limitations: capital investment is high, as is production cost. A commercial enterprise would also have to pay interest or dividends on its capital, 56 million FCFA, for a relatively low production volume of 40 million FCFA per year. For these reasons, the product will not be cheap: its current production cost is 10,000 FCFA/ha, which is fairly high compared to its competitors. Karate, one of the most popular acridicides, is sold in Ghana at 7000 FCFA/ha, in Benin at 12,000 FCFA/ha.

Although the product is relatively expensive, it has major economic advantages. Due to secondary pick-up, only one application per season is necessary, and damage to the environment, human health, and livestock are nil. For a full comparison, application and distribution costs still need to be included. Future research needs to concentrate on elaborating the relationships and parameters involved in the production process, and in finding the most economic application dose. LUBILOSIA's implementation plan envisages eventual commercial production of Metarhizium by the private sector. It is likely that this would result in lower costs.

The production plant shows that mycopesticides can be produced in a small to medium size production plant in West Africa. This generates employment and economic activity, and is also of political importance. Our national partners have a strong preference for technologies that can be generated locally, as compared to those that are dependent on imports.

### **3.5. Cost of application**

No exact data on the application cost are available, but the available rough data suggest that the cost of application is relatively minor to that of the product. A ULV sprayer costs around 40.000 FCFA, lasts two to three years and can spray 0.5 ha/hour, so the average equipment cost might be around 100 FCFA/ha. It takes 6 batteries (200-1400 FCFA/pair depending on the quality), that last for maybe 5 hours, so operational cost might be 50 FCFA/ha, and labor at 500 FCFA/day comes to 30 FCFA/ha, total 180 FCFA/ha.

An alternative under study is a small hand held bicycle pump like sprayer or flit gun. It costs 500 FCFA, last 1 year (maybe 50 ha) and has no batteries. It takes a lot more effort and one hectare might take two hours. Total cost per ha is estimated at 10 FCFA for the purchase and 120 FCFA for labor, or 130 FCFA/ha in total. This preliminary analysis indicates that the flit gun is economically more interesting for small surfaces. Indeed, farmers use it extensively in the Mono region of Benin. Comparative participatory trials showed that for treating larger areas, farmers preferred the battery-operated spinning disc sprayer.

While application costs might be relatively small, the costs of the Plant Protection agents are not. The agents assist the brigades and require salaries, per diems, transport, training etc. Spraying by plane avoids a lot of these costs. A plane cost 250,000 FCFA per hour, but can spray 1000 ha per hour. The plane used by LUBILOSA in Niger had a capacity of 800 ha, so one has to include a trip to the airport for every 800 ha, which might double the costs per ha treated. A comparison of different methods in Niger shows that the total cost (including the chemicals, the extension agents, transport, applications etc.) for treating with brigades is around 7000 FCFA/ha, while aerial spraying only costs around 1000 FCFA/ha (PLURITEC/EDUPLUS, 1993). However, this was before the devaluation and these prices have probably more than doubled.

### **3.6. Health costs**

A major benefit of biological control programs is the decreased risk to humans, animals and the environment. The economic value of these benefits is notoriously hard to measure. Last year, LUBILOSA commissioned a study to estimate the effect of chemical pesticides on human and animal health. The expenses for treating human sickness due to treating a hectare with chemical pesticides against locusts was estimated at 68 FCFA/ha (Houndekon, 1997). Although this figure is quite small, it should be considered as a bottom value for the health costs: many people are simply too poor to pay for treatment, which does not mean that their health problems have no value.

A more detailed study in the Philippines reveals that the medical costs of pesticide use in rice roughly equals the benefits of reduced crop loss, making pesticide use obsolete (Pingali, Marquez and Palis, 1994).

A second measure of loss due to chemical pesticides is the value of domestic animals that died after locust treatments. The average number of animals that died was extrapolated and their value at current market prices was estimated at 2400 FCFA per treated hectare. This value is not negligible and should again be considered a bottom value: non-lethal loss of productivity is not taken into account.

### **3.7. Environmental**

Environmental costs due to chemical pesticides are again very hard to measure. They are, however, of major importance, stressed in policy guidelines from the World Bank and the United States among others aiming to reduce the amount of toxins that end up in the environment. One immediate result has been the banning of a number of persistent chemicals such as dieldrin, popular in locust treatment.

LUBILOSA's exotoxicological studies are very optimistic. They show that *Metarhizium* has almost no negative impact on non-target organisms, unlike chemical acaricides. A quantitative environmental cost comparison between biocontrol and chemical control is, however, not yet feasible.

### **3.8. Other factors**

None of the numbers produced in the above analyses are very precise. The analysis is complicated further by a substantial number of non-economic factors that play a role in the decision making process. Research and analysis of these factors is important to ensure that the biocontrol methods under development will meet a positive response.

The donor community has to pay attention to the preferences of its constituency, including response to disaster, ecological concerns, preference for national suppliers, and a preference for grassroots development. In the past, donors have been quite responsive to disasters such as major desert locust outbreaks, but are not as ready to finance an IPM strategy against grasshoppers. Increasingly, environmental concerns are being stressed, responding to strong feelings within the general public as well as strong lobbying groups expressing those feelings. In the past, donors have often favored suppliers from their home countries but, given the possible inefficiency of these restrictions, there is some tendency away from it. Finally, in response to the inefficiency and waste observed in many large scale, top-down projects, many development agencies are now favoring a bottom-up and demand-driven technology development, including a participatory research component.

Bureaucracies such as plant protection services (PPS) also have their specific motivations. All bureaucracies have an implicit desire to grow. Therefore, they usually support policies that increase their area of activities, resulting in proportional increases in personnel, vehicles etc. They are also subject to political pressure. Democratic institutions in Africa, and especially West Africa, have not been well established yet and play therefore only a minor role. Often there is strong pressure on bureaucracies that services should be distributed equally (or proportionately) over regional entities, each region having their spokespeople at different levels of institutions. Once a service has been assigned to a particular region, politicking takes place to influence the exact location of treatments (fields of village leaders often get treated first).

Very visible problems will also get quicker attention than latent ones, and the pressure is strong to “do something”, even if the available options are not very efficient. Furthermore, bureaucracies are often driven by technocrats, with their own particular bias, due to training or other interest; new shiny technology often get more attention, planes get more points than hand held sprayers.

Governments and bureaucracies are also subject to nationalistic sentiment. Donors prefer to donate products from their own industry. Recipient countries prefer to invest in local production.

Scientists, finally, also have their own reward system, such as publishing articles and collecting insects, which are not influenced by economic concerns. They also have to respond to the agencies who finance their research, and are subject to peer pressure.

It should not come as a surprise that locust and grasshopper control has, in the past, not followed a very economical logic. Therefore, the non-economic factors need to be studied and taken into account when developing and promoting a new technology such as biocontrol of locusts and grasshoppers. The evidence collected so far is, however, very promising. Most donors prefer environmentally friendly products, LUBILOSA has a strong dedication to participatory research, contacts with PPSs are good and biocontrol fits their interest and needs.

## **4. FARMERS' PERCEPTIONS AND PARTICIPATORY RESEARCH**

### **4.1. Objectives and Methods**

Instead of calculating which alternative technology has the best cost/benefit ratio, one can also ask the farmers directly what they think about it. Although seemingly obvious, it is not that common for researchers to ask the farmers first about their perception of a problem. Knowing their basic knowledge, their opinion, and their practices can make a major difference in assessing a new technology. It makes it possible to identify and diagnose problems, prioritize them from a farmers' perspective, and even quantify them up to a certain degree.

Several methods exist to observe farmers' perceptions : oral history, participatory rural appraisal (PRA), group discussions and individual discussions. A number of social scientists have collected individual oral histories of farmers in the Sahel, and the electronically stored accounts are available for further analysis. A first search has already produced all the references by interviewed farmers concerning locusts. A preliminary analysis indicated that peoples' perceptions may outweigh the real economic losses. People related accounts of locust swarms going back 30 years, while other pests of known economic importance like millet stem and head borers are not mentioned. A more detailed search might help us to link damage due to locusts with geographical and other factors.

Participatory Rural Appraisal is a combination of techniques performed by a multidisciplinary team during several days in a village, in order to assess a problem in close collaboration with the population. PRAs were conducted during 1997 in Benin, Mali and Niger. They give a rough overview of the situation and indicate in what direction future actions should go.

More formal surveys can also be very useful, preferably in combination with the previous methods. For an earlier study commissioned by LUBILOSIA (Stonehouse, 1995) farmers in North Benin and Niger were interviewed. Grasshoppers were reported to be the most important crop pest, but actions against them vary widely. Another socioeconomic survey was commissioned in Mali, but only a preliminary report is so far available. A survey in Niger (Maiga et al. 1997) confirmed that grasshoppers were among the main pests in the region and indicate that mycopesticides used in communal actions have a role to play in their control. A danger with these surveys arises when the farmers are aware that the researchers have an interest in grasshoppers. This might result in strategic answers, i.e. a response calculated to elicit aid rather than a thoughtful answer.

In participatory research, however, strategic response becomes obvious early on. This type of research brings together farmer and researcher in a joint effort to develop a technology to solve farmers' problems, profiting from the pooled information and experience. In both Benin and Mali, this stage has been reached and has lead to promising results.

## 4.2. Benin

The only grasshopper in the humid areas of West Africa is *Zonocerus variegatus*, the variegated grasshopper (Paraiso *et al.*, 1992). This grasshopper is a very versatile grasshopper, readily able to adapt to new plants, including crops (PRIFAS, 1993). From the beginning LUBILOSAs has been testing *Metarhizium* on this grasshopper, mostly out of convenience. This grasshopper does, however, cause serious damage and in a number of villages in Nigeria (unpublished survey data from the ESCAPP project) it is mentioned as most important pest. A survey in the Mono region of Benin confirmed this.

As a result, PRAs around grasshoppers were executed in several villages in this region. Tools used were village mapping, transect, agricultural calendar, group interviews, and individual farm visits. The results indicate that in a number of villages the Variegated grasshopper is the major pest. The farming system here is based on two rainy seasons, with major crops corn and cassava, cotton and palm trees. Grasshopper damage occurs mostly on cotton and cassava, crops of the second season, and influence yield as well as quality. Farmers could not estimate their willingness to pay yet, they wanted to see the efficacy of the product first. After an initial demonstration a program of participatory research was set up to test a number of options: brigades vs. individual treatment, fallow treatment or not, ULV or “pompi”, a small cheap sprayer popular in southern Benin.

A number of results show the value of the method. Fallow treatment was quickly rejected by the farmers as impractical: the bush can not be penetrated in this season. Flit guns” were suggested by farmers in stead of ULV. The initial test show that they might be very useful for treating the early grasshopper stages. Finally, the price of *Metarhizium* is too high at the original dose of 100 g/ha. In participatory tests these doses are now being drastically reduced, based on results of previous tests (Langewald *et al.* 1997). Finally, we study the impact of grasshopper damage to the cotton yield, in order to determine the economic threshold.

## 4.3. The Dogon area in Mali

Several years ago Stonehouse (1995) pointed out the Dogon area in the Mopti region of East Mali as promising for the LUBILOSAs project. Grasshoppers are a major problem here and a local NGO supported by Secama (Secours Catholique du Mali) was already doing a substantial effort in grasshopper control, which now culminated in a specific project, PDAD (Projet Diocèsane d’Agriculture Durable). Initial contacts resulted in two years of field tests, producing excellent results. Research now needs to focus on how to integrate application of the mycopesticide into the existing structures. A first round of PRAs was conducted in 4 villages before the 1997 campaign, and more extensive surveys will follow. The tests are moving from researcher managed towards participatory research, in which the farmers take more and more responsibility in determining the agenda.

The name Dogon refers to an ethnic group, originating somewhere in Burkina Faso, but pushed eastward by other groups. Tradition has it that they fled to the inhospitable area of the Bandiagara cliffs to escape persecution and to keep their culture and religion intact. They do indeed inhabit a difficult area, with little water and lots of sand. Its rainfall varies between 350 and 750 mm. Since the droughts of the seventies, and even more after the drought of the early 80s, the region suffers from substantial deficiencies in basic food production, especially cereals. According to the agroecological classification of the DNSI the Dogon plateau covers the four eastern districts of the Mopti administrative region, more than half of the regions surface (48,000 km<sup>2</sup>) and its population (774,000 in 1993). A narrower, more geographical definition, makes the Dogon plateau correspond more or less with the Bandiagara district.

The economy of the Dogon country is based on agriculture. The traditional cereal crop of millet is no longer able to feed its population, and horticulture in the dry season is becoming increasingly important, in particular onions. The PRA confirms millet as the most important field crop, which takes between 50 and 80% of the cultivated land. Other crops of importance, although variable, are sorghum, fonio, cowpea, peanuts and bambara nuts (voandzou). Millet is strictly for home consumption, but peanuts are sold, and to a lesser degree sorghum and babara nuts. In horticulture, onions are the most important crops. Most of it is grown in the counter season, and almost all the produce is sold. Yield estimations vary between 100 kg/ha in a bad year (even 0 after a locust attack) to 1000. The official statistics indicate an average of 500 kg/ha. Prices for millet vary substantially over the year, last year on average 100 FCFA/kg. The average value of a ha of millet is then 50,000 FCFA.

The major pest in the villages was locusts and grasshoppers, except for one where blister beetles had taken over in the last 6 years. Other major pests are beetles and stem borers. Yield reduction is estimated between 60 and 100 % and seem to have impact on all farms, although not all fields: those closer to fallow are more affected. The damage due to locusts and grasshoppers is very variable from year to year and from village to village.

In the villages visited, there was a clear interest in biological control. People who observed the tests easily recognize its effect and its comparatively slower action.. Traditional methods, however, are no longer popular. There is a limited willingness to pay for a mycopesticide, around 5000 FCFA/ha (some farmers indicate 10.000 FCFA/ha) which is roughly 10% of the crop value, and amounts to half of the cost of Metarhizium. The WTP seems to be linked to availability of cash, strongly influenced by income and onion production, the major cash crop. Access to credit might play an important role. The discussions on application technique were inconclusive: the ULV formulation requires expensive batteries, but does not need water while the EC formulation does not need batteries, but substantial amounts of water that need to be transported to the field. It is important to point out that these results are indications, and not representative. A more structured and quantitative survey over a randomized sample is needed to cover the whole area.

The participatory trials show that the NGO has a solid extension organization, with motivated workers. The brigades, however, do face a socioeconomic problem. For reasons not immediately clear, the brigadiers are chosen among younger men. Although we did meet some older farmers who had previously received some locust control training, they had not been considered for the brigade now. This causes a serious lack of continuity, and makes training difficult. Moreover, these young people have little decision power on the farm, so the brigade is not the right discussion partner of a PPS or an IPM project, especially to decide where and when to treat, and how to organize the co-financing. Finally, young men have the highest probability of emigrating. It is therefore important that older, settled farmers, need to be implicated to participate in the decision making and to supervise and supply continuous training for the younger members, who will then do the field work. Women have also been systematically excluded from the brigades. To avoid further gender bias, they should be included in the decision making process.

Several other organizations, NGOs as well as bilateral projects, are active in the region, and a public relations effort is urgently needed. LUBILOSA needs to identify potential partners for the extension of the technology and start the dialogue. Information of the technology needs to be disseminated to the potential partners.

#### **4.4. Niger**

LUBILOSA has been working in Niger since its inception, and has an office in CILSS-Agrhymet campus in Niamey. The country, most of which is located in the desert or in the Sahel, is very poor, and is going through an economic slump, exacerbated by the devaluation of the FCFA in Jan 1994. Due to political instability, donor support for government programs is at a low point.

The Niger PPS, supported by Agrhymet's DFPV and plant protection projects initiated by CIDA and GTZ, has developed an extensive network of brigades. These brigades are essentially donor driven, and have little future without this support (De Groot 1995). Some NGOs also organize brigades, but the number of ha they cover is limited compared to those supported by the PPS. In the same way, the brigades cover relatively little area compared to aerial spraying. Both brigade activity and aerial spraying is financed by donors, and economic factors are hardly taken into consideration, compared to bureaucratic and political factors.

In 1997, LUBILOSA conducted a major aerial test in the Maine-Soroa district, Diffa arrondissement in Southeastern Niger. In this area a PRA was conducted shortly after the test. The results show that the people here are sedentarized Fulani, traditionally nomadic herdsman. Their villages are not very structured and crops are not their major source of income. As a result, they rarely produce enough millet to cover their needs. The village closest to Maine-Soroa would earn extra income from the sales of wood or labor there, but the other two rely mostly on livestock sales to cover their cereal deficit. Although they routinely invest in their animals (buying salt, vaccinations, etc. ) they do not buy any inputs

for agriculture. After the harvest, some of the straw is left to feed the cattle here in the dry season, and the field profits from the droppings. In this way the same fields can be cultivated for many years on end.

So there is no use of fertilizers, improved seeds or pesticides, except the rare interventions by the plant protection service. Grasshoppers are generally considered the major crop pest on millet, the major crop. Others are stem borer, millet head miner and cutworm.

The Fulani have no unit for measuring surfaces, making yield estimates impossible but not total harvest per family. The farmers estimate their harvest in a good year (good rains and no grasshoppers) at 1500 to 5000 kg per family, consisting of 5 to 15 people. This would be slightly above the Agricultural Ministry's minimum requirement of 250 kg/person/year. A heavy grasshopper infestation would reduce this to 300 -1000 kg, or a loss of 80%. At 100 FCFA/kg, this would mean that an average family could lose 240,000 FCFA or \$400.

As a result of those potentially high losses, farmers are willing to pay to control the grasshoppers. Answers were remarkably similar in the first two villages: 200-300 kg, and 300 kg per family. (The third village estimated the WTP for the whole village at 40,000 FCFA, but this would mean only 4 kg of millet per family and is in retrospect unusually low, probably due to the different approach). The result of the first two villages, however, are again close to 10 % of the expected harvest. Say that the average harvest in a good year were 600 kg/ha, we could estimate their harvested area at 5 ha, and derive that they find 6000 FCFA a reasonable price to pay to protect their crops against locusts. This result is remarkably similar to Mali.

The villagers in the *Metarhizium* fields were very happy with the results. They had observed that the fields treated with chemical got reinfested after a few days, while *Metarhizium* still kept grasshoppers under control after three weeks. Therefore, they judged *Metarhizium* clearly superior to the chemical treatment.

The region of Maine-Soroa is less suited for launching participatory trials and an IPM program: population densities are very low and so is the percentage in land under crops, which would make any large scale action quite expensive. The Nigerian PPS, in collaboration with LUBILOSA, has been conducting participatory trials for the last two years in the more densely populated areas of the mid South. LUBILOSA will present its results on a national workshop, to be organized in April, where the strategy will be decided in coordination with our partners.

## **5. SOCIOECONOMIC SURVEYS**

### **5.1. Overview**

On several occasions, we are confronted with problems that need further research. So far, three have been identified and will be given particular attention.

The first one is the confrontation between technology and socioeconomics and concerns the application method to be used: ULV, EC, pompi or airplane. The others concern intra-household resource allocation: a generation conflict between young brigades and old household heads, and the observed gender bias in pest control.

### **5.2. Application technology**

So far, LUBILOSA has worked with ULV formulation. Although it is a technically superior method, it has some major drawbacks, basically high initial costs and higher operational costs (batteries). At first view ULV is economically more interesting: the more even spray allows for a lower dose, and a larger area is covered in less time. The investment cost and operation costs are recovered by the benefits of reduced damage. As a result, ULV is generally used by larger organizations or by farmers who have access to a credit and extension system, usually organized around cash crops such as cotton. Farmers outside these systems generally use EC formulations in little knapsack sprayers.

In a recent meeting the PPS-representative from Guinea let us know that farmers have no access to ULV there at all. The representatives from Burkina Faso and Benin at the Bamako conference told us that non-cotton farmers did not have access to ULV, although many vegetable producers have EC knapsack sprayers. In Mali, ULV is used by cotton farmers and by PPS-supported brigades. During a recent discussion with farmers in the Mono-Benin, they expressed their dislike of ULV, although the arguments were not clear to us, and seem to center around the cost of batteries, which are not included in the cotton credit program.

As a result of those constraints, capital for initial investment and cash during the campaign for the batteries, low resource farmers, especially women, are more likely to use EC formulation than ULV formulation. Therefore, LUBILOSA should consider the use of EC formulation and pompi's, and combine it with socioeconomic research on the adaptability of the two options for different circumstances.

### **5.3. Brigades**

In Niger and Mali, among other countries, the locust and grasshopper control has been organized through village brigades. A number of villagers get training in pest control

techniques and will form the link between village and plant protection agency. The brigades usually receive equipment and free pesticides. When villagers observe grasshoppers in his field, they contact the brigade who come to treat if they judge necessary.

The brigades do face two major problems: a generational and a motivational. As discussed above for Mali, for reasons not immediately clear, the brigadiers are chosen among younger men. In Mali, we did meet some older farmers who had previously received some locust control training they had not been considered for the brigade. This causes a serious lack of continuity, and makes training difficult. Moreover, these young people have little decision power on the farm, and the brigade is therefore not the right discussion partner of a PPS or IPM project, especially to decide where and when to treat, and how to organize the co-financing. Finally, young men have the highest probability of emigrating. Therefore older, settled farmers need to be implicated to participate in the decision making and to supervise and supply continuous training for the younger members, who will then do the field work.

The second problem concerns motivation. The brigade members are supposedly volunteers working for the benefit of the community, and do not receive any compensation. This system seems not sustainable: they need some motivation, be it through the PPS (training, equipment) or from the farmers whose fields they are treating.

The brigades have been studied by a number of people and organizations. Unfortunately these reports have rarely been published. LUBILOSA is now in the process of collecting the existing information. The problems with brigades are being discussed with our partners in the PPSs, and with the brigades and farmers in our test villages. During our participatory trials, we hope to adjust the system to include sufficient motivation for the brigades. Other options, such as commercialization of the treatments, are being studied, especially in areas with commercial crops.

#### **5.4. Gender aspects of pest control**

Within the socioeconomic research, LUBILOSA pays particular attention to incorporate gender analysis. A number of studies have demonstrated the gender specific roles and the biased intra-household resource allocation in West Africa. Development and extension of new technologies tend to focus on men, risking an unequal distribution of its benefits, even an appropriation of resources traditionally reserved for women (low land rice fields, forest products). In particular, it has been observed, however, that pest control is to a large extent considered a male responsibility. This development is based on a number of assumptions, for example that women do not participate in the decision making on the farm or that women do not produce for the market, so that only men are likely to adopt new technology. These assumptions have not been, but should urgently be, tested before they become self-fulfilling prophecies.

Some trends can now be observed that develop in the opposite direction. Increasing urbanization incites migration of young men give women more responsibility on the farm. Women are more and more involved in commercial crops. Women become more vocal and express a willingness to participate in the development progress, including training on new technologies such as pest control. National and international institutions, donors, policy makers become increasingly aware of gender biased development.

While gearing up towards its implementation phase, LUBILOSA wants to make sure no gender biases are implicit in the biocontrol methods it develops. It has been shown that it substantially increases the chance of new technologies to be adopted.

Therefore a particular effort is made to include individuals from different groups, such as age and gender, in group discussions and participatory research. Moreover, the gender aspects need to be compared to classical chemical control methods. The working hypothesis is that chemical pest control is biased towards men, given the reproductive duties of women, while biocontrol is gender neutral.

LUBILOSA is currently looking for a student or consultant to execute this study. After interviewing key informants from the region and informal group interviews with farmers, more formal individual interviews will be organized in several ecological zones and with several ethnic groups.

## 6. MARKETING

Africa imports more than \$500 million worth of pesticides. In the last 10 years, locust and grasshopper control programs have cost between \$ 7 and 40 million, or between 1 to 9% of total pesticide spending. Total donor support for locust control reached \$ 275 million for the outbreak of 1986-1989, 36% of which for pesticides. Desert Locust, Red Locust and migratory locust control in FAO's EMPRES central region, Mozambique and Madagascar are heavily donor financed, and donors are the key decision makers. Lately, the cost efficiency of locust campaigns have been put into question (Joffe 1995), and concern about environmental costs are increasing (OTA, 1990). Therefore, a 20% substitution of *Metarhizium* for chemical acridicides seems possible.

The market for acridicides used against Sahelian grasshoppers is equally complex. Relatively good data are available for Niger, a country almost completely located within the Sahel. It has around 10 million ha under cultivation, 6 m of which in sorghum and millet (Service de l'Analyse des Politiques et de la Coordination des Statistiques. 1996.). Over the last 20 years, there have been regular treatments against locusts and grasshoppers, ranging from 0.2 to 1 m ha (not all land under cultivation, and not all infested land), and 0.7 m ha on average from 1987-90 (Landry, 1992).

Assuming that 60% of the area infested was treated, we can calculate an average infestation rate of 15% of sorghum millet area for a typical Sahelian country. Extrapolation would give a (very) rough estimate of an infested area of 2 million ha in the Sahel, 3 m ha for West-Africa.

Although no systematic data base exists, Monard (1994) collected the available data from the OCLALAV countries. The average hectares treated (mostly but not uniquely against grasshoppers and locust) for (mostly) 1986-1991 for 8 countries in West Africa total up to 2.5 m ha. This is in the same range as the first estimate.

A market for acridicides against grasshoppers in the humid areas of West Africa is also emerging. In Cote d'Ivoire for example, the variegated grasshopper is a major problem of coffee and cassava, minor of cotton, banana and vegetables. Estimates of the total market of acridicides in this country between 10,000 and 200,000 ha. Given the size of other areas with similar climate, a regional market of 50,000 to 1 million ha seems realistic.

Some other commercially interesting situations include Tree Locust in Gum Arabic plantations, Brown Locusts in South Africa, and *Zonocerus elegans* in Kenya. A survey of the national plant protection agencies is being prepared on past and current pesticide use and policy.

Worldwide, after some 30 years of research, interest in biological pesticides is slowly increasing. A full discussion paper analyzing this slow uptake is in preparation.

## REFERENCES

- Coffi A. 1992. Acridid situation in Benin, in C.J. Lomer and C. Prior (eds.) *Biological Control of Locusts and Grasshoppers*. CAB International, UK; pp. 86-89.
- Coop L.B., Dively G.P., A.J. Dreves and B. Sidibe. 1993. "The adjusted length method". In Jago, N.D. *Millet crop-loss assessment methods*. NRI Bulletin 62, Chatman, UK: Natural Resources Institute, 61 pp.
- De Groote H., O.K. Douro-Kpindou and T. Togo. 1998. Biological Control of Locusts and Grasshoppers in the Dogon Area : a Rapid Rural Appraisal. LUBILOSA Socioeconomic Working Paper Series No. 98/4. Report of a Rapid Rural Appraisal in the Dogon Area, Mali, June 1997
- Douro-Kpindou O.K., I Godonou, A. Houssou, C.J. Lomer and P.A. Sha. 1995. 'Control of *Zonocerus variegatus* with ULV formulation of *Metarhizium anisopliai* conidia. *Biological Science and Technology* **5**, 371-377.
- Environmental and Natural Resources Policy and Training (EPAT) Project. *Pesticides and the Agrochemical Industry in Sub-Saharan Africa*. Arlington Virginia, Winrock International Environmental Alliance.
- Gittinger J. P. 1982. *Economic Analysis of Agricultural Projects*. Washington DC, The World Bank.
- Grimm C. and F. Guharay. 1997. *Potential of entomopathogenous fungi for the biological control of true bugs in physic nut (Jatropha curcas L., Euphorbiaceae) plantations in Nicaragua*. Submitted to Jatropha. 1997. Proceedings of the International Symposium on Biofuel and Industrial Products from Jatropha curcas and other Tropical Oil Seed Plants, Managua/Nicaragua, 23-2 February 1997.
- Herok, C. and S. Krall. 1995. Economics of Desert Locust Control. Tz. -Verl.-Ges. Rossdorf.
- Houndekon V. 1997. *Etude médico-économique de l'utilisation des pesticides dans la lutte anti-acridienne*. Consultant Report, Cotonou, LUBILOSA.
- Jago, N.D. 1993. *Millet crop-loss assessment methods*. NRI Bulletin 62, Chatman, UK: Natural Resources Institute, 61 pp.
- Jago, N.D. 1993. *Millet pests of the Sahel - biology, monitoring and control*. Chatman, UK: Natural Resources Institute, 66 pp.
- Jago, N.D. Kremer, A.R. and West, C. 1993. *Pesticides on millet in Mali*. NRI Bulletin 50, Chatman, UK: Natural Resources Institute, 45 pp.
- Jenkins N.E. and C.J. Lomer. 1994. 'Development of a new procedure for the mass production of conidia of *Metarhizium flavoviride*. International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section Bulletin Vol. 17 (3).
- Joffe S. R. 1995. Desert Locust Management - A Time for Change. *World Bank Discussion Papers* No. 284. The World Bank, Washington D.C.
- Kogo S.A. and S. Krall. 1997 "Yield losses on pearl millet panicles due to grasshoppers: a new assessment method". In Krall S., R. Peveling and D. Ba Diallo (eds.) *New Strategies in Locust Control*. Birkhäuser Verlag, Basel, Switzerland.
- Krall S. 1994. 'Importance of locusts and grasshoppers for African agriculture and methods for determining crop losses' in *New trends in locust control*. by Krall S.

- and H. Wilps (ed.). Eschborn, Deutsche Gesellschaft für Technische Zusammenarbeit.
- Krall S., O. Youm and S.A. Kogo. 1995. Panicle insect pest damage and yield loss in pearl millet. Pages 135-145 in Nwanze K.F. and O. Youm, eds. *Panicle insect pests of sorghum and pearl millet: proceedings of an International Consultative Workshop, 4-7 Oct 1993 at ICRISAT- Niamey*. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.
- Krall S., R. Peveling and D. Ba Diallo. 1997. *New Strategies in Locust Control*. Birkhäuser Verlag, Basel.
- Landry, J.-P., 1992. Etude comparative des appareils de traitement utilisés en Protection des Végétaux au Niger et recommandations pour un choix technologique par la Direction de la Protection des Végétaux. PLURITEC/EDUPLU, Projet Nigero-Canadien Protecti
- Legg J.P. and A. Togola. 1993. Practical assesment of pearl millet (*Pennisetum glaucum*) crop loss caused by grasshopper pests (Orthopter: Acrididai)- a major outbreak in north-west Mali. *Bulletin of Entomological Research* **83**, 395-403.
- Lomer C.J. 1997. *Metarhizium flavoviride*: recent results in the control of locusts and grasshoppers. In Krall S., R. Peveling and D. Ba Diallo (eds.) *New Strategies in Locust Control*. Birkhäuser Verlag, Basel, Switzerland, pp. 415-424.
- Lomer C.J. and C. Prior. 1992. *Biological Control of Locusts and Grasshoppers*, Proceedings of a Zorkshop held at the International Institute of Tropical Agriculture, Cotonou, Republic of Benin, 29 April-1 May 1991. Ascot, C.A.B. International.
- Lomer C.J. and Langewald J. 1997. Green Muscle® Users' Handbook. Cotonou, LUBILOSA project, IITA-PHMD.
- Maiga I.H., O.K. Douro-Kpindou, C.J. Lomer, J. Langewald. Etudes des donnees socio-économiques avec relevance sur l'eventuel utilisation de Matarhizium flavoviride Gams & Rozsypal en milieu paysan au Niger. for submission to Insect Science and its application.
- Mendonca A. F. 1992. 'Mass production, application and formulation of *Methariium anisopliae* for control of sugacane froghopper, *Mahanarva posticata*, in Brazil', in Lomer C.J. and C. Prior. 1992. *Biological Control of Locusts and Grasshoppers*, Proceedings of a Zorkshop held at the International Institute of Tropical Agriculture, Cotonou, Republic of Benin, 29 April-1 May 1991. Ascot, C.A.B. International.
- Ministère du développement Rural. 1995. Compendium des Statistiques Agricoles et Alimentaires 1970-1992. MDR, Direction de l'Analyse, de la Prévision et de la Synthèse, Service de la Statistique, Cotonou, Benin.
- Monard Anne. 1994. L'information acridienne dans les pays-membres de l'OCLALAV. Collectem transfertm analyse et diffusion. CIRAD-GERDAT-PRIFAS: Montpellier (France)/Ministere de la cooperaton : Paris
- Neuenschwander P. 1993. Human Interactions in Classical Biological Control of Cassava and Mango Mealybugs on Subsistence Farms in Tropical Africa. In Ateri M. (ed.) *Crop Protection Strategies for Subsistence Farmers*. Boulder, Westview Press.
- Office of Technology Assessment (OTA). 1990. *A plague of Locusts - Special Report*. OTA-F-450. Washington D.C. U.S. Government Printing Office.

- Pantenius U. and S. Krall. 1993. "A new method for determining yield losses caused by damage to the heads of pearl millet (*Pennisetum glaucum* (L.) R. Br) due to diseases and pests." *Journal of Plant Diseases and Protection* **100** (5), 522-529, 1993.
- Paraïso A., Lomer C. J., Godonou I. and D. Kpindu. 1992. Preliminary studies on the ecology of *Zonocerus variegatus* in the Republic of Benin. in C.J. Lomer and C. Prior (eds.) *Biological Control of Locusts and Grasshoppers*. CAB International, UK; pp. 133-141.
- Pingali P., C.B. Marquez and E.G. Palis. 1994. *Impact of Pesticides on Farmer Health: a Medical and Economical Analysis*, American Journal of Agricultural Economics, PLURITEC/EDUPLUS. 1993. *Estimation des coûts de protection des végétaux au Niger et évaluation de la capacité de prise en charge de ces activités par les différents niveaux d'interventions*. Projet Nigero-Canadien Protection des Végétaux du Niger, Niamey, Niger.
- Prior C. and D.J. Greathead. 1989. 'Biological control of locusts: the potential for the exploitation of pathogens.' *FAO Plant Protection Bulletin* Vol. 37, No. 1, 1989.
- Rola A. and P. Pingali. 1993. *Pesticides, rice productivity, and farmers' health*. International Rice Research Institute, Los Banos.
- Rowley, J. and O. Bennett. 1993. *Grasshoppers and Locusts: The Plague of the Sahel*. London: Panos Institute.
- Schönhuth M. and U. Kievelitz. 1994. *Les méthodes participatives de recherche et de planification dans la coopération u développement: Diagnostic rapide en milieu rural, Diagnostic participatif, Une introduction commenté*. Eschborn, Deutsche Gesellschaft für Technische Zusammenarbeit.
- Service de l'Analyse des Politiques et de la Coordination des Statistiques. 1996. *Annuaire des statistiques de l'agriculture et de l'élevage 1991-1995*. Ministère de l'Agriculture et de l'Elevage, Direction des Etudes et de la Programmation, Niamey, Niger.
- Showler A.T. 1995. 'Locust (Orthopter: Acrididae) Outbreak in Africa and Asia, 1992-1994: An Overview.' *American entomologist*, Fall 1995; 179-184
- Sperling L. M.E. Loevinsohn and B. Ntabomvura. 1993. 'Rethinking the farmers' role in plant breeding: local bean experts and on-station selection in Rwanda'. *Experimental Agriculture* 29: 509-519.
- Stonehouse J. 1995. Social and Economic aspects of mycoinsecticide against sahelian grasshoppers. Report of a Consultancy Visit to Benin, Niger and Mali for LUBILOS, Jly-October 1994.
- Swanson D. 1995. Economic Feasibility of Two Technologies for Production Viability of Mycopenicidines for Acridid Control in Africa. *Memoirs of the Entomological Society of Canada*, submitted.
- Swanson D. 1995. Economic Viability of Mycopenicidines for Acridid Control in Africa. Final Report of a Consultancy for LUBILOS. Cotonou, IITA.
- Trurmann P., J. Voss and J. Fairhead. 1996. Local Knowledge and Farmer Perceptions of Bean Diseases in the Central African Highlands. *Agriculture and Human Values* 13, 4: 64-70.

Wewetzer A., S. Krall and F.A. Schulz. 1993. *Methods for the Assessment of Crop Losses Due to Grasshoppers and Locusts.*

## Appendix: LUBILOSА Socioeconomic Working Papers Series

- Joffe S. 1993. Socio-economic Aspects of the Biological Control of Locusts and Grasshoppers: Proposals for Research. Natural Resources Institute project No. C0304. LUBILOSА Socioeconomic Working Papers Series No. 93/1. Report of a Consultancy for LUBILOSА. Cotonou, IITA, 57 p.
- Swanson D. 1995. LUBILOSА Socioeconomic Working Papers Series No. 95/1. Economic Viability of Mycopensticides for Acridid Control in Africa. Final Report of a Consultancy for LUBILOSА. Cotonou, IITA.
- Stonehouse J. 1995. Social and Economic aspects of mycoinseticide against sahelian grasshoppers. LUBILOSА Socioeconomic Working Papers Series No. 95/2. Report of a Consultancy Visit to Benin, Niger and Mali for LUBILOSА, July-October 1994. Cotonou, IITA.
- Houndekon V. A. Etude économique des externalités liées à l'utilisation des pesticides dans la lutte anti-acridienne. LUBILOSА Socioeconomic Working Papers Series No. 98/1. Cotonou, IITA.
- De Groote H., Z. Ouambana and S. Attignon. 1998. Biological Control of Locusts and Grasshoppers in Niger, a Rapid Rural Appraisal. LUBILOSА Socioeconomic Working Papers Series No. 98/2. Report of a Participatory Rural Appraisal in Maine-Soroa, Niger, August 1997. Cotonou, IITA.
- Attignon S., H. De Groote et A. Tonkoanon. 1998. Observations paysannes sur les invasions de sauteriaux et les pertes de récolte occasionnées dans le Département de Zinder, Niger. LUBILOSА Socio-economics Working Paper Series No. 98/3. Rapport d'une enquête socio-économique effectuée dans le Département de Zinder, République du Niger, Mars-Avril 1998.
- H. De Groote, O.K. Douro-Kpindou and T. Togo. 1998. Biological Control of Locusts and Grasshoppers in the Dogon Area : a Rapid Rural Appraisal. LUBILOSА Socioeconomic Working Paper Series No. 98/4. Report of a Rapid Rural Appraisal in the Dogon Area, Mali, June 1997
- De Groote H. 1998. Potential for Mycopensticide Use in Africa: A Preliminary Socioeconomic Analysis. . LUBILOSА Socioeconomic Working Paper Series No. 98/5. Paper presented at the LUBILOSА Project Management Committee Eschborn, December 10-12 1997. Paper presented at the LUBILOSА Project Management Committee Eschborn, December 10-12 1997.
- Müller D., C. Gbonboui, H. De Groote et O.K. Douro-Kpindou. 1998. Diagnostique participative sur le criquet puant (*Zonocerus variegatus*) dans quelques villages du Département du Mono. LUBILOSА Socioeconomic Working Paper Series No. 98/6.
- De Groot A. 1995. The functioning and sustainability of village crop protection brigades in Niger. *International Journal of Pest management*, 41(4) 243-248.
- De Groote H., O.K. Douro-Kpindou, Z. Ouambana, C. Gbonboui, and D. Müller. 1998. Biological Control of Locusts and Grasshoppers in West-Africa: The Farmers' Perspective. LUBILOSА Socioeconomic Working Paper Series No. 99/1