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# Biological Control of Locusts and Grasshoppers in West-Africa: The Farmers' Perspective

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## Abstract

In a survey in three countries of West-Africa using participatory rural appraisal techniques, we assessed the possibility of replacing chemical pesticides used against locusts and grasshoppers by biological control, based on an indigenous pathogen fungus produced at IITA-Cotonou. Using structured group and individual interviews combined with field visits, farmers' perceptions on locust and grasshoppers as a crop pest were assessed, as well as their quantitative estimation of crop losses and willingness to pay for locust control. Farmers as well as plant protection officers generally perceived locusts and grasshoppers as important pests that cause a lot of damage The use of the fungus with an oil-formulation and ULV equipment was demonstrated, and the results discussed with farmers. Their impressions of biological control were favorable, and the expressed an interest in using the technology. Farmers' expressed willingness to pay for locust control is small, but not negligible. Although political pressure for locust control is strong, national governments spend little on it, depending mostly on foreign donors. The results of the survey indicate that a market for biopesticides against grasshoppers and locusts is emerging for cash crops in the humid areas. Moreover, the potential for a market in the Sahel exist, but it depends on a reduction of costs or a subsidy of its price. This subsidy could be justified by reduced environmental and health costs.

**keywords**: participatory rural appraisal, locusts, grasshoppers, biological control, West Africa

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## 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 at a cost of $275 million (US Congress 1990), dissatisfaction with the heavy and continuing use of chemical pesticides was growing (Louis Berger and Associates, 1991). 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 Locustes et les Sauteriaux), a research program initiated in 1989. A network of collaborators from CABI Biosciences (formerly IIBC: International Institute of Biological Control), IITA (International Institute of Tropical Agriculture), CILLS (Comité Permanent Interetats de Lutte Contre la Secheresse) and GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) is implementing the program.

In the initial phase a biopesticide was developed based on the spores of a fungus, *Metarhizium anisopliae var. acridum*, a natural pathogen of locusts, virulent but highly specific. A pilot plant was developed for the production of large quantities of spores (Jenkins et al., 1996), and an oil-based application formulation was developed. In the second phase of the project (1993-1995) field trials were carried out on different locusts species in several African countries (Lomer, 1997), including those of the humid tropics of Benin (Douro-Kpindou *et al.* 1993) as well as the Sahelian species in Niger (Kooyman et al. 1997) and Mali (Shah *et al.* 1998). The results are promising, with mortality rates of 80% or higher, although this mortality is only reached after one to two weeks, and the product is easy to store and to apply. The developed biopesticide is technically clearly a powerful technology, but its economic viability has not yet been demonstrated.

Therefore, farmers' interest in this new technology needs to be assessed. More specifically, the benefits need to be compared to the costs, potential sociological constraints examined, and the interest of the political decision makers assessed, especially plant protection agencies and donors.

Farmers in different Sahelian countries generally consider locusts and grasshoppers as major pests (Stonehouse et al 1997), but its control is judged beyond the individual farmer's capacity. Farmers clearly want the government to take this responsibility, but no economic analysis is really available to justify such an intervention. A attempt to quantify crop losses due to different pests on a national scale was organized over three years in Niger (Krall, Youm and Kogo, 1995). The results indicated that locust and grasshoppers cause relatively small losses, and that their control is probably not economically justified. Another attempt, pooling existing data of the desert locust and making a fair number of assumptions to fill the blanks, comes to the tentative conclusion that desert locust control is only economical 10% of the years (Joffe 1997).

To shed more light on these conflicting views, a broad survey was organized consisting of interviews with farmers, extension officers, NGOs and officials in locust prone areas of Niger, Benin, and Mali. This survey was part of a participatory research effort by the LUBILOSA program. The present study elaborates on previous work and extends it to the humid zones, and includes farmers' ranking of crop pests, quantitative estimates of crop losses, farmers' interest in and willingness to pay for locust control, and their observations concerning the use biopesticides against locusts and grasshoppers.

The paper is organized as follows. First the methodology will be discussed, with a review of the concepts, the choice of region and villages, and the tools used. The results for the three different areas will then be discussed in three separate sections, followed by the conclusions and recommendations for further study.

## 2. METHODOLOGY

### 2.1. Concepts in Participatory Research

Standard economic analysis evaluates technologies by calculating and comparing indicators such as the cost benefit ratio or the marginal rate of return. The quality of this analysis depends heavily on the quality of the data collected, which is a particular problem in the evaluation of locust control. An alternative is to solicit the farmers' opinion directly, and to ask them to evaluate technologies and to participate in the technology development process. To include farmers' knowledge, opinion, and practices can make the difference in assessing new technologies, by making it possible to diagnose major problems, prioritize them from a farmers' perspective, and even quantify them, up to a certain degree.

Therefore, farmers' participation in agricultural technology development is more and more solicited, although many different methods exist and a wide range of confusing terminology is used. The most convenient way to classify approaches is by level of farmers' participation, such as the four categories proposed by Biggs (1989). In the most basic type of participation, *contractual*, farmers only provide land or services to the scientist for regular or demonstration trials. In a second stage, called *consultative*, scientists consult farmers about their problems and then develop solutions. In this group we might include also Rapid Rural Appraisal (RRA), which was a reaction against the slow, tedious and costly traditional assessment surveys. It tries to gain time and efficiency by a concentrated approach of a multidisciplinary team, with a flexible methodology to get a grasp of a problem in a rural area. The method included extensive discussions with farmers and villagers, and was used for this survey in Niger in combination with demonstration trials.

It can be argued that farmers, the intended beneficiaries of agricultural research, have a right not only to express their opinions but also to direct the research agenda. Others argue that it is simply more efficient to include farmers in the early stages of technology development (Kamara, Defoer and De Groote, 1996; Sperling, Loevinsohn and Ntabomvura, 1993). Biggs (1989) groups these approaches in a third category, the *collaborative* approach, in which scientists and farmers collaborate as partners in the research process. Similarly, *Rapid Rural Appraisal* became *Participatory Rural Appraisal* (PRA), moving from an appraisal (the researcher's point of view) to a participation by the farmers. LUBILOSA's efforts in Mali can be situated here, where the technology is tested by farmers' organizations, with the support of an NGO, and farmer's opinions and suggestions are actively sought.

In a fourth category of participatory research, *collegial*, scientists work to strengthen farmers' informal research and development systems in rural areas. In this sense, PRA moved from appraisal to learning and action, implying a joint effort, now often called *Participatory Learning and Action* (PLA). This rather intense approach is only feasible where researchers are relatively close to the farmers, which means for LUBILOSA close to the IITA station in Benin. Here farmers' suggestions are solicited and immediately incorporated into the research agenda.

In each of the categories, the major objective of the participatory approach is to assess a problem in collaboration with the local population, and to discuss and test potential solutions, in this case the potential of using a biopesticide against locusts and grasshoppers. For that purpose, a number of steps are always followed, starting with overview of the ecological and socioeconomic environment. Subsequently, the farmers' assessment of the problem is obtained through a prioritization of the constraints, with a first attempt of quantification. The farmers' opinion on the new technology is then solicited, after a demonstration or a participatory trial. Finally, the farmers' willingness to pay for this method is assessed, and this is compared with the expected cost of providing the technology.

Several techniques are used throughout the different steps: group discussions, village transect walks, individual discussions with men as well as women, and visits to individual farms. The approach is both systematic and flexible: systematic because the same data are collected from different villages, but flexible, meaning open to other information to let new problems other aspects of a problem surface. In conjunction with this research, crop loss assessment studies are executed in the same regions, to allow for a comparison of traditional scientific techniques with the social science approach in a later stage of the research.

## 2.2. Data and Methods

In previous years, field trials had been conducted in Mali, Niger and Benin. Mali and Niger are Sahelian countries, with a consistent problem of Sahelian grasshoppers including the Senegalese grasshopper, while southwestern Benin has a regular problem of the Variegated Grasshopper. The trials in those regions showed repeatedly high efficacy of the mycopesticide and a high interest of the farmers, and therefore they were maintained for the present survey.

Visits with multidisciplinary teams were organized in the three countries. First, experts were interviewed, and secondary data and technical reports collected. In each country, several villages were then visited in the region most prone to grasshoppers and locusts (see map in Figure 1).

In Benin, previous surveys indicated that the variegated grasshopper was a common pest in the three southern provinces: Mono, Oueme and Atlantique (Paraïso *et al.* 1992). The Atlantique province was discarded because of bad accessibility, and during a preliminary survey 11 villages were visited in the Mono and some villages in the

Atlantique. Finally, the northern part of the Mono province was chosen because cotton production has given farmers access to pest control technology and credit.

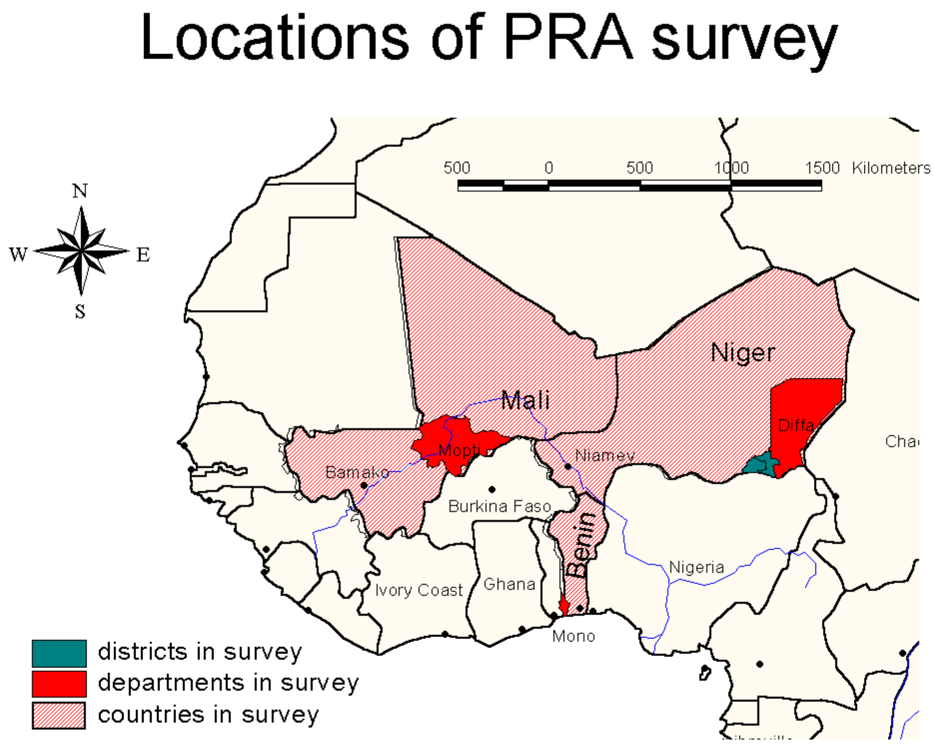


Figure 1. Location of PRA surveys

After collecting secondary information about the region, an interdisciplinary team executed a two day PRA in three villages of the Mono province during March and May 1997. Village maps was elaborated with the villagers and, based on that map, the team walked over a transect (cross section) of the village territory together with key informants. Group interviews were conducted with three groups of villagers: older men, women and young men, followed by several individual interviews with men and women. At the end, the team presented a summary of findings to the village assembly for discussion. The PRA resulted in a demonstration trial and the planning of a collaborative research (PLA).

In Mali, the biopesticide had previously been tested in Mourdiah in the North West, and the Dogon area in East-central Mali. Both areas have a recurrent grasshopper problem, but in the Dogon area a Non-Governmental Organization (NGO) has been active in locust control for several years. Therefore, this area was selected for a PRA, executed in June 1997 by a multidisciplinary team, consisting of IITA scientists, NGO field workers and agents from the Plant Protection Service (PPS). Four villages were selected among those where the biopesticide had previously been tested, in response to heavy grasshopper problems, spread over the area. The team had a tour of each village, made a transect walk and a village map. Informal discussions were held with villagers along the walk and points of interest were clarified.

In each of the villages a structured group interview was conducted with the farmers, led by the local project extension agent. The topics that were discussed included village organization, the agricultural calendar and the crops, the importance and prioritization of pests, locust control practices, and impressions of the biopesticide. In two villages, women were also interviewed, more particularly on the role of women in agriculture, their prioritization of pests, and their role in grasshopper control. In two villages, individual farmers were interviewed, and their house and fields visited for more in-depth discussions. Between villages, the most important services and projects in Mopti, Sevare, Bandiagara and Pel were also visited.

In Niger, the PRA took place in August and September of 1997 in the subdistrict of Maine-Soroa, district of Diffa in Southeastern Niger (see map in Figure 1). It followed the aerial trial which took place in the beginning of August 1997, and in which 800 ha area were treated with the biopesticide and compared with a control area and the treatment of a similar area with the chemical pesticide fenitrothion.

The PRA-team consisted of IITA scientists, and officials of the Niger PPS and agricultural extension service. After a first visit of the three areas, group discussions with local farmers were organized in all three places, next to the millet fields of the trial. The owner of the field would usually participate, as well as the village headman and several council members, assisted by some interested farmers. The discussion followed a rough and open guideline, and dealt systematically with the relevant topics. After a description of the farming systems, an assessment was made by the villagers of the major pests in the area, a quantification of grasshopper damage was attempted, the farmers' impression of the treatment was evaluated, and their willingness to pay for a grasshopper treatment estimated. During the tour, officials were visited in the relevant ministries and departments in Maïné-Soroa, Diffa, and Niamey. The officers of Maine-Soroa were invited to the treated fields and discussed the results with the farmers.

## 3. THE VARIEGATED GRASSHOPPER IN THE MONO, BENIN

### *3.1. The region*

Benin is still a largely rural country, although commerce is becoming increasingly important. It has a GNP of $340 per inhabitant, small but substantially higher than the other countries of this survey (see Appendix 1 for more details). The political situation is stable, democracy seems to be established, and the economy is taking off. The Mono

Department is located in the South West of the country, and has a natural vegetation of derived savanna. For a surface area of 4,009 $km^2$, its current population is estimated at 829,820 people, or 169 inhabitants per $km^2$ (Institut National de la Statistique et de l'Analyse Economique. 1998), growing at a rate of 3.2 % per year.

The villages explained how the agricultural calendar is driven by two rainy seasons (Figure 2). In the first season (March-July), mainly maize, cowpea and peanuts are grown. In the second, short rainy season (September to November), cotton is the main crop, often planted between the maize rows. Cassava is planted in the first rainy season but only harvested after the second rainy season. Farmers usually have only one field at a time, with oil palms mixed in with the crops. When, after some years, the soil is depleted, the field is left in fallow except for the palm trees. The farmer moves on to an old palm orchard, cuts the trees and clears the land for a new field.

### 3.2. The Variegated Grasshopper

The variegated grasshopper (*Zonocerus variegatus)* is the only serious grasshopper pest in the humid coastal areas of West Africa, where it can attack almost any crop, but mostly cassava. It is a non-migratory pest which prefers the humid lowland forests, where it is restricted to the sun-lit edges and clearings (Modder, 1996). From the 1950s onward, deforestation and agricultural intensification opened new areas for this grasshopper species, and its economic impact is increasing.

In all three villages of the survey, the variegated grasshopper was mentioned as one of the three most important pests, attacking all crops. Other pests, mentioned in at least two villages, were aphids, rodents, caterpillars and the larger grain borer. In the group discussions, villagers remarked that although the grasshoppers have always been around, only over the last 5 years had they become a major problem. They described how grasshoppers typically emerge at the end of the first rainy season to reach a peak at the end of the second rainy season. The population then slowly decreases over the dry season to disappear quickly at the beginning of the rainy season (Figure 2). Contrary to a study in Nigeria where farmers understood the egg laying behavior and the life cycle of the grasshoppers (Page and Richards, 1977), farmers of the Mono have acquired little knowledge of grasshopper biology. They assume that grasshoppers reproduce through eggs, although they have not yet seen them, and they consider the larvae and the adult grasshoppers as two different species. They do observe a high mortality and the end of the main rainy season, which they attribute to the rainfall.

### 3.3. Damage and pest control

The villagers observe defoliation by the variegated grasshopper of all plants except for the neem tree. The grasshopper also eats the bark, especially of cassava, and kills seedlings. The defoliation decreases yields, but mostly in the second season when the grasshoppers are abundant: this affects second season maize and especially cotton. Some farmers made individual estimates of yield losses, such as 90% for cowpea, 30% on maize and cotton. Losses are very variable and averages could not be obtained. The attacks on young plants can cause substantial loss of seedlings, a loss of seed and of labor.

Since grasshoppers density is low in the first rainy season, yield loss to first season crops is rare, particularly in cassava. When grasshoppers start to attack cassava, the plant is already older and will shed some leaves for the dry season anyway. Grasshopper attacks have, however, a major impact on the quality of the tuber, which changes color from white to pinkish, while the tubers change structure and become watery, severely hampering processing, and therefore decreasing its market value. The loss of the bark also makes the attacked cassava stems useless for cuttings.

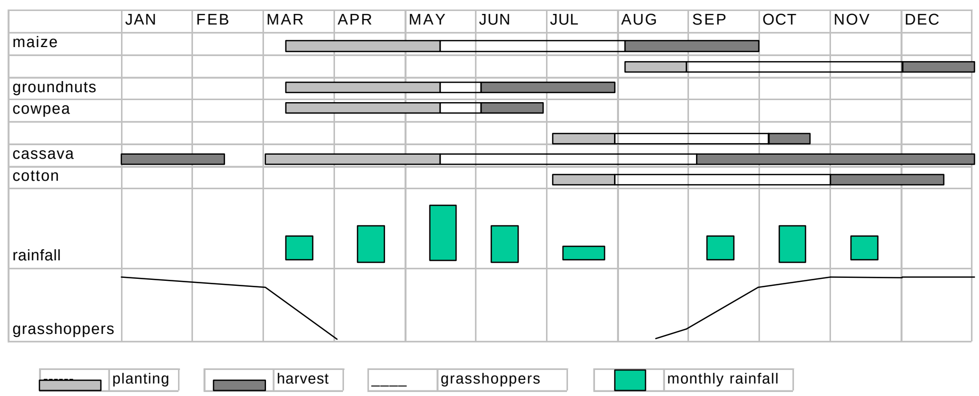


Figure 2. The agricultural calendar as developed by the villagers of Hontoui

Since the grasshopper was not really a problem until recently, farmers have not developed any control methods. They did try cotton pesticides, which they found not to be very effective against grasshoppers.

They use two kinds of sprayers: flit guns, which are manual, bicycle pump type sprayers (external air-shear nozzle sprayer), and spinning disc sprayers, which are battery driven and use Ultra Low Volume (ULV) applications. Many, but not all, farmers in this area prefer the flit guns for treating their crops. Advantages cited are lower initial cost (less than $2 against about $60 for the spinning disk sprayer), no need to buy batteries, and a slower pace of application which increases the accuracy of spraying low doses.

### 3.4. Further Participatory Learning and Action

In all villages, it was concluded that the variegated grasshopper was a serious problem and that farmers would appreciate a control method such as the biopesticide. They were, however, hesitant to estimate how much they would be willing to pay, having not seen its efficacy. In the first survey village, a demonstration trial impressed the farmers, but in the other villagers it was too late in the season. Nevertheless, all villages expressed interest in training, which was then organized. Eight people in each village attended, and a participatory research agenda was agreed upon. Factors to include are flit guns versus spinning disc sprayers, a reduction of the dose to reduce costs, preventive spraying of early stages, and spraying of the fallow.

# 4. THE SAHELIAN GRASSHOPPERS IN DOGON COUNTRY, MALI

## 4.1. The environment

Mali is a large landlocked country in West Africa with a wide range of climates. Although is still very poor, with a GNP of 250$ per capita, the transition from military dictatorship to democracy was successful and brought stability and substantial donor support to fuel the economy. The Dogon live in one of the most inhospitable areas in the North East, and their country ("pays Dogon") covers the four eastern districts of the Mopti administrative region, an area of surface of 48,000 km$^2$. It is dominated by the Bandiagara escarpment, a 150 km long series of sandstone cliffs, which divides the area in the northern Dogon plateau, and the lower area, called Seno. The villages visited were chosen for geographic distribution, and were located at the western end of the cliff (Koa), on the plateau (Golokanda), on top of the cliff (Yawa) and underneath (Nombori).

This area has a typical Sahelian climate (Figure 3). After a hot dry season the rains fall during about five months, followed by a cooler dry season. Its rainfall varies between 350 and 750 mm, but has decreased recently. The average rainfall in Bandiagara for example, 550 mm over the last 70 years, has decreased to 450 over the last 25 years. As a result, the region suffers from substantial deficiencies in basic food production, especially cereals.

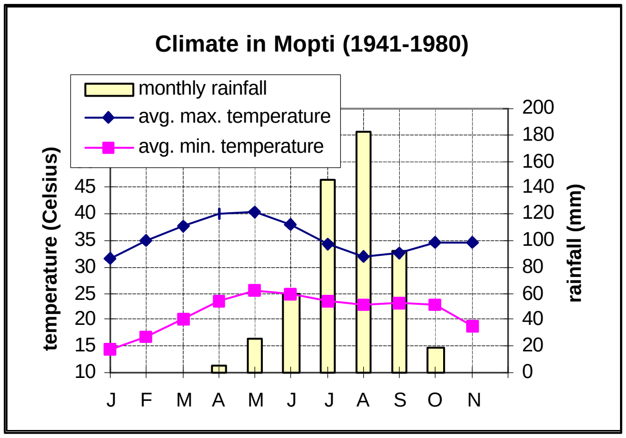


Figure 2

## 4.2. Population

In 1993, the population of the Dogon area was estimated at 774,000 people. The low population density of 15,6 people per km$^2$ reflects the harsh living conditions, which cause a lot of emigration. Population growth is only 1.53%. The Dogon live in villages spread out over the area. In Bandiagara, a village has around 450 people constituting 38 households, or around 12 people per household. The visited villages vary in size from 20 to 101 households. A household can be defined as a group of related people who live and work together, usually the brothers and sons of the household head, together with their wives and children. Polygamy is common. Men can marry women from the same village or from other with some restriction on family relations. Although before adult men would not set up their own household before their father died, this seems to become more common. Within the household several nuclear families can exist, defined as a husband with his wives and children. This group has certain functions and can eat together several months a year. Individuals within the household can have their own private plots.

The largest villages and the district centers have rural markets, which are held every 5 days. The general use of donkey carts has made the area more accessible to far away markets.

### 4.2. Agriculture

The economy of the Dogon country is based on agriculture. Land tenure system is traditional, in which the family who first arrived owns the rights. No land markets exist. The villagers estimate that households have between 2 and 15 ha of land in cultivation. Apart from the family fields individuals can have small private plots, on which they are allowed to work one or two days a week.

Millet is the major crop, which takes between 50 and 80% of the cultivated land (see Table 1 for an overview of villagers' estimates). Other crops of importance, although this varies among villages, are sorghum, fonio, cowpea, peanuts and bambara nut (voandzou).  Millet is strictly for home consumption, but peanuts, and to a lesser degree, sorghum and voandzou, are sold. Local production can no longer feed the population, and horticulture in the dry season, especially onions, becomes increasingly important as a cash crop.

**Table 1. Agriculture, villagers' estimates**

| | *Koa* | *Golokanda* | *Yawa* | *Nombori* |
|---|---|---|---|---|
| households/village | 20 | 37 | 45 | 101 |
| ha cultivated /hh | 10 | 5-15 | 12 | 2-15 |
| hh with oxen (%) | 100 | ? | 55 | 75 |
| % of land in millet | 1 (50%) | 1 (75%) | 1(>80%) | 1 (75%) |
| sales (field crops) | 1/3, esp. sorghum | only peanuts (40%) | none | peanuts, bambara nut |
| sales (horticulture) | onions, most other | | onions, most of rest | all |
| yield of millet (kg/ha) | 1000 | 480 | 200 - 600 | 100-500 |
| price of millet (FCFA/kg) | 70 | 37.5 (harvest)<br>90 (at survey time, August) | | 80<br>100 |

During the survey, farmers estimated their millet yields vary between 100 kg/ha in a bad year (even 0 after a locust attack) to 1000 kg/ha, so 500 kg/ha seems a good middle value. The department of agricultural statistics' estimates for 1993 to 1995 was 447 kg/ha (DNSI, 1995). Farmers estimate the millet price between 40 and 100 FCFA/kg. Prices in Mopti at the time of the survey were at the high end of that range, and stayed at around 100 FCFA/kg even after the 1997 harvest. At a middle value of 70 FCFA, the production of one ha of millet can be estimated at 35,000 FCFA, or roughly $60, at the higher value 50,000 FCFA or $80/ha.

### 4.3. Pests

Villagers generally considered locusts and grasshoppers as their major pests, except for one village where blister beetles had been more important for the last 6 years (see Table 2 for an overview). The other major pests mentioned were beetles, stem borers, and head borers. Farmers estimate the yield reduction caused by locusts somewhere between 60 and 100 %. The locusts do damage on most farms, although not on all fields: fields closer to fallow are reportedly more attacked. The damage due to locusts and grasshoppers is very variable from year to year and from village to village.

**Table 2. Ranking of major pests reported on field crops by village**

| | *Koa* | *Golokanda* | *Yawa* | *Nombori* |
|---|---|---|---|---|
| locusts and grasshoppers | 1(on cereals, not on legumes) | 1(on millet) | 1 | 1 (from 88-90) |
| blister beetles | 2 | | 3 | 3 |
| lepidoptera | 3 (on peanuts) | 3 (but 1 on onion) | 2 (ear borers, miners) | 1 (90-96) |
| coleoptera | | 2 (millet) | | |
| striga | | 4 | | |
| rodents | | | 4 | |
| monkeys | 4 | | | |
| remaining yield after locust attack | 0-40% | 1/24 | 1/3 | almost nothing |
| 10 last years of locusts | | 4 medium 1 very bad (95) | ‘96, <86 good, rest bad | bad in 88-90 |

In the past, villagers controlled locusts by beating them with sticks or by digging trenches to bury them. Farmers complain, however, that the locusts changed their behavior in recent years, “they are a lot smarter now”, so there are few alternatives to the use of chemical pesticides.

A local NGO, PDAD (Projet Diocèsane d’Agriculture Durable), supported by the catholic church and donors, has been supporting the villages in locust control with chemical pesticides. The four visited villages participate in the program, and have a village brigade, a group of young farmers responsible for locust control. In the past, villages had to contribute 20,000 FCFA each, and provide men for the brigades, with the NGO providing pesticide and spraying equipment. From 1997 on, the villages are asked to pay 25% of the cost of the chemicals.

Farmers displayed a positive attitude towards the biocontrol. Most people who attended the demonstrations easily recognized its comparatively slower action but acknowledged its longer persistence. They declared a modest willingness to pay. Although not all villagers agreed, a figure of 5000 FCFA/ha was often mentioned, roughly half of the production cost of the biopesticide, but  10 % of the crop value. Some people declared they could not pay this, or only if they had the cash, while others offered to pay up to 10,000 FCFA, even 20,000 FCFA. The willingness to pay is clearly linked to cash availability, strongly influenced by income and onion production. Access to credit might play an important role here.

The discussions on application technique were inconclusive: the ULV formulation requires expensive batteries, but does not need water while the Emulsifiable Concentrate (EC) formulation does not need batteries, but substantial amounts of water that need to be tranported to the field

### 4.4. Further Research

Grasshoppers and locusts are clearly a major problem, at least in the villages interviewed. Unfortunately, the value of the crop is quite low, so treatments are really only economically justified at high yield losses. More structured and quantitative research is needed on a representative sample to estimate yield losses and link them to insect population densities to determine the intervention threshold.

Contrary to a previous survey (Stonehouse *et al*. 1997), it was found that farmers are willing to contribute to locust control. These potential contributions, although not negligible, will usually cover the cost of the biopesticide, or any other pesticide. Tests need to be conducted to see in how far doses can be reduced without loosing efficacy, but some subsidy will most likely be necessary. Fortunately, the local NGO is already subsidizing locust control. Moreover, their donor, their German donor organization Misereor has strongly encouraged them to look for alternatives to chemical control. Collaboration is clearly indicated, ad an optimal subsidy level found.

Most of the crop losses caused by locusts occur in the households' millet fields, not on the individuals or on the more intensive onion fields. Locust control, on the other hand, is organized through village brigades. The member of those brigades are young man, and they have little weight in the decision making process and are also the group most likely to emigrate, causing a lot of rotation. Fortunately the NGO has a solid extension organization, with motivated workers. Several other organizations are active in the region, so a public relations effort might bear fruit.

# 5. THE SENEGALESE GRASSHOPPER IN MAINE SOROA, NIGER

## 5.1. Locusts and grasshoppers in Niger

Niger is a large landlocked country in the middle of West Africa with a climate ranging from the desert in the North to Sahel in the South. It is one of the poorest countries in the world, and its Gross National Product per capita, which has steadily been decreasing over the last ten years, is now at $300 per capita. The military regime is clinging to power, and tensions with the donor community have substantially reduced foreign aid.

Locusts and grasshoppers are a consistent pest of agricultural crops in many areas. The Senegalese grasshopper (*Oedaleus senegalensis)* is the most important Sahelian grasshopper, but 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 country has a well-trained Plant Protection Service (PPS), supported for many years by the international donor community with training, capital and working funds. With this help, the PPS has been able to treat many thousands of ha each year against a range of pests, but mostly against the Senegalese grasshopper. On average, 440,000 ha was treated each year over the last 10 years, of which 300,000 ha against locusts and grasshoppers. These areas vary a lot between years, and during locusts invasions such as in 1988 more than 600,000 ha are treated.

Most of the locust control is done by plane, although participation by the rural population has been encouraged through village brigades. Volunteers receive training in plant protection, and are provided with the basic equipment: sprayers, clothing and so forth. In the past, the brigades have been provided with pesticides according to needs, and they have treated up to 50,000 ha a year. Unfortunately, the organization of the brigades was mainly driven by the needs of the PPS and its donors (De Groot, 1995). The activities of these brigades are heavily dependent on outside funding, and are not sustainable without them. Although recently some NGOs have also been organizing brigades, the area they treated is small compared to the area treated by PPS sponsored brigades. Moreover, the area treated by all brigades combined is still a fraction of the aerial treatment.

Village brigades do have the advantage of involving the local population. But so far, the population's contribution has been only in labor. The field costs to the PV per ha treated by a brigade was estimated in 1991 to be 7100 FCFA or roughly $28 at that time (PLURITEC/EDUPLUS 1993), which is much higher then aerial treatments, estimated at 1140 FCFA or $ 4.6. Treatment by truck is slightly cheaper than by plane, but not feasible in many areas. On top of the field costs, fixed costs have to be taken into account. Spread over the area treated (all pests and all types of applications combined), they were estimated at 5000 FCFA/ha or roughly $20. Clearly, these costs are not within the means of the farmers or of the national service. Both brigade activity and aerial spraying are paid for by the international donor community, and economic factors seem to play only a minor role in the decision making process, dominated by bureaucratic and political factors.

### 5.3. Maine Soroa

Maine Soroa is the southwestern subdistrict of the department of Diffa, which is situated in the southeastern corner of Niger. From 1995 to 1997 its average yearly rainfall was 323 mm. The rains typically start in April or May, to peak in July or August, as illustrated by the monthly rainfall in the last three years, represented in Figure 4. Diffa is the least populated department of Niger, with only 190,000 inhabitants, of which about half live in the subdistrict of Maine-Soroa. Most of the agricultural land, land is planted with millet (61%), followed by beans (22%) and sorghum (17%). LUBILOSA conducted a field test with aerial application of the mycopesticide, North of the town of Maine-Soroa, and the villages of the three sites were visited shortly thereafter for this survey.

The survey revealed that inhabitants of this region are mostly sedentarized Fulani, traditionally nomadic herdsmen. Their villages are not very structured and their main income is from livestock, not agriculture, so that in most years, the millet production does not cover the needs. Those villagers living closer to Maine-Soroa earn extra income from the sales of wood or from working in the town, but the others rely mostly on livestock sales to cover their cereal deficit. Although expenses for livestock such as salt and vaccinations are common, people rarely purchase agricultural inputs. Only grazing on the stubble provides some manure.

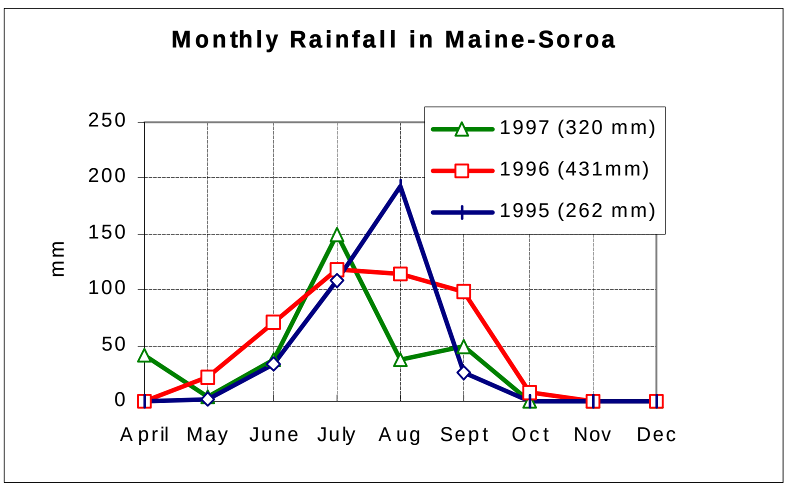


**Figure 3**

Yields are low and variable. The average millet yield calculated by the agricultural statistics department for 1994 to 1996 was 353 kg/ha (Ministère de l'Agriculture et de l'Elevage du Niger, 1996). The subdistrict produces on average 149 kg of cereals (millet and sorghum) per person, far short of the 250 kg/person needed for self-sufficiency.

Table 3. Characteristics of research villages

| name | Gel Adouage | Kayeya | Bara |
|---|---|---|---|
| treatment | control | MF | Fenitrothion |
| people | 500 | 150 | 500 |
| families | 61 | 30 | 100 |
| land in millet (%) | 20 | 30 | <10 |
| millet production in good years (sacks of 100kg/hh) | >50 | 30 | 15 |
| self-sufficient | no | no | no |
| sources of revenue | wood, trade, labor | sale of animals, work in Nigeria | sale of animals |
| ruminants | 1000 | 2000-2500 | 15000 |
| cattle | 200 | 1250 | 3000 |

The number of cattle estimated by the villagers varies from 3.5 to 41 per family. The value of these animals varies between 70,000 for a young cow and 155,000 FCFA for a bull. These figures also indicate that livestock is at least as important than agriculture in this area.

### 5.3. Locusts and grasshoppers in Maine-Soroa

During the discussions, farmers consistently declared locusts and grasshoppers as the major pest on millet, their first crop. Other pests are stem borer, millet head miner, and army worms. Estimation of crop losses usually start with yield estimation (production per ha), but this was not possible here since the Fulani have no unit for measuring surfaces. They estimate their harvest in a good year (with good rains and no grasshoppers) at 15 to 50 sacks of 100 kg per family, which usually contains between 5 and 15 people. This would be slightly above the minimum requirement of 250 kg/person/year, as estimated by the Ministry of Agriculture. A heavy grasshopper infestation would can this production to 3-10 sacks, or a loss of 80%. At 100 FCFA/kg (average price over 1997), a family could loose 240,000 FCFA or $400 ($1=600 FCFA).

As a result of these potentially high losses, farmers are willing to pay for grasshopper control. Answers were remarkably similar in the first two villages: 2-3 sacks and 3 sacks of 100 kg per family, about 25,000 FCFA. This is almost 10 % of the expected harvest of 30 sacks in a good year. Assuming a yield of 600 kg/ha for those years, the area can be estimated at 5 ha. We can conclude that farmers find 5000 FCFA/ha ($8/ha) a reasonable price to pay to protect their crops against locusts. This result is remarkably similar to Mali.  In the third village, the estimate was unfortunately given for the whole village, 40,000 FCFA, which results in a very low 4 kg of millet per family.

In the village where the test plot had been treated with Metarhizium, the farmers were very happy with the results. They considered the biopesticide, which its persistence of several weeks clearly superior to the chemical pesticides, which effect only lasted a few days.

Table 4. Farmers' perceptions of pests in Maine-Soroa

| name | Gel Adouage | Kayeya | Bara |
|---|---|---|---|
| principal pests | grasshoppers, caterpillars, birds | grasshoppers | grasshoppers, head miners |
| millet production after grasshopper invasion (MT/household) | 5-10 | 0-3 | 4 |
| number of invasions over the last 10 years | 6 | 4 | 7 |
| damage to pasture (%) | 80 | 50-80 | >80 |
| willingness to pay per household | 2-3 sacks | 3 sacks | 3 kg |

### 5.4. Economic analysis of locust control

Agriculture in the Sahel is a low income activity. The average price for millet in 1994-1996 was 100 FCFA/kg, and for cowpea 187 FCFA/kg. The average crop value of Maïné-Soroa can be estimated at 2 billion FCFA ($ 3 million) per year. For the whole district of Diffa, average crop value for 1991-1995 is estimated at $ 7 million. Expenses for plant protection in Diffa for 1991, on the other hand, were estimated at about half a million dollars, or roughly 7% of the crops' value. In other words, at least 7% of crop losses need to be avoided to make the treatments cost effective. Direct of crop loss estimates by the Niger PPS (Krall, Youm and Kogo, 1995) estimate the average yield loss on millet caused by locusts at 15%, much less then farmers' estimates but higher then the intervention cost. Unfortunately, no data are available on the efficacy of plant protection measures.

### 5.5. Further Research

The attitude towards biological control in Niger is quite positive. Most people, farmers as well as PPS and Ministry of Agriculture officers are interested; they are open to it and are willing to give it a chance.

The survey showed that farmers are willing to pay some money for locust control but, given their very limited income, only a small amount can be expected. Even when biocontrol of locust would overall be cost effective, it is unlikely that farmers would be willing or able to pay its full cost. In the best possible scenario, farmers would make a substantial contribution, but the community will have to pay the rest, up to the level where locust control is economically feasible. The challenge to LUBILOSA is to develop a use strategy in which farmers can pay their contributions, to be supplemented by the international donor community with technical support of local services.

In the short run, Maine-Soroa is not a good target area for such a program, even though locust infestation is high and relatively predictable. Human population density is low, farms are spread out far and wide, crop production is not the main activity here, and extension services are spread very thin. It would be better to aim for areas were population density is sufficiently high and farming is the major occupation, even if locusts and grasshoppers are not as consistent a pest. The problem of treating fallow would thus be avoided, and extension and distribution of biopesticides would be a lot cheaper.

## 7. DISCUSSION AND CONCLUSION

The results of this survey now need to be interpreted in the light of its objectives, the potential of using biopesticides in the control of locusts and grasshoppers. In order to predict its acceptance we captured the perspective of the farmer, but need to fit it into a larger framework of socio-economic and political decision making.

At the farmers' level, and in all regions visited, locusts and grasshoppers are generally perceived as a major pest problem. Where farmers saw a demonstration of the biopesticide, the response was usually positive. The slow speed of kill, while clearly observed, was not considered a problem. Its persistence, on the other hand, was seen as a major advantage. Farmers, especially in the Sahel, are very poor, but still consistently do express a small but significant willingness to pay for locust control. Since there were no efficient acridicides available on the local markets, this WTP has so far not translated into real purchases.

The PPS agents and the extension agents generally share this favorable viewpoint on the technological aspects. On the economic aspects, however, they think that farmers are not able or interested in purchasing such a technology, but they feel very strongly that it is the duty of the government and the international donor community to provide this service. Although political pressure for locust control is strong, national governments are spending only very little on it, depending mostly on foreign donors. Donors have shown an increasing reluctance to finance programs that are not sustainable, especially for chemical pesticides in a fragile environment. But since the donors are usually taking into account externalities such as environmental costs and health costs, biopesticides have a potential advantage. Chemical pesticides, on the other hand, benefit from substantial promotional efforts from the pesticide producers, to influence the decision making in the national PPS.

Future focus needs to focus on four issues: when is biocontrol cost-effective, how can the farmers' contributions be captured, and what structure needs to be put in place to combine their contributions with those of donors, extension services and the private sector. Any structure needs to be put in the perspective of a long term and durable development.

Although many gaps remain in our understanding, the outline of some possible scenarios becomes clear. In the humid areas, where the variegated grasshopper is an important, but non-migratory pest, biocontrol of the locust should be financed and carried out by the farmers themselves. They have sufficient cash income and, in the Mono at least, are familiar with basic pesticide use. A local committee or brigade can be organized and trained, preferably in connection with the cotton producers' village association. This association can than provide credit, as it does for cotton inputs. Some technical and organizational aspects still remain, but those should be solved during the next phase of the participatory research. The PPS is capable of providing training, if funds are made available.

In the Sahel, farmers' income is very low, and cash availability an important constraint. Moreover, locust attacks are highly unpredictable, so it is unlikely that the private sector will carry a suffficient stock and that individual farmers will buy it. Moreover, the chance is always there that the PPS provides the pesticides for free, wiping out the market. The PPS officers are well-trained, but they cover huge areas with little operational funds provided by the national government. Donors, on the other hand, are increasingly hesitant to finance locust treatment. A number of NGOs and projects have come to play a major role in providing extension either directly, or through by supporting government services. Decision making in this situation is very complex, and any project needs to advance carefully and taking into account the aspirations and capacities of the key decision makers.

All possible scenarios for the Sahel necessarily include subsidizing biopesticides. The simplest scenario is to convince donors to purchase biopesticides as a substitute for chemical pesticides, and using the existing PPS structures to distribute them. PPS are well qualified to provide the service, organization and training to the village brigades, if they have the funds to do so. This scenario could be pursued in Niger. A second option is to promote biocontrol with the NGOs, and to provide them with information and training to incorporate biocontrol in their activities. It is important that the interested NGOs have sufficient independent funding, such as for example the NGO in the Dogon country. A third option would be a direct price intervention, in which subsidized biopesticides would be sold directly to farmers or farmers' groups.

To obtain optimal results, care should be given to design a proper subsidy policy, based upon clearly specified criteria. To assist the decisions making process in locust management, more quantitative information is clearly needed. Further studies need to establish the relationships between the pest, the damage it causes and the crop loss in which it results. These data will allow for an estimation of the expected economic loss due to locusts and grasshoppers. On the other hand, data are needed on the efficacy of different treatments and strategies, to calculate the expected benefit of these strategies and compare it with their cost.

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**Appendix 1. Basic indicators for the three countries in the survey.**

| Indicator | units | Benin | Niger | Mali |
|---|---|---|---|---|
| Population | million | 4.9 | 9.0 | 9.8 |
| population density | | 106 | 15 | 17 |
| population growth | % | 2.9 | 3.3 | 2.9 |
| urban population | % | 42 | 23 | 27 |
| urban population growth | % | 5.1 | 7.2 | 5.3 |
| active population, % in agriculture | % | 62 | 91 | 93 |
| active population, % in industry | | 8 | 4 | 2 |
| active population, % in services | | 30 | 5 | 5 |
| life expectancy at birth | years | 50 | 47 | 50 |
| infant mortality rate | 0/00 | 95 | 119 | 123 |
| adult illiteracy rate | % | 63 | 86 | 69 |
| female adult illiteracy rate | % | 74 | 93 | 77 |
| BNP/person | $/person | 370 | 220 | 250 |
| rank of BNP/inhab among countries (from lowest) | | 29 | 10 | 18 |
| BNP total | $ million | 1813 | 1980 | 2450 |
| BNP change in 1985-1995 | % | -0.3 . | | 0.8 |
| external debt | % of BNP | 82 | 91 | 132 |
| present value of debt | % of BNP | 46 | 53 | 73 |
| foreign aid (in 1994) | % of BNP | 17.4 | 25.0 | 24.5 |
| foreign aid (in 1994), total | $ million | 315 | 495 | 600 |
| foreign aid (in 1994), per person | $/person | 64 | 55 | 61 |

Source: World Bank. 1997. World Development Report. WorldBank, Washington DC.