Guidelines for Promoting Safer and More Effective Pest Management with Small Holder Farmers:

a Contribution to USAID-FFP Environmental Compliance

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Contents

Foreword

These guidelines were initiated in late 1999 as one of the products of two USAID-FFP supported training workshops on Safer Use of Pesticides (SUP) and Integrated Pest Management (IPM) held in Latin America. Innumerable problems delayed their completion until now. Their original purpose was to contribute to develop the capacity of NGOs implementing USAID-FFP programs to comply with USAID environmental regulations, as epitomized by 22 CFR 216, better known as Regulation 216. As such, their focus was to be on SUP and the promotion of Integrated Pest Management programs. During the past few years, however, USAID, mainly in its Africa programs, has stepped forward and moved from a SUP to a pesticide risk reduction approach. The underlying realization and lesson learned is that, for small holder farming in the developing world, "the safe use" is an insufficient approach to "safer pest management". The reduction of the risks posed by pesticides to the users, applicators, handlers and consumers, has to be achieved not only through the reduction of the exposure to these products but also by reducing the toxicity of pesticides being used.

These guidelines have been developed for all those who direct, manage or supervise projects and who, in turn, have to help farmers to manage their pests. They are not limited to USAID-FFP funded projects but they provide general guidelines for reducing the risks of pesticides and for IPM to virtually any agricultural development project. They are a contribution to disseminate the current state of the art in pest management, the problems faced in its implementation, as well as to provide concrete examples and ideas for promoting IPM. The manual is not intended to be a technical guide for extension agents and does not attempt to repeat information contained in already-available publications of that sort. Rather, this publication fills a now existing vacuum in the IPM and development literature by providing guidelines, and examples, on how to proceed in the promotion of safer and more effective pest management. The guide has been written and developed by a team of highly qualified and experienced IPM specialists; it has been reviewed by several well-known IPM practitioners and PVO staff members; and it has been validated in various pest management training sessions.

The Guidelines have finally come to be a reality thanks to the generous contributions of USAID-FFP and CARE USA.

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Acknowledgements

The guidelines presented here were developed to accompany skill-building workshops for PVO managers who are subject to review on compliance with US CFR Regulation 216. We are grateful to the organizers and participants present in Choluteca, Honduras and Sucre, Bolivia during the workshops held in 1999 for their feedback on the first draft. Mario Pareja kept pest management high on the agendas of PVO managers and tirelessly guided the workshops and written materials through to completion. He carefully edited an earlier draft of the guidelines and provided strategic guidance. Comments by Bernal Valverde are also gratefully acknowledged.

Summary

THIS GUIDE WAS PREPARED AS A complement to training activities that have been developed to help agricultural assistance projects and programs comply with Regulation 216 and reach beyond compliance to help small holder farmers grow their crops with acceptable yields and quality, while negative impacts on their health and the environment due to exposure to synthetic chemical pesticides are kept at a minimum. Many, perhaps most, projects have recognized that reducing dependence on synthetic pesticides is the basis for safer pest management among small holder farmers. Often though, effectiveness in pest management has been sacrificed as we have focused on catch-all alternative strategies for pest problems, with low long-term adoption rates for the alternatives as a result. Farmers need increased understanding of the pest and a wider view of the options for bringing their populations under control if non-chemical management methods are to be adopted on a wide scale. When confronted with those pests that cannot presently be effectively managed without synthetic pesticides, they also need help in choosing among synthetic products in order to reduce risks to their own health, to consumer health, to non-target organisms including those that are economically important, and to the environment.

The guidelines are written for project managers and staff members who will be working with small holder farmers and will confront issues of pest management. The goal of the guidelines is to help managers understand the field of pest management and its major strategies and components. It is hoped that the document can be used to develop a strategy for promoting safer and more effective pest management among farmer partners. It will hopefully guide projects in the search for solutions to specific problems, via in-house expertise, networking with researchers and extension personnel, or the published literature, and help evaluate the contribution that each makes to the program.

The geographic focus of the guidelines is the developing countries of Latin America and the Caribbean but it is hoped that many elements will be useful for African and Asian countries as well. Examples are drawn more often from Central America than from South America, not because pest management is better developed there, but because of the work experience of the authors. The focus is on small holder pest management in crops, although many of the concepts can be applied to pest management for livestock, homes, or gardens.

Chapter 1 describes the nature of the problem when small holders depend upon synthetic pesticides. In summary, farmers overwhelmingly use synthetic pesticides as a management tool, the products they use are the most acutely toxic, and they are most often used without personal protection

or knowledge of their consequences in the environment once they have been applied. The second chapter poses questions that may help projects clarify the goals of the work they do with farmers in order to rectify the problems pointed out in Chapter 1. It calls attention to the breadth of the stakeholders in crop pest management and what the interests of each stakeholder party is. The importance of clear project goals for pest management is emphasized.

Preliminary decisions are made in approaching any particular pest problem and the background for making those decisions is the subject of Chapter 3. The chapter indicates the analytical process that an expert would use for a pest problem as a basis for choosing likely management options and rejecting unlikely ones. At the same time that it indicates an expert process, the chapter emphasizes that background knowledge will also help farmers understand and rationalize different management options. The chapter begins with pest identification and ways of classifying damage and progresses through considerations of pest life history, including movement, host plant range, and natural enemies. It presents the overriding importance of estimating the pest's population size and understanding its effect on yield loss at different stages of the crop's development. The chapter discusses the root causes of pest problems in light of differences in agricultural vs natural systems. Given a probable root cause, pest ecology and behavior, the landscape arena in which a given pest must be managed effectively is discussed.

Preventive management of the pest is based upon creating an unfavorable environment for pests while conserving yield and quality in the crop. Chapter 4 discusses and offers examples of the principal components of preventive management: cultural management, genetically-based resistance (natural and based on genetic engineering) and the conservation of living natural enemies.

When preventive management alone cannot keep pest populations at acceptable levels, curative options must be used to prevent losses (Chapter 5). Mechanical control, a viable and economical option for many pest/crop combinations, is discussed and illustrated. Biological pesticides based on living predators, parasitoids, weed herbivores or microorganisms or on plant extracts are discussed in light of their use pattern among small holder farmers, effectiveness, human safety, and environmental safety.

A major section of Chapter 5 is devoted to synthetic chemical pesticides in an effort to help projects chooses least damaging options beyond compliance with Regulation 216. The important properties of synthetic pesticides, selectivity, toxicity to people and to non-target organisms, mobility in the environment, persistence in the environment, and propensity for provoking resistance in pests, are defined and illustrated. Various schemes for classifying synthetic pesticides as a basis for choosing safer ones are presented and finally, mitigation strategies for human health effects, environmental effects and resistance are discussed.

Farmers must not only understand non-chemical options for pest management but be motivated to use them. In Chapter 6, a generalized framework for the pesticide and pest management policy context in which projects will work is presented. Ideas on how the policies may affect efforts to reduce pesticide use and encourage alternative management are offered. The programming guidelines offered in Chapter 6 are intended to help programs develop activities that may lead to more long-lasting field implementation of safer and more effective pest management. Ways in which programs can build their own capacity in pest management and guidelines for evaluating their own work are presented.

Chapter 1
Pest Management in Small Holder Communities: the Nature of the Problem

THE MISUSE OF SYNTHETIC pesticides causes some of the most acute and long-lasting environmental and health problems encountered in the developing countries of Latin America and the Caribbean. Synthetic pesticides were created for use in countries where negative impacts are mitigated by myriad regulations. Farmers or professional applicators use respirators, masks, closed cabin tractors, and clothing that protect them; they understand the environmental effects of the pesticides they apply and how to avoid them. Field re-entry times and pre-harvest pesticide application intervals are prescribed, monitored and regulated to safeguard farm laborer health and consumer safety. Pesticides allowed only for registered uses are sold exclusively to licensed, knowledgeable applicators.

Despite the recognized need for heavy restrictions on pesticide use, the same compounds are routinely used in the developing world where those safeguards rarely apply. The results are unacceptable rates of acute poisonings and of chronic, pesticide related diseases among farmers and laborers, unknown effects on consumers of pesticide residues on food, documented groundwater contamination in many communities and largely un-quantified effects on wildlife and beneficial organisms in agricultural ecosystems.

Application of Regulation 216 is an important step toward rectifying problems caused by misuse through removal of some of most damaging compounds in the pesticide load, requiring training for users, and requiring the mitigation of potential adverse environmental effects. Steps beyond compliance with Regulation 216 can be taken to further prevent damage by more profoundly influencing farmer pest management choices and decisions.

A few general statements about small holder practices can help to establish a context for work with policies such as Regulation 216 and efforts beyond compliance.

1.1 How do small holder farmers manage pests?

Most small holders use synthetic pesticides at least some of the time

Most small holders are surrounded by readily available synthetic pesticides at low prices, they listen to ads for their use on the radio, are visited by extension agents, talk to salesmen in village stores and are strongly influenced by what their neighbors do. Not surprisingly, pest management by small holders is overwhelmingly based upon applications of synthetic chemical pesticides. The statistics on synthetic pesticide use derived from some recent studies are summarized in Table 1.

Table 1. Recent evidence for the pervasive use of synthetic pesticides by small holders in Central America.

Author	*Year*	*Country*	*Crop*	*% Users*
Centeno	1997	Nicaragua	all	97
Araya, et al.	1999	Costa Rica	cabbage	100
Hruska, et al.	1995	Nicaragua	maize	89

The studies found that the following qualities of synthetic pesticides were most cited as beneficial by their users

- reliable effectiveness
- speed of action
- facility of use
- availability
- low price
- cultural acceptability

In other words, in the absence of strong motivators for avoiding them, pesticides are hard to beat.

The most commonly used pesticides are the most dangerous available

Synthetic insecticides mentioned as most often used by small holders are the generally highly acutely toxic organophosphates and carbamates (Table 2).

Methamidophos and methyl parathion are listed by the World Health Organization (WHO) as Class I pesticides, extremely dangerous or highly dangerous to human beings. Chlorpyriphos was listed as a restricted use pesticide (RUP) in the United States in 2003.

Why do small holders in developing countries tend to use the most acutely toxic pesticides? Most importantly, these pesticides are significantly *cheaper* than «new generation», safer pesticides that have been developed more recently under much more stringent testing requirements. As older compounds, they are often no longer protected by patents and are produced cheaply by companies in a number of developing countries, notably China, Taiwan, Brazil, India, and Argentina.

Second, the cheaper, acutely toxic pesticides are also typically *broad spectrum*, working against a wide variety of pests, and often are still effective against difficult pests such as whitefly. Finally, government sponsored give-away programs may promote them because they are cheap and broad-spectrum and therefore can be massively distributed for a variety of crops.

Small-holders seeking inexpensive pest management tools are also vulnerable to the illegal sale of repackaged prohibited and out-of-date compounds (Figure 1). Such presentations are particularly dangerous when the person who applies them is un-

Table 2. Recent documentation of the pesticides most commonly used among small holders in Central America.

Author	*Year*	*Country*	*Crop*	*Pesticides most used*
Trabanino, et al.	1997	Honduras	beans	methamidophos methyl parathion
Cuellar	1997a	El Salvador	maize beans tomato peppers	carbosulfan phoxim methamidophos methyl parathion
Hruska, et al.	1995	Nicaragua	maize beans	methamidophos chlorpyriphos

Figure 1. The prohibited organochlorine, heptachlor, is still sold illegally in repackaged form for leaf-cutter ant control (Nicaragua).

aware of what they contain and at what concentration.

Small holders rarely use protective equipment and clothing while applying pesticides

The vast majority of small holder farmers don't use equipment and clothing for personal protection when they apply pesticides, even after they have been trained to use them (Figure 2). Agrochemical companies, together with various donors, have financed educational campaigns promoting the «safe use of synthetic pesticides,» including instruction on the use of more comfortable personal protection equipment that producers can make themselves. Tens of thousands of farmers in Central America alone have received «safe use» training yet Araya et al (1999) in Costa Rica, Cuellar (1997b) in El Salvador, and Bustamante and Rodríguez (1996) in Nicaragua report no significant change in farmer behavior. (Figure 3)

Without training, small-holders rarely understand the environmental fate of the pesticides that they use

Pesticides are invisible in the environment; once applied they are forgotten. The *persistence* of pesticides in the environment, the damage that they do to water resources and their effect on wildlife, beneficial insects and other organisms and livestock almost never influence how small holders use pesticides, where they store them and how they wash application equipment (Figure 4). It is also rarely understood how pesticides move in the environment and especially how they migrate to subterranean or superficial bodies of water.

Figure 2. Pesticide application without personal protection in a tomato crop.

Figure 3. Training session on «safe use of pesticides».

Figure 4. Washing spraying equipment and deliberate dumping of pesticides in rivers and streams result in fish kills.

Small holders use some pesticides, especially for plant pathogen control, irrationally

Small holders recognize much of the behavior of certain pest organisms, but those that they can't see because they are too small or in cryptic habitats remain mysterious. Insect life cycles and especially plant pathogen life cycles, are generally unknown. From the confusion, results the inappropriate or irrational use of pesticides, for example fungicides used by 30% of bean farmers in Honduras to combat golden mosaic virus (Trabanino et. al, 1997) or insecticides used when insect pest individuals have developed past a susceptible life stage.

Adoption of alternative preventive and curative tactics for pest management is irregular and difficult to find on a massive scale, especially in negative policy frameworks

There seems to be no formula for insuring that new, non-chemical methods of managing a pest will be accepted and adopted by large numbers of small holder farmers. Some exceptional farmers will try just about anything and enjoy innovating and demonstrating change on their holdings. No real impact can be made, however without changing the pest management practices of the vast majority.

Sometimes mass adoption of non-chemical methods does occur, even when no great effort in the field has been made to change preferences. We might find welcome instances on a massive scale when:

- the pest has become resistant to and un-controllable with synthetic pesticides
- the small-holders benefit from economic incentives to avoid synthetic pesticides, e.g. in certified organic production
- a cultural consensus against synthetic pesticides has been built in the community
- national policies support shifts to non-chemical methods

Where preferences among small-holders for non-chemical pest control *have* been changed on a large scale in the face of «attractive» pesticide options, the extension efforts involved most often share characteristics such as

- offering a better (cheaper, more effective) alternative to the pesticide
- assuring continuity and follow-up
- teaching about the negative impacts of the pesticides
- involving farmers in generating the new technology
- involving farmers in training other farmers
- teaching the new techniques via hands-on learning

Chapter 2
Goals of a Safe and Effective Pest Management Program

2.1 Develop a goal-explicit framework

A GOAL-EXPLICIT FRAMEWORK, or paradigm, for pest management interventions will help a program move beyond compliance with Regulation 216 to more profoundly resolve pesticide generated problems. The answers to a series of questions about pest management objectives posed to all stakeholders can help build that framework:

- *What are the objectives of our farmer partners?*
- *What are the objectives of other members of society, especially consumers of food and water?*
- *What are our institutional objectives?*
- *What are the objectives and requirements of our donors?*
- *Can all of these objectives coincide with those of our farmer partners ?*

The final set of objectives we agree upon may well extend beyond the perceived needs and expectations of the small holder farmer. It will include the goals of society as a whole, as well as those of direct stakeholders in pest management.

A framework of goals could include:

- minimizing losses to pests at low cost
- protecting the health of the producer and consumer
- promoting self-sufficiency, minimizing the purchase of inputs and products, especially imported ones

- promoting self-sufficiency by developing small-holder capacity to develop and produce alternatives to synthetic pesticides
- stabilizing pest impact, preventing uncontrollable problems in the future
- minimizing environmental damage

2.2 Alternative paradigms

The small holder farmer might illustrate the goals of his or her paradigm by calling it «*Effective, Quick, and Cheap Pest Management*».

Effective, quick and cheap: farmers tell us over and over again that this is what they want when they choose to use synthetic pesticides. However, in the long term, even a synthetic pesticide based paradigm doesn't always satisfy the interests of the small holder; pesticides lose effectiveness and become expensive on the ***«pesticide treadmill»*** when resistance develops, higher and higher doses are needed, and new pests emerge from the background species mix.

Any alternative paradigm that will be adopted on a wide scale must be congruent with that of the farmer. We cannot reasonably expect the farmer to voluntarily use more expensive, less effective, or more time-consuming solutions to pest problems in the interest only of other stakeholders. An alternative solution to a pest problem must be effective, cheap and not too time-consuming. An alternative must *improve* pest management from this perspective at the same time that it achieves the goals of society.

Integrated Pest Management (IPM), is the most commonly used alternative to a synthetic pesticide based paradigm. Recent permutations, also method-explicit, are «*Ecological Pest Management* « and «*Integrated Crop Management*».

IPM is a paradigm dating from mid 20th century, and its proponents have included actors with widely diverging goals. The word «*integrated*» gives a clue as to the methods one would use, but doesn't tell us what the goals of the paradigm are. It merely implies using several components of pest management instead of only one.

Because goals are not explicit in the IPM paradigm, different IPM «promoters» may have somewhat differing goals and still all call their programs «IPM». In developing countries, some IPM promoters consider a farmer's self-sufficiency, including liberation from the need to buy inputs, to be a primary objective. Promoters from this school of thought will differ at times with others who consider that simply substituting a safe commercial biological product for a dangerous synthetic product, is a positive change. Pesticide companies also promote IPM; their objectives are to sustain the use of their products through better pesticide management, not to diminish pesticide sales.

IPM as a pest management paradigm is so widely used throughout the Americas and the rest of the world, that it would be a mistake to deny its usefulness. It benefits from «name recognition», even if confusion has also marked its implementation. Whatever a program chooses to call its alternative pest management paradigm, the goals behind it should be understood so as to give direction to the search for solutions, even if those goals are not explicit in the name.

Chapter 3
Management Strategies: Preliminary Decisions

3.1 Developing Basic Understanding of the Pest Problem

BETTER UNDERSTANDING OF PEST BIOLOGY and ecology always leads to more effective pest management and frequently to reduced use of pesticides. Small holder farmers may overuse or misuse pesticides because they don't know what the pest is, how it does its damage, or how its populations grow and decline. They may suffer unnecessary losses for the same reasons.

As a first step in rationalizing and reducing pesticide use and in making pest management more effective, an agricultural support program cannot miss by facilitating farmer acquisition of basic knowledge.

How do you define a «pest»?

The term **«pest»** can be defined in broad or narrow terms. The extension agent and the researcher use the broadest definition of the word to include any noxious organism that affects crop yield. A pest can be an insect, mite, mollusk, rodent, bird, mammal, weedy or parasitic plant, plant pathogen or nematode.

In many countries, farmers use the word «pest» in reference only to insects, the group of pests most easily seen. Pathogens causing plant disease are often not included in the definition of a pest and weeds are often called «brush» o r «bad plants», not pests. Working with small holders requires understanding how they are using the word «pest» and what diverse labels they use for the other pest organisms in the productive environment.

Figure 5. A new pest, coconut lethal yellowing, has devastated coconut trees in the Caribbean and Central America from Mexico to Honduras in the past several decades.

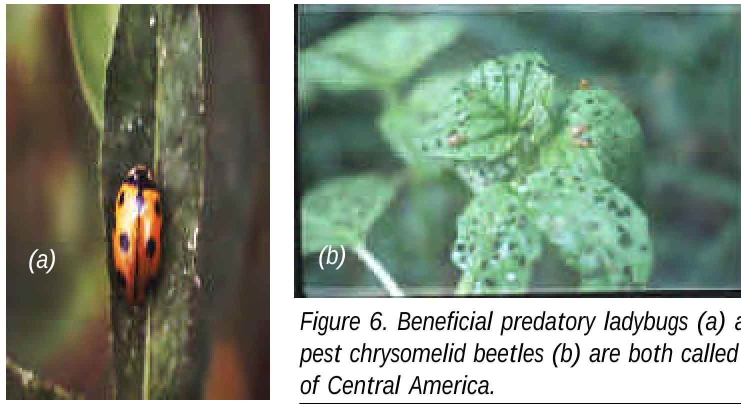


Figure 6. Beneficial predatory ladybugs (a) and herbivorous pest chrysomelid beetles (b) are both called «maya» in parts of Central America.

Figure 7. Nutsedge, Cyperus rotundus*, is a worldwide weed pest whose commonly used name varies from «coyolillo» to «pimientilla», with many variations in between.*

Figure 8. «Maize bushy stunt» (a) is caused by a complex of pathogens vectored by the leafhopper, Dalbulus maidis *(b).*

What is the pest?

Correct identification of the pest is fundamental for good management. The majority of insect, vertebrate and weed pests are known by small holders but are called by different names in different places. Very occasionally, a new pest appears in the community and must be given a new name (Figure 5).

Aside from being variable, common names can also be too general to be useful. Species and even families are grouped under the same name, even if they are differentiated visually. In the most confusing cases, the same general name may be used for a beneficial species and a noxious species (Figure 6).

Weed names tend to be species-specific, but vary from place to place (Figure 7).

The biggest problem in the identification of pests occurs in those groups that are microscopic, or almost so: the plant pathogens, nematodes and mites. These organisms cannot be seen and their presence must be presumed according to the symptoms the plant expresses in response to them. Unfortunately more than one pathogen may cause the expression of similar disease symptoms (Figure 8). The presence of a plant pathogen is missed entirely if farmers attribute the symptoms of disease to adverse weather. The farmer must know at least what group of pathogens is causing the disease, or he/she can easily use the wrong synthetic pesticide.

Case Example 1. Workshops help farmers identify plant diseases.

Plant diseases are often poorly understood by small holder farmers. Identification of the disease by its symptoms and subsequent classification by causal agent is essential to choosing a useful management strategy.

Workshops were developed in Honduras in the 1990's to help farmers expand their ability to recognize and correctly identify diseases and pathogens of important crops. The workshops have since been modified for local needs and offered to thousands of farmers throughout Central and South America. Farmers draw the disease symptoms, discuss with the facilitator the basic classification of causal agent as fungus, bacteria or virus, and learn about transmission, dissemination and environmental factors that favor disease proliferation.

In order to be able to share information outside the community, it is important that the extension agent at the very least, if not the farmer as well, know the pest's given scientific name. Cultivating a more precise classification and nomenclature system in the community should be an important goal.

What kind of damage does the pest cause?

In order to efficiently confront a pest, the farmer needs to recognize the type of damage that it causes. Type of damage limits the farmer's effective management options. Certain kinds of damage must be contained quickly; other types are more tolerable and can be managed with slower-acting methods. Most plant diseases are incurable and can only be managed with preventive measures.

Key pests within a complex of various pests affecting a single crop or system are those that cause the most economic damage. The key pest or pests should define the focal point of a management strategy. ***Secondary pests*** are those that cause economically minor damage, relative to the key pest. Their management is often achieved with the strategy applied to the key pest (Figure 9).

Figure 9. Key pest of small holder cotton in Paraguay is the boll weevil, Anthonomis grandis. *Cotton leafworm,* Alabama argillacea*, and cotton aphid,* Aphis gossypii, *are secondary pests.*

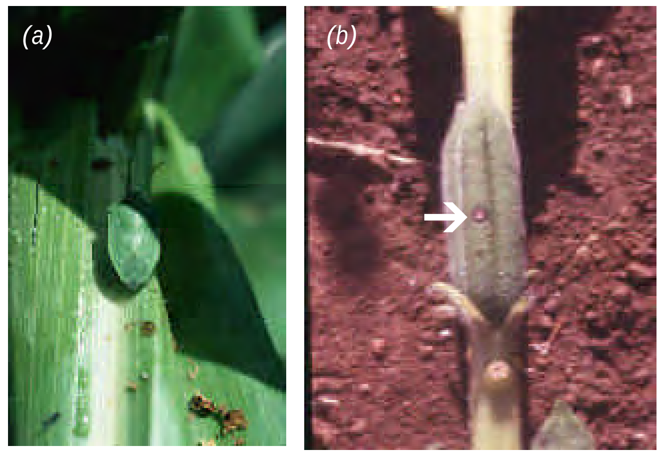


Figure 10. Green stinkbug, Nezara viridula*, (a) causes direct damage (spotting) to sesame seeds when it perforates the capsule with its mouthparts (b).*

Figure 11. Cassava hornworm, Erinnyis ello*, causes indirect damage to cassava when it defoliates the plant.*

Pests cause damage of several types to crops, stored foods and forestry species. Some damage is difficult to detect and distinguish, for example, low yields in crops resulting from 1) pests that attack the roots, 2) diseases without obvious symptoms or 3) the competitive activity of weeds.

Direct damage**,** (Figure 10) discoloration or other cosmetic damage, perforations, or rotting in the product that we directly consume, is easiest for the farmer to detect. In many cases, he or she also correctly recognizes ***indirect damage*** (Figure 11) caused either by pests that feed on or infect the foliage that is the sustenance of the plant or by pests feeding on or infecting the root. Uncontrolled indirect damage can have important effects on yield. Some types of indirect damage can be managed with slower-acting tactics but others, such as viral infections, cannot (Figure 12).

When only the damage is observed, farmers sometimes mistakenly relate the presence of a visible and especially abundant organism with damage that another organism causes (Figure 13). Symptoms of nutritional deficiencies are easily confused with damage caused by plant pathogens (Figure 14).

The most difficult damage to understand and manage is that caused by plant viruses and ***phytoplasmas***, microscopic pathogens that enter the plant via the mouthparts of insect vectors (Figure 15). The symptoms of disease caused by viruses and phytoplasmas are fairly easily recognized, but management must be directed at the insect, which is often small and not very abundant in the environment. Rural families confront malaria, a disease caused by a microorganism transmitted to people by *Anopheles* mosquitos. In the case of malaria, there are curative measures that can be taken by infected people, but this is unknown for plant viruses and phytoplasmas. Management must be preventive and directed at the insect vector. It cannot be slow-acting because the speed of transmission in almost all cases is a question of seconds or minutes and insect vectors may feed on many plants in a short space of time.

Figure 12. Virus in peppers is a form of indirect damage, in that the virus's insect vector affects the leaf. It is transmitted so quickly and with such devastating effects that the vector must be managed with fast-acting tactics or the pathogen with genetic resistance.

Figure 13. Predatory earwigs, Doru taeniatum*, are blamed for damage in rice that is most likely caused by less conspicuous, nocturnal herbivores.*

Damage may be classified further as ***primary*** or ***secondary***, the latter occurring after and because of the activity of a primary pest. For example, some plant pathogens and ***saprophytes*** are able to penetrate plant tissues only after damage by insects (Figure 16). The secondary damage may affect yields more than primary damage, but a management strategy should be directed to the organism responsible for the primary damage.

What is the pest's life history?

If a farmer understands the life history of the pest, principally where in the environment it can be found during each of its life stages and how it moves between microenvironments such as the soil, weedy borders and the crop, he or she will have more options for successful management.

Figure 14. Anthracnose disease in coffee (shown here) is sometimes confused with symptoms of potassium deficiency.

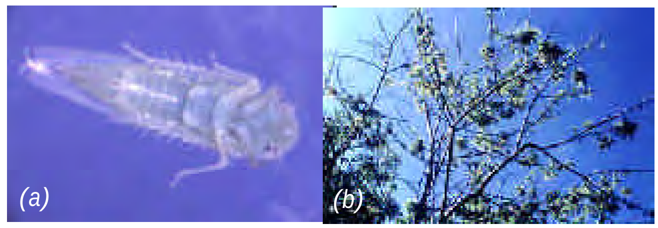


Figure 15. A phytoplasma transmitted by leafhopper vectors (a) causes Gliricidia little-leaf disease, whose symptoms are yellowing, brushy growth, dieback and eventual death (b).

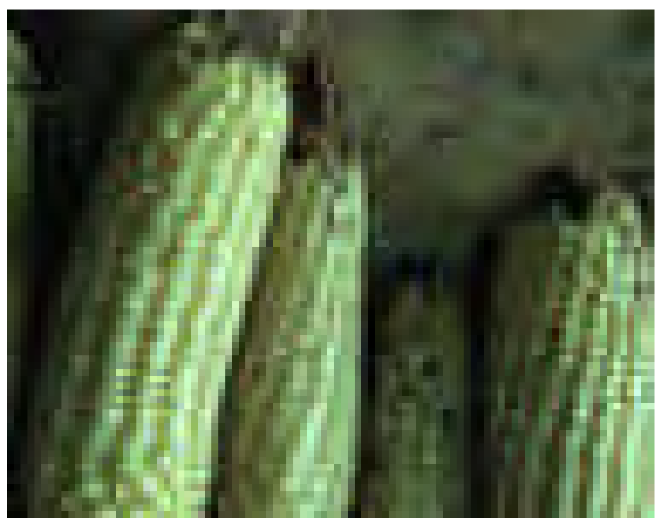


Figure 16. Primary damage caused by corn earworm, Helicoverpa zea*, and secondary damage caused by saprophytic fungi.*

Farmers may comment on the spontaneous production of insect pests from mud and water. The habitat from which insects emerge has been identified but it is also important to know that any pest

Case Example 2.
Learning about leaf-cutter ant life history by excavating nests.

Leaf-cutter ants in the genus *Atta,* occur from Mexico to Brazil, and are considered one of the most devastating pests in the Americas. Worker ants strip the leaves off of a wide variety of crops and can defoliate even large trees in a single night.

Complete elimination of an *Atta* colony is considered very difficult for several reasons:

1) a single, long-lived queen who is found very deep in the soil is responsible for all of the colony's reproduction

2) the colony, composed of thousands of workers constructs a very deep and complex subterranean nest which is difficult to penetrate with conventional pesticide application equipment.

Farmers often try irrational control measures with leaf-cutter ants because they do not know these facets of their biology. Training workshops in which farmers excavate nests to learn about the colony's caste system and behavior of different castes, the queen, and physical characteristics of the nest, were developed in Honduras in 1997 and have been replicated in the intervening years with farmers throughout Central America. The workshops require nothing more than shovels and picks and a sprayer filled with soapy water to ward off the angry ants. Farmers see first hand that unless they can eliminate the queen, they will face constant battle with the colony. They also learn which application techniques will at least partially penetrate the nest toward the queen's chamber and which won't, and the extent of the nest that must be intervened. Most importantly, they gain a respect for the colony that inspires them to use other techniques entirely, such as physical barriers on fruit trees, that are not based on eliminating the colony.

has a ***life cycle*** and that all pest individuals come from the same species in a previous generation. It is essential to be able to recognize all life stages, and know that they form a life sequence, with a certain amount of time spent in each stage.

Few pest organisms complete their life cycles in a single microenvironment. They may, for example, survive inhospitable times in the soil, develop and reproduce in parts of plants, and disseminate through the air. The successful management of difficult pests such as those causing damage in cryptic environments like the soil may depend upon management of a more susceptible life stage, even if it is not the one responsible for the damage observed (Figure 17).

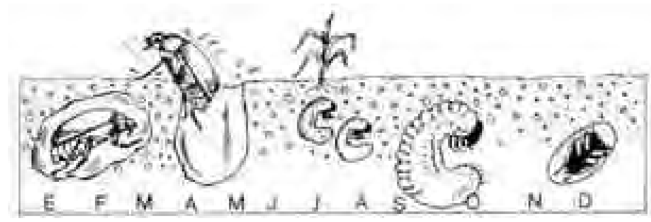


*Figure 17. More control tactics for white grubs (*Phyllophaga *spp) have been based upon adult behavior than have been developed for soil-dwelling larvae. (Source: Zamorano).*

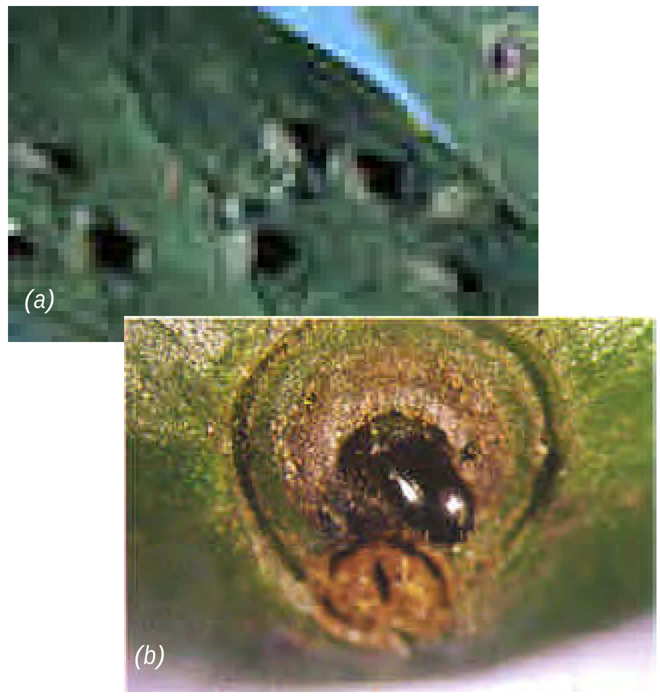


Figure 18. Generalist pest (a), aphids, Aphis gossypii*, and specialist pest (b),coffee berry borer,* Hypothenemus hampei.

Figure 19. Whitefly, Bemisia tabaci*, has a broad host range including many weed species, where its populations may be controlled as well as in the crop.*

Few pests are associated with all of the plant species in a given environment. Each pest species is limited to a ***host range,*** or restricted number of host species, a relationship that it has evolved over time in avoidance of its natural enemies and of competition with other similar species, or because of close co-evolution with its source of food. The host range of any given pest species may be narrow or wide. In tropical regions, many host ranges for important pests are still incompletely known, but may be predicted by examining the life histories of related species.

Depending upon a pest's host specificity, it can be placed in a continuum ranging from ***specialist (monophagous***) pests to ***generalist*** (***polyphagous***) pests (Figure 18). For the same reason that it is important to understand how different pest life stages make use of different microenvironments, successful pest management may depend upon manipulating the pest when it makes use of other species in its host range, even if those species are not economically important (Figure 19). On the other hand, if we know that a pest is a strict specialist, management activities can be focused exclusively on the single host species (see Case Example 7).

Without exception, all pests are eaten, competed with, or parasitized by something else. The role that

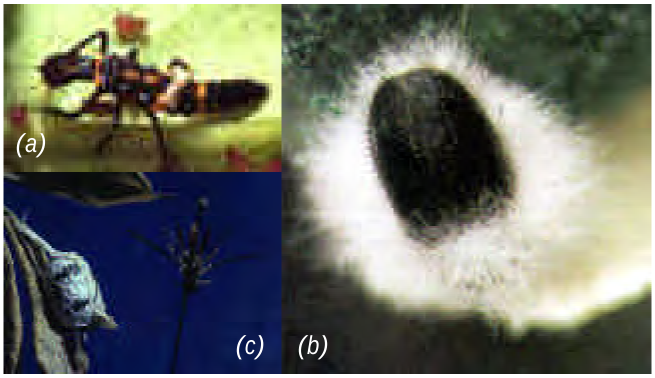


Figure 20. Types of insect natural enemies: predator (a), insect pathogenic fungus (b), parasitoid wasp (c).

Figure 21. Leaf miners, Liriomyza *spp, are known to be induced pests on melon crops that are excessively sprayed with pesticides.*

Figure 22. In maize, fall armyworm, Spodoptera frugiperda *is a chronic pest (a) and* Mocis latipes *is a sporadic pest (b).*

a pest's ***natural enemies*** (Figure 20) play is the foundation for a management strategy that complements this «free» component, however large or small, of ***natural control*** and above all doesn't weaken it.

Some pests, especially some insects and mites, should not *be* pests if the productive environment is managed well. A pest that under better management conditions should not be a pest is called an ***induced pest***, induced usually by an excessive or misdirected use of synthetic pesticides that has eliminated the natural enemy complex (Figure 21).

Environmental factors, especially heavy rains and the sun´s radiation, are ***natural abiotic mortality factors*** for pests. They can be understood and used to some extent by the small holder, but it should be recognized that they are also unpredictable.

Pests move by themselves and travel on farm equipment and machinery, on hands and feet, seed, wind, and rain. By understanding how a pest arrives at its host, and where it resides when it is not in or on the host, the small holder opens the door for many elements of preventive management. Pests that always or almost always find and affect the host are ***chronic pests***. Those that attack in a more irregular fashion are ***sporadic pests*** and those that invade in massive numbers with usually very destructive results are ***invasive pests***. ***Migratory pests*** travel over long distances to establish themselves in the host crop, as in the case of migratory locusts (Figure 22). The pest's movement behavior and its routes for invasion into the host will determine in part how difficult it is to control.

If we can find the fundamental cause of a pest problem, we can solve the problem in a more sustainable way, instead of investing time and money continuously in management. Recovering collective memories of small holders of a pest´s status can help identify changes in the general environment, cropping systems, varieties, or pesticide use that may have provoked an increase in the pest population or its propensity to damage crops. If those remembered changes can be reversed, the pest problem may be efficiently and permanently solved.

Case Example 3. Recovering local knowledge: interviewers uncover possible management strategies for little-leaf disease of *Gliricidia sepium.*

Madero negro, *Gliricidia sepium*, is a valuable, multi-use tree native in semi-arid zones from Mexico to Colombia. Because of its easy propagation by cuttings, rapid growth and uses as firewood, live fencing, fodder, coffee and cacao shade, it has been introduced to Africa and Asia.

Trees with unusual symptoms of disease were reported for the first time by researchers in 1992. A phytoplasma vectored by leaf-feeding insects, was subsequently described as the causal agent and the complex of symptoms was denoted as Gliricidia little-leaf disease.

Since the tree is so important to the people, especially indigenous peoples, living in the lower elevation, hotter parts of the Isthmus, perceptions of the disease could be tapped through interviews in communities where the disease was especially severe. People reported to interviewers that mainly large trees were dying, and that affected trees took a long time to succumb. Pruning branches appeared to them to prolong the life of the tree. Insights contributed by the people allowed researchers to focus on possible management strategies, and to work toward uncovering changes in previous decades that may have led to the increase in disease incidence. (C. Mackenzie, 1995. «El Palo Mas Util Aqui»: local perceptions of the uses and diseases of *Gliricidia sepium.* Natural Resources Institute, Chataham, UK.

How big is the pest population?

The essential purpose of estimating the density of a pest population is to differentiate between an economically damaging and an economically non-damaging population. There is no crop that is completely pest free. However, there must be enough pest individuals present to warrant taking action against them. Any control measures, however simple, will incur costs in money and time.

In some fashion, either quite systematically or more loosely after accrued experience, a farmer needs to continuously estimate how much pest there is in the crop through a process of observation or ***sampling*** (Figure 23). His or her system could consist of a prescribed process of counting pest individuals, or noting evidence of the damage they cause, calculating a percentage or total number on paper and comparing the estimate of pest density to an ***economic injury level*** (EIL), or damaging pest population size. The EIL will have been previously determined by researchers in studies relating yield loss to pest population size. If the pest population is above the EIL, economic loss will exceed the costs of control and the farmer should intervene; otherwise he or she waits.

The size of a pest population can also be calculated and compared with the EIL, but then the producer may modify his or her decision about intervention according to patterns observed in other biotic or abiotic factors. If the crop is suffering through a drought, he/she may decide to intervene when a smaller population is detected. If the pest is about to change life stage and leave the crop alone or has metamorphosed beyond its damaging life history phase, he/she may not need to intervene even if the population size is large. If it is going to rain the day that the sample is taken, a large population may be tolerated if rain partly controls that particular pest. Evidence for a building population of natural enemies needs to be taken into account. The best decisions, incorporating these kinds of observations together with a good estimate of population size, are only possible if the farmer has a good basic understanding of the pest's biology and interactions with its environment, including its plant host.

Once the farmer has accumulated experience with a pest species and its host, sometimes he or she will quit systematically quantifying and noting down information about the pest population. He or she develops a «***clinical eye***», an ability to quickly and representatively estimate pest population size by eyeballing the crop (Figure 24). Considering as well the state of the crop or plantation, he or she decides whether or not to intervene. Although a clinical eye is frequently used at the end of a learning process, during the earlier stages of using a more systematic sampling method, the farmer has learned certain important concepts:

- for a given pest species, there are harmful populations and there are populations that are too small to be economically harmful

Figure 23. Sampling pest populations.

Figure 24. Most farmers use a clinical eye, rather than quantitative measurements, to decide when to weed.

- an estimate of pest population size has to be made in several parts of the productive area so that it is truly representative ***(random sample).***
- the plant's response to the pest depends upon more than simply the number of pests that are attacking it.
- samples must be taken over time at appropriate intervals in order to detect changes, which in some environments can be sudden

Interventions, both chemical and non-chemical, are rationalized by simply evaluating the population of the pest. Monitoring pest population density is essential to any program of safe and sustainable pest management.

Figure 25. The critical period in tomato for virus damage is the pre-flowering stage.

In order to rationalize pest management, the producer also must understand that a pest is not equally harmful during all stages of plant growth. There are sensitive periods or ***critical periods*** to the damage and very resistant periods when the same pest population will not cause a yield decline (Figure 25). It is important to recognize the plant's response in order to orient interventions appropriately and to avoid costly non-necessary interventions.

When we talk about sampling the pest population, what precisely are we sampling or observing? We need to know what life stage of the pest is vulnerable to the management tactics available. This life stage will define the ***sampling unit***. Many products based on living organisms (biological and microbial products) work only during certain «windows» in the pest life cycle. Sometimes they work only in certain microsites in the productive environment. The adult coffee berry borer, for example, is only susceptible to insect pathogens while it rests superficially for a week or two in the pulp surrounding the bean (Figure 26). Population samples, besides quantifying the population and designating it as harmful or non-harmful, serve to pin-point the most opportune moment, or *timing* for intervention.

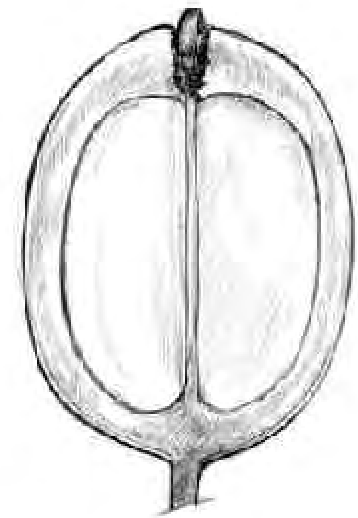


Figure 26. Coffee berry borer, Hypothenemus hampei *resting in the outer layer of coffee berry pulp as it waits for the bean to achieve proper consistency.*

3.2 Defining the Management Arena

In what arena must the farmer operate in order to manage a pest effectively and with a minimum of synthetic pesticides?

A pest is member of a natural ecosystem in historic and current times that, for one reason or another, also occurs in systems managed by man and causes damage in them. If we examine the natural, un-perturbed system where the pest has evolved, we will probably find that the negative impact it has on its plant hosts is slight. In natural systems, ***limiting factors*** exist that reign in the limitless growth of «pest» populations (Figure 27).

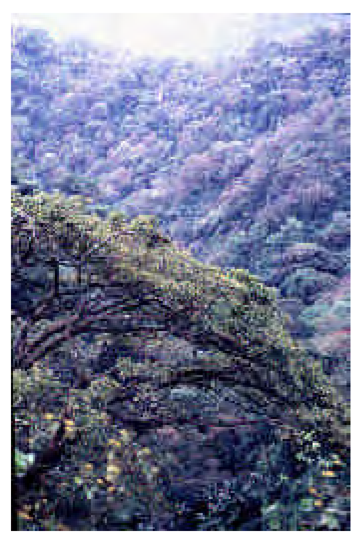


Figure 27. Undisturbed tropical forests rarely suffer excessively large populations of native insects or outbreaks of disease.

Case Example 4.
Sampling a pest population: reduces insecticide applications: The case of *Spodoptera frugiperda* in maize.

CARE Nicaragua began an IPM project among resource poor farmers in western Nicaragua in the late 1980s. During this time, the Nicaraguan government was heavily subsidizing pesticides, in the hope of increasing maize production. As a consequence of this policy, insecticide use was very high.Baseline studies showed that farmers were applying six times per crop cycle on average, whereas one to two were probably needed.

The project taught farmers about the idea of basing applications on density of the key pest, fall armyworm, *(Spodoptera frugiperda),* plant critical period, and expected yield loss. A simple decision rule of waiting to apply insecticide until 40% of the maize plants were infested (EIL), and only during the late whorl stage, was emphasized. Field extension agents worked with farmers to experiment with the threshold level. Training focused on how to sample, calculate the percentage, and make a reasoned decision. The decision making process was enriched by discussions of how such factors as rainfall, crop condition and stage could influence the effect of the pest. Training about the health risks of pesticides also influenced farmers' decisions in the face of extremely cheap pesticides.

Within two years, over 50% of all the applications in maize by small holder farmers in the project area were made based on sampling. Dramatic reductions were documented in the use of pesticides and pesticide intoxications in the area (Hruska & Corriols, 2002). Some of the reductions were due to increases in the prices of pesticides, as a result of changed government policy, but some of the reduction was directly attributable to the training.

The training appears to have had a lasting effect. An ex-post evaluation of the project by Pareja et al. (1995) showed that between 50 and 90% of the farmers were still using sampling as a basis for pest management decision-making five years after the training ended. Most interesting was the finding that farmers were applying skills in sampling to other crops, especially rice.

Why does the impact change so between natural systems and systems managed by the man? In other words, why does a «pest» become a pest?

Some fundamental explanations for the conversion of innocuous organisms to pests are:

- the pest organism has been accidentally imported from its area of origin and lacks natural controls by higher trophic-level organisms in the new geographic area (Figure 28).
- the pest organism lacks higher trophic level controls, such as predators, because they have been eliminated by pesticides or other practices within or outside of the crop (Figure 29).
- the pest colonizes and reproduces more quickly in the agricultural system and outstrips the capability of its natural controlling organisms because:
  - it finds its plant or animal host more easily (Figure 30).
  - the plant host lacks defenses that inhibit pest reproduction and development.
- natural breaks have been eliminated in host availability because of planting patterns that allow the host to be present year-round (Figure 31).

In an ideal world, we try to attack a problem at its root. In some cases, we know with certainty the fundamental cause of a pest problem and we can correct it. In other cases, we have «an idea» of the probable cause, and we can, within practical limits, try to correct it. But in the majority of cases, the root of a pest problem does not lie within the hands of a single farmer. It is the product of a profound, complex, and widespread alteration of the ecosystem in which the pest organism has evolved.

It is almost impossible to return to a system «natural» enough that the pest problem disappears. Still, if we understand the fundamental cause of a pest

Figure 28. Citrus leafminer, Phyllocnistis citri*, is an exotic pest native to the Old World that was introduced accidentally to Central America in the 1980's.*

Figure 29. (See Figure 21)

Figure 30. Squash grown at low density among natural vegetation (a) resists colonization by specialist pest, squash vine borer, Mellitia satyrniformis *(b).*

(a)

(b)

Figure 31. Maize irrigated during the dry season (a) provided year-round habitat for corn leafhopper, which increased in numbers and affected small holder maize grown in the rainy season (b)(Nicaragua).

Figure 32. The Dominican Republic used crop-free mandated periods (bans) in the 1990's to reduce whitefly populations affecting crops in the family Solanaceae (peppers, tomatoes and eggplant).

problem, we can orient our interventions in order to have better results. Where do we focus? How do we proceed?

Do we focus our interventions solely on the pest organism? This narrow focus can be sufficient when the pest is imported or induced. Reestablishing altered ***trophic relationships*** at a local level can reduce an essentially non-mobile pest population to non-damaging levels for an individual farmer. If the pest is exotic, the farmer will have to wait for a research program to bring in natural enemies; this strategy is well beyond individual capability.

When does the farmer need to focus on a broader arena? The approach known as ***Integrated Crop Management,*** focusing beyond the pest to the whole crop environment, is useful when the pest problem results from farming systems differences with the natural, native environment.

With mobile pests or pests that attack many types of hosts, a single crop is still too small an arena. Farmers confronting these types of pests, and most fall in this category, will be limited to constant curative interventions if the management program does not modify more profoundly the farm or even regional landscape.

Area-wide management programs, including pest eradication attempts, *crop-free mandated periods*, (Figure 32) and control of migratory species are implemented in situations requiring the broadest operational arena. They involve cooperation between producers at the community level, district level and beyond.

Chapter 4
Preventive Management

PESTS ARE MUCH EASIER TO MANAGE in some agricultural environments than in others. A small holder's farm landscape and its components, including the crop plant itself, can be designed or modified over time to prevent a considerable number of potential pest problems from ever becoming a reality.

Preventive management builds upon the biological and ecological knowledge base described in Chapter 3 and encompasses three main areas of work:

- assuring a healthy crop and an adverse pest environment (cultural management)
- using genetically-based plant defenses to reduce susceptibility (genetic resistance)
- protecting and nurturing the natural enemies of pests

4.1 Cultural management

Cultural pest management is any manipulation of the productive environment carried out to make it less favorable for pests. It includes practices such as modifying planting density, changing a plowing strategy, pruning for better aeration, irrigation, and deliberately using other plants and materials in the productive environment in strategic ways. Cultural tactics in pest management prevent the increase of pest populations that already occur in the small-holder's productive environment as well as prevent the arrival of pests from outside the area.

Some cultural tactics function to prevent pest problems in the short term (for the protection of crops already planted) and others will only result in a gradual reduction and stabilization of pest populations into the near future. Cultural man-

Figure 33. Well-drained elevated seedbeds have fewer disease problems.

agement with long-term effects requires time and money; logically the investment will be far more attractive for farmers who own the land they plant or who are able to assume that they can continuously rent the same area into the future. It is less attractive to, and unlikely to be adopted by, farmers who use the land through occupancy, common property, or rent in a spontaneous and unstable fashion.

Successful use of cultural tactics relies upon a solid understanding of pest biology, life cycles and movements, host selection and susceptibility to mortality factors. Our overall purpose with cultural management is to make the environment as hostile to pest populations as possible, achieving at the same time an optimal productive environment for the crop and optimal marketing strategy. We attempt with cultural pest management to:

- destroy reservoirs of colonizing populations before and after planting
- interrupt movements of the pest
- invigorate the plant so that it can resist pest attack
- avoid planting dates that are favorable for the pest
- conserve living natural enemies and utilize abiotic mortality factors

Improve soil health

Soil-dwelling pests, (weeds, nematodes, insects, bacteria and fungi) are among the most difficult organisms to control because they, or their propagation units such as seeds and spores, live hidden within an almost impenetrable medium, the soil. Cultural methods are often the only viable pest management tools for this diverse group of pests.

Adequate soil drainage prevents the reproduction of fungi and bacteria as do elevated planting beds (Figure 33). Certain inputs, like lime, decrease soil acidity thereby diminishing the propagation of soil fungi. Coffee pulp incorporated into nursery soil helps to control root-knot nematodes.

Mulch and leaf litter improve the structure and water infiltration rate for the soil at the same time they control weeds and provide slowly - released nutrients. Organic matter incorporated into the soil generally increases the diversity of organisms that compete with or kill plant pathogens and can result in an ***antagonistic soil***.

Select low - pest planting dates

Although planting date is dictated more by crop physiology, weather patterns especially rains, and price fluctuations in the market, within these constraints it may be possible to avoid periods during which pest damage is most severe. Some crops are impossible to grow in the most economically favorable seasons because of unacceptable losses. If the small holder can invest resources, this situation may be turned into a profitable marketing opportunity, as long as the pest can be controlled without undo risk, albeit with more expensive techniques such as absolute enclosure barriers (Figure 34).

Figure 34. Mosquito netting prevents the access of whitefly, Bemisia tabaci*, to tomato transplants during the critical period (pre-flowering).*

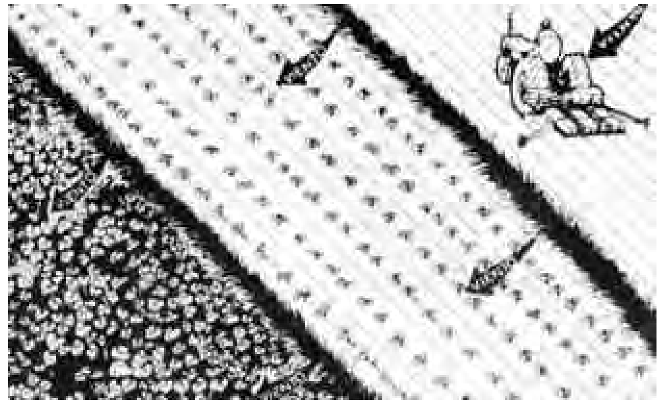


Figure 35. If crops must be planted late, they should be located upwind from earlier crops (source: Zamorano).

Figure 36. Plantain cuttings that show signs of insect and pathogen damage can be disinfected in hot water for 15 minutes before planting (source: Zamorano)

Figure 37. Seed can be harvested from healthy, high yielding pepper plants.

Synchronizing planting with neighbors is usually better than planting late. Pest populations tend to build in a community during a cropping season and, if they are at all mobile, will move in vast numbers onto late-planted fields (Figure 35).

Use pathogen-free seed and vegetative material

The transmission of some plant diseases occurs via seed or vegetative material used for propagation. Disease-free certified seed is more expensive, but for some crops is a necessary guarantee against complete crop failure.

Some seeds and vegetative material produced on farm can be treated with synthetic or organic products before they are planted out to large areas where diseases will be much more costly and difficult to control (Figure 36). Farmers should also learn to recognize diseased parent plants and avoid them as a source of seed (Figure 37).

Adjust planting density

Depending upon the cost of seed, certain crops can be planted densely, allowing pest insects to take their share and increasing crop ability to compete with weeds.

Correct planting density allows for better aeration and ambient humidity reduction, helpful in reducing losses to fungal and bacterial diseases.

*Figure 38. Pruned and fertilized coffee bushes resist anthracnose disease (*Colletotrichum *sp) and perhaps leaf-cutter ants.*

Figure 40. Flooding in rice field suppresses weeds and soil-dwelling insects.

Fertilize and water adequately

Plant vigor depends upon the nutrients and water that are available at critical moments during development. The effect of pests is buffered and sometimes compensated for by vigorous growth (Figure 38). However, unbalanced or excessive nutrition for crops, especially an excess of nitrogen and calcium, can make them more susceptible to insect attack. Weeds respond to the same nutrients as plants; over-fertilizing can lead to increased competition with weeds for light (Figure 39).

A good use of water can manage pests. Overhead aspersion kills mites and small insects. Flooding, as in rice production (Figure 40), helps eliminate weeds and soil-dwelling insects. The quantity and timing of irrigation should be well controlled, avoiding saturated soils where soil dwelling pathogenic fungi can germinate and multiply.

Figure 39. Vines in coffee grow more quickly after fertilization and must be eliminated.

Manage other plant species in the productive environment

Non-commercial plants such as weeds

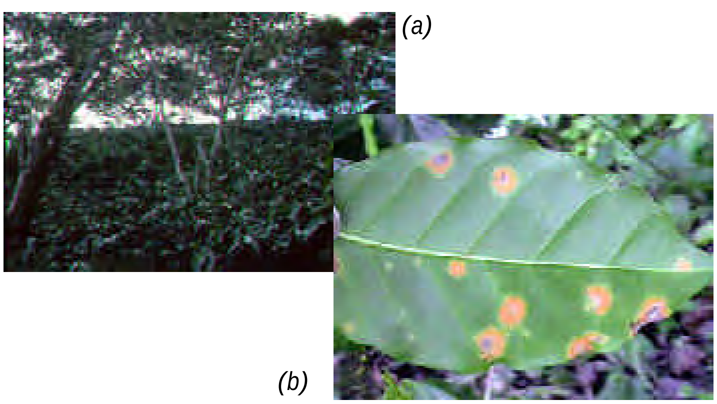
Pests living on weed hosts in fallow areas and on residual and new volunteer plants can invade new productive areas (Figure 41). These sources of pest infestation should be managed but, for each crop, the timing of management and the important reservoir plants need to be well understood.

It is generally taught that all residues left in the field after harvest should be removed and burned or buried in order to eliminate pest reservoirs. The small holder must take into consideration that while the reservoirs are sources of pests, they are probably also important reservoirs for the pest's living natural enemies. Especially at the end of a crop cycle, natural enemy numbers may be particularly high. The net impact of eliminating pest reservoirs in non-commercial plants could be positive or could be negative, and in most cases we do not know how to predict the outcome (Figure 42).

It is often difficult to convince small holders to invest time and money in managing non-commercial plants in or near the productive environment. Suc-

Figure 41. Weed species known to be hosts for viruses affecting melons (Source: Zamorano).

Figure 42.Cabbage residues at the end of harvest may harbor high numbers of parasitic wasps.



(a)

(b)

Figure 43. Well-regulated coffee shade trees (a) permit aeration and reduce humidity, helping to regulate coffee rust, Hemileia vastatrix *(b).*

cess in introducing this kind of management is most often realized when pests are uncontrollable by other means, such as during whitefly outbreak years.

Figure 44. Cotton monoculture, one of the biggest consumers of synthetic pesticides per hectare.

Shade component in shade-grown crops

Well-managed tree and shrub species in shade-grown crops such as coffee and cocoa diminish the negative effects of certain fungi and insects (Figure 43). The correct proportion of shade to sun permits humidity management and good aeration and promotes the survival of certain living natural enemies.

Shade plants are often multiple-use. Pruned branches are used by the small holder for firewood, forage or mulch, thus making attractive the additional costs of managing shade species. The concept of pest management by shade in optimal form is often the aspect of shade management that is least appreciated by the smallholder and can be reinforced by training.

Diversification of the farm landscape

The diversity of vegetation on a farm is often related to the size of pest populations and to the severity of pest damage. Generally speaking, the biggest pest populations and worst damage occur in undiversified systems, the most extreme case of these being *extensive* ***monocultures*** *(*Figure 44). Diversified farms and farm landscapes, made up of small plots of plants in monoculture (Figure 45), crops that are ***intercropped***, ***strip-cropped,*** or ***al-***

ley cropped, agroforestry systems, ***cover crops***, forest patches, windbreaks and hedgerows, ***live fences and barriers*** (Figure 46), benefit from the delayed arrival and/or slower increase of pest populations. Fortunately, many small holders live on these kinds of farms. Others that own or rent small plots may not have the opportunity to diversify much and are limited to an hectare or two of crop monoculture.

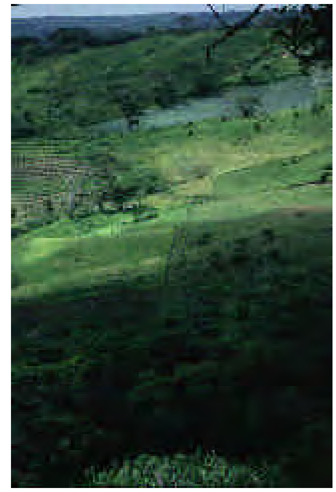
How does plant diversity interact with pest populations?

Increased diversity in the farm landscape generally helps the farmer by keeping pest populations smaller for several reasons:

- diverse systems physically impede the movements of mobile pests (eg Taiwan grass barriers around vegetables and small fruits)
- diverse systems compete better with weeds for essential requirements like sunlight and water (eg, cover crops)
- vegetational diversity affects the ability of some mobile specialist pests to find their hosts
- a greater diversity of organisms that naturally control pests lives in diverse environments
- a diverse environment that include trees and cover crops buffers the negative effects of sun and heavy rain, thereby improving soil properties and producing in the end a more vigorous, pest-resistant crop (eg shade in coffee and cacao)

Trap crops or trap vegetation for insects or mite pests are one special application of the idea of diversification. Trap crops/vegetation are strips or areas of plants that are more attractive to the pest than the principal crop. They are attractive due to certain intrinsic properties or because they are planted earlier than the crop. The pest accumulates in the trap crop and can either be eliminated or left there (Figure 47).

Figure 45. Diversified farm landscape; small plots of different monoculture crops.



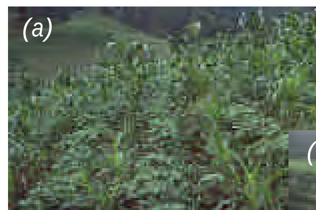
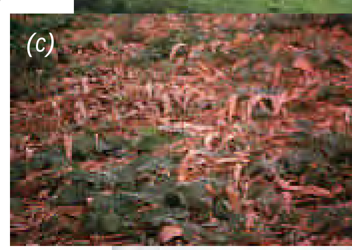
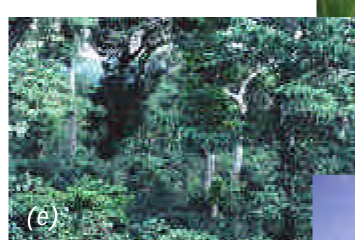


Figure 46. Examples of on-farm diversification: (a) intercrop: maize and beans (b) forest patches and windbreaks (c)cover crop: Mucuna *in maize (d) stripcrop: cotton, rice and maize (e) agroforestry system: coffee (f) live fence: madero negro,* Gliricidia sepium.





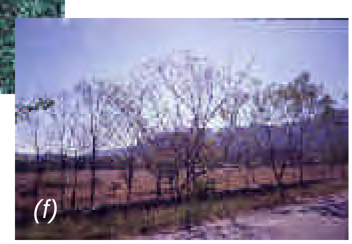


Figure 47. Beans are a trap crop for whitefly, Bemisia tabaci, *preventing accumulation in a tomato seedbed.*

Trap crops require advance planning and small areas of land to spare. Although they are used by large growers in tropical cropping systems such as tomato, the concept has been slow to be applied and adopted by small holders, in part because trap cropping, in that it requires more detailed understanding of pest ecology, has been little promoted.

Optimize field selection, crop rotation, and fallowing

A good location for a new crop or plantation is essential to success. If the smallholder has enough land to provide some leeway in where to plant, he/she should take into consideration how the land was used in previous years in order to avoid insect and pathogen populations, especially soil-dwelling, that

Figure 49. Wind and soil erosion will limit pest management options in crops grown here.

Figure 48. White grubs, Phyllophaga *spp, accumulate in pastures. Care must be taken when land use changes and pastures are plowed up to plant crops.*

have remained from previous crops, pasture grass, and natural vegetation. Many pest problems can be predicted according to past land use and also according to the experience with a particular field (Figure 48).

Sources of pests from downwind fields, excessive wind, dust and excessive water will make pest management a struggle in a new planting (Figure 49).

Especially before planting high-value vegetable crops and new perennial fruit tree and coffee plantations, the soil pathogen load and density of nematodes and soil-dwelling insects should be evaluated. Simple sampling techniques for soil-dwelling insects have been developed and are often widely adopted by farmers (Figure 50). Techniques for detecting patho-

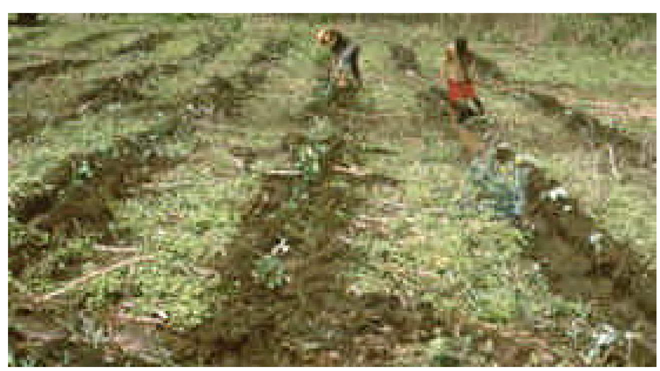


Figure 50. Farmers estimating density of white grubs, Phyllophaga *spp, in a plowed field by counting grubs per meter. Another method involves digging holes in representative parts of the field.*

Figure 51. Farm planning maps help farmers plan pest-sensitive crop rotations over several years.

Figure 52. Tin or plastic barriers keep leaf-cutter ants from detecting and stripping fruit trees.

gens by planting indicator plants in soil samples are available, but require considerable advance planning and investment of time.

Some important resident pests of annual crops, especially those with narrow host ranges and short life spans, can be eliminated with a planned crop rotation, including fallow periods (Figure 51). While crop rotation is a mainstay of pest management for farming in the developed world, small holders and even large growers in the developing world are much less likely to use this essential pest management technique. Uncertainty in credit opportunities and volatile markets, unstable access to land, and cropping systems that are subject to the whims of tropical weather, make up the world of the small holder. Fixed, rational crop rotation patterns that minimize losses to pests and pesticide applications are a goal that should be sought after, when other conditions permit.

Crop-free periods are sometimes mandated by law when pests are otherwise unmanageable. The purpose of these is to deprive the pest of host material for reproduction, thereby introducing a break in an otherwise unmanageable population buildup. Especially where farmers are poorly educated and communications are hindered, crop-free periods are controversial, difficult to enforce and unpopular with some farmers. Still, they do attack a pest problem at its root, and lead to better options for the community as a whole.

Physical barriers

Physical barriers prevent contact between pests and their hosts. Physical barriers may require a continuous investment in materials and labor, or may require a single high initial investment, as in the case of metal silos used for storing basic grains, temporary greenhouses or screenhouses, or metal and soft plastic barriers against leaf-cutter ants (Figure 52).

Live barriers, for example wind-breaks, (Figure 53) can interfere partially with movement of a pest, but rarely is this enough for satisfactory management. Live barriers serve as refuges for natural enemies as well and may also have uses as forage or firewood.

4.2 Genetically based resistance

Genetically based resistance makes deliberate use of pest-killing, pest-tolerating or pest avoidance mechanisms intrinsic to the crop plant that are passed along from generation to generation. All of the plant may have resistance or some parts, as in the case of resistant rootstocks for grafted fruit trees

Case Example 5.
Physical barriers: post harvest storage silos for insect and rodent control.

Nearly 250,000 metal silos for on-farm and home storage of maize and beans have been sold or donated to small holder families living in Central America by national programs and NGO's supported by the Swiss Agency for Development Cooperation (COSUDE) since the 1980's. The silos, which hold from 200-3,000 lbs of grain, prevent post-harvest losses to insect pests and rodents based on the principal of physical barriers. The dried grain is added to the silo, this is sealed and fumigated once with an insecticide which dissipates within weeks. Further colonization of the grain is impeded by hermetic seals.

The silos replace such traditional storage techniques as outside aerial lofts, sacks, and wooden boxes. Farmers who used such structures treated their grain with dry formulations of often very toxic organophosphates and organochlorines and losses were still significant. During the last 20 years, it is estimated that more than half a million pounds of organochlorine insecticides, 145,140 pounds of organophosphates, and 210,000 pounds of the obsolete fumigant carbon disulfate been avoided with the silos that replaced aerial lofts. Families that used fumigants in porous sacks no longer are exposed to the gas in their homes. (*Source*: Gladstone, S., L. Asturias, y A. Hruska, 2002. Estudio de Adopción y de Impactos de Tecnología Postcosecha, COSUDE.)

Figure 53. Taiwan grass barrier planted to lower access of diamondback moth, Plutella xylostella*, to cabbage.*

Figure 54. Fruit trees grafted to disease resistant rootstocks.

Figure 55. Bean varieties resistant to golden mosaic virus are now available.

Figure 56. In Nicaragua, susceptible red bean varieties are still planted in preference over darker, resistant varieties because of consumer preference.

(Figure 54), may resist pests or compensate through sufficient growth for pest damage.

The crop variety that a small holder chooses is, in some crops, the first or only non-chemical line of defense against losses (Figure 55). Tropical crop varieties resisting or tolerating plant pathogens have been developed far more often than have varieties that resist insects and mites. Fortunately, insects and mites are in general more easily managed by other means than are plant pathogens and nematodes.

Small holders tend to use resistant seed and vegetative material according to their economic means at the moment of planting, but also according to marketing considerations. Pest resistance in a variety is not always positively correlated with marketability, and small holders are reluctant to choose varieties for pest control reasons when taste, consistency, or durability of the product is compromised Especially in the case of basic grains, selection for pest resistance has not always coincided with improvements in flavor, color, or cooking qualities (Figure 56). When farmers work with researchers to develop and test new resistant varieties on farm, as in the Comites de Investigacion Agricola Locales (CIAL), developed first in Colombia in 1987, (Proyecto IPRA, 1993) rejection of resistant varieties for marketing reasons can be more often avoided. Promotion of resistant varieties of export

Figure 57. The coffee variety Catimor, is a heavy yielder and is resistant to coffee rust but is rejected by discriminating coffee buyers.

crops such as coffee also must consider market demands (Figure 57).

Farmers may be especially reluctant to buy new pest resistant material for perennial crops such as coffee, bananas, citrus and plantains, since these crops are traditionally and cheaply propagated from material collected on the same farm. It is incumbent upon program leaders to understand the constraints impeding the use of resistant varieties and work toward solutions. Most likely, the resistant variety in the long-term will be an economically rational pest management solution even if it requires high initial output.

Resistant transgenic crop varieties, also called genetically modified organisms (GMO) contain genetic material natural to another species, perhaps only very distantly related to the crop species, that confers resistance to insects or to pathogens.

The three major pest control traits in commercial GM crops are:

- insect resistance – a number of crops have been modified to produce variants of the insecticidal toxin of the bacterium *Bacillus thuringiensis (BT)*

Case Example 6. Genetically-based resistance: Sigatoka negra resistant plantains are more productive but need new marketing strategies.

The Honduran Foundation for Agricultural Research (FHIA) presented a solution to small holder plantain farmers in the 1990s that helped to resolve the principal disease problem faced by them, black Sigatoka disease, caused by the fungus, *Mycosphaerella fijiensis.* The disease, the most serious in Central America, defoliates the plant and reduces the yield in plantains.

The variety known as FHIA-21 confers resistance to the plantain plant. Farmers who have obtained resistant material for reproduction on their small farms were pleased with the disease-combatting results but also commented that the head of plantains tended to ripen differently, creating new considerations in marketing. The variety was also more demanding of water and inputs for optimal yield.

- virus resistance - modified to produce a viral protein. The crop attains resistance to the specific virus, for example, potatoes tolerant to potato virus Y
- herbicide tolerance (HR) - crop modified in such a way that it tolerates specific herbicides and as such enables a more targeted approach to weed control

GMO cotton, corn, and soybeans are widely used in parts of the developed world, especially the United States, Canada, and Argentina, and have been since the mid 1990’s. As of late 2003, no GM crops are commercially produced in the developing countries in the Americas. Few GM research programs focus their efforts on solving the pest problems of small holder crops.

Controversy currently surrounds this potentially useful technology for reducing the pesticide burden in the developing world. Proponents of GM crops for the developing world argue that pesticide applications have been reduced dramatically elsewhere as a result of the technology and could do the same in small holder crops, for instance maize. Aside from those deriving from bias against the giant seed companies that have developed GM seed, the arguments against developing and promoting GM crops for small holders in the developing world fall into five major categories:

- fears that the crops are not healthy for consumers, either because foreign proteins may stimulate allergen production, which may in turn cause allergic reactions in the people who consume them or because they are nutritionally inferior, or because the studies of their effects have been inadequate
- accelerated development of resistance to the currently very useful microbial insecticide, *B.T.*
- escape of foreign genes from GM crops into wild living crop relatives, and the conversion of these to uncontrollable weeds
- escape of foreign genes and contamination of native plant gene pools
- damage to on farm and off farm biodiversity

A number of international studies have recently been published reviewing the data available on these concerns.

A recent study done for the government of the United Kingdom concluded that seven years after GM crops first were massively planted, there is not sufficient evidence supporting the first three concerns. The study found sufficient evidence only for negative effects on biodiversity, on and off farm. The study does recommend additional study in several areas before GM crops can be declared innocuous on other counts. At present, the greatest sure risk presented by GM crops grown in the developing world may be their lack of marketability in countries such as most of those in Europe that have prohibited GM food crops.

The World Health Organization will soon release its review on the health effects of GMOs. The main conclusion from the pre-publication draft is:

«GM foods currently available on the international market have passed risk assessments and are not likely to present risks for human health in any other form than their conventional counterpart.» The document will soon be available at the WHO web site (*www.who.int*).

Another important review with conclusions is *Transgenic Plants and World Agriculture*, prepared under the auspices of the Royal Society of London, the U.S. National Academy of Sciences, the Brazilian Academy of Sciences, the Chinese Academy of Sciences, the Indian National Science Academy, the Mexican Academy of Sciences, and the Third World Academy of Sciences. This report is available at *www.royalsoc.ac.uk/files/statfiles/document-116.pdf.*

The main conclusion of the study is: «GM technology, coupled with important developments in other areas, should be used to increase the production, reduce the environmental impact of agriculture, and provide access to food for small-scale farmers.»

National policy governing the introduction of GM varieties to each developing country will determine ultimately how much an intervention program can make use of them. Donor policies will be a second hurdle and public opposition, a third. For the time being, discussion of the introduction of a GM crop may be premature; by the time it happens the arguments in favor and against introduction may have been debunked or supported by years of new data.

Figure 58. Field guides help farmers learn more about natural enemies, including insect pathogens.

4.3 Conservation of living natural enemies

All pests suffer some kind of reduction in population size due to their natural enemies (see Chapter 3): predators, antagonists, parasitoids, and diseases. Some pest species, in a favorable environment, can consistently be maintained below harmful levels by their natural enemies. Other species, because of the nature of the damage they do or because of their life histories, lack sufficient control by their enemies and will require additional actions in order to be adequately managed even in an ideal environment.

The ***conservation of natural enemies***, is one of the strategies comprising ***biological pest control***. It is fundamental to achieving safe, effective and sustainable pest management using a minimum of chemical inputs. It tends not to be *consciously* employed by most small holders, although in low input production it is probably an important «hidden» management tool.

In order for a small holder to consciously conserve his or her natural enemies, he or she must recognize and appreciate their role in the productive environment. Small holder knowledge of natural enemies is usually quite minimal except in some crops where the action of natural enemies is more apparent and their activity is easier to observe. Small holders recognize beneficial insects much more often than beneficial pathogens and the effects they produce on insects, mites, weeds and plant pathogens. (Figure 58).

The impact that naturally occurring enemy populations have on pest populations is poorly known in most tropical crops. The best evidence that they are extremely important in regulating some pests surfaces when induced pest populations explode. In the current tropical agricultural landscape, natural enemy populations are probably less than sufficient for effective regulation of many important pests and need reinforcing by integration with other pest reduction methods. On the other hand, loss of natural enemy populations through broad spectrum pesticide wastes an economically valuable resource.

Deliberate actions that attract and conserve natural enemies are known for many species and these are sometimes promoted. Their implementation is low if perceived to be too time-consuming or expensive.

Minimizing the use of broad-spectrum synthetic pesticides is undoubtedly the single most important step toward conserving a robust natural enemy population. Diversifying vegetation in the small holding is related to improving numbers of predators

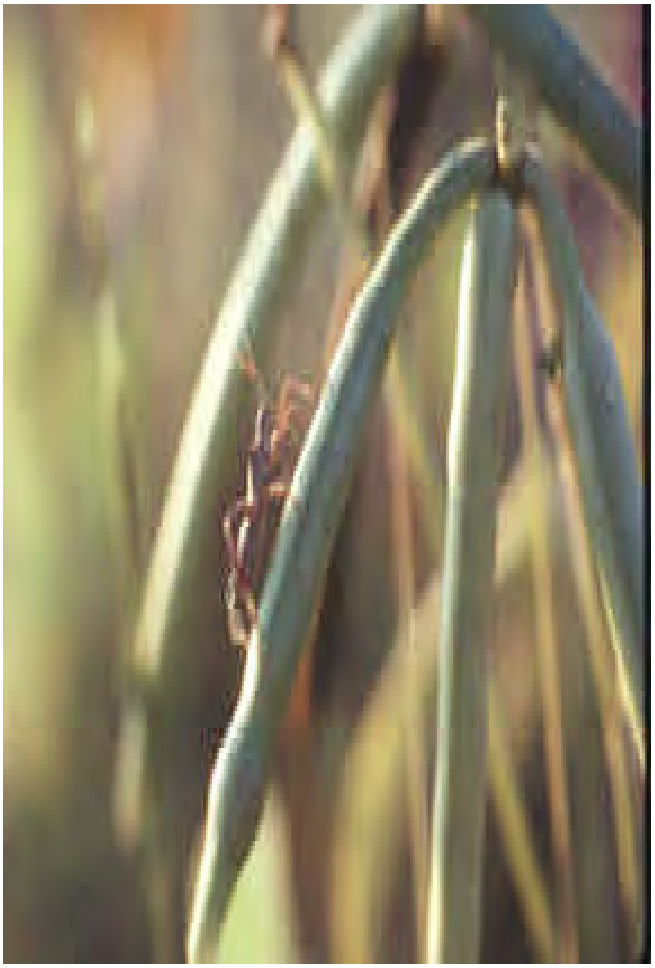


Figure 59. Sorghum barriers around crops attract aphids which in turn attract large numbers of generalist predators.

and parasitoids who need alternative food sources such as pollen, nectar and additional insect species, especially during fallow periods (Figure 59).

Chapter 5 Curative Management

RESPONSIVE, OR CURATIVE, TACTICS are actions that the farmer takes when a pest population is already present at levels sufficient to cause economic damage or is approaching an EIL. The most common responsive intervention is an application of synthetic chemical pesticide but other fast-acting and sure interventions may be used, including some discussed previously as preventive measures.

5.1 Mechanical Removal

Mechanical control or ***physical control*** of a pest is defined as removing a pest by hand or with some kind of implement. Insects can be directly picked off plants or diseased plant parts can be pruned away. Weed control by machete is a mechanical control tactic used throughout the developing world.

Removing a pest physically stops its damage immediately, and keeps its population from increasing and causing greater damage in the future. Physical removal is very efficient in that it targets precisely the pest and only the pest: there is no damage to other organisms in the environment except to those ecologically linked to the pest. Even «broad-spectrum» weed control by machete can be fine-tuned somewhat in order to leave beneficial ground covers.

Case Example 7: Mechanical removal of the coffee berry borer in coffee.

From Mexico to Bolivia, especially at elevations below 1000 meters above sea level, the coffee berry borer (CBB), *Hypothenemus hampeii,* is the principal insect pest of coffee. A CBB female perforates the maturing cherry and tunnels through the ripening pulp and into the bean when it reaches a particular consistency. Once embedded in the bean, she lays eggs, and the bean is destroyed as her larvae emerge and grow. CBB is always found inside the coffee fruit, either ripe fruit for reproduction or in old, dry cherries for resting during the months when no new fruit is present.

Chemical control of CBB requires several applications of endosulfan, a highly toxic organoclorine, responsible for a high percentage of the pesticide poisonings reported every year in coffee-growing countries.

Especially in countries where coffee ripens during certain months of the year only, chemical control of CBB is reduced and often eliminated entirely by physically removing all refuges, residual cherries on the plant and on the ground, during the «off months». Complete application of the principal of mechanical removal may require up to four actions at different times of the year

- early ripening fruit, usually heavily infested, is picked before it falls to the ground
- monetary incentives during harvest ensure that paid pickers remove dry cherries and green fruit
- residual fruit, usually dry or green, is removed in a final pass after the harvest
- fallen fruit is picked up from the ground

CBB in a coffee plantation subjected to all of these steps has nowhere to live while it waits for a new crop of cherries to form. CBB populations that are relatively isolated from neighbors (who may not be as careful) can be essentially eliminated.

While it is efficient in principle, mechanical removal is also highly labor intensive. It can constitute an economically rational use of resources when alternatives such as pesticides are expensive and labor is cheap and available. When a community of small holders develops economically and labor costs increase or labor becomes scarce, these tactics tend to disappear from the farmer's repertoire and replacement by synthetic pesticides often ensues.

Even under unfavorable cost and labor scenarios, pruning diseased plant parts or parts damaged by insects is a practical option for high-value crops, such as coffee, precious wood trees (Figure 60), plantain and bananas. Hand removal and disposal of diseased seedlings and saplings is used in seedbeds, fruit orchards, and open field plantations of vegetables and fruits such as melon, tomato, and cabbage.

Soil-dwelling pests can be eliminated directly or can be deliberately exposed to living natural enemies or the sun. For example, soil preparation during dry periods controls certain weeds and insect pests (Figure 61). «***Solarization***» of seedbeds or pouring boiling water over seedbed soil kills or weakens nematodes, weeds, fungi, and bacteria (See Case Example 9).

For some insect pests, small holders may use physical traps baited with an attractant consisting of a natural or synthetic chemical that simulates odors emitted by the insect's host plant, or designed to attract insects with light or color (Figure 62). Small holders and extension agents sometimes mistakenly use traps that were designed for monitoring populations as a means of control on a large scale. An effective trap for control captures the insect in numbers large enough to reduce its population to economically innocuous levels. With a monitoring trap, we are only interested in sampling the population

Figure 60. Pruning affected parts is the best alternative to eliminating shoot borers, Hypsipyla grandella *in mahogany and Spanish cedar.*

Figure 61. Plowing in the dry season (a) dries out tubers of nutsedge, Cyperus rotundus, *(b) and can eliminate a large percentage of the population.*

Case Example 8. Selective mechanical removal: beneficial weeds can help in machete-cleared coffee plantations.

Many small scale coffee producers weed their plantations by machete. Up to five weedings per year in shade-grown coffee may be necessary in the first three to four years after establishment. The most injurious weeds are vines, aggressive grasses and sedges, and broadleaf weeds with deep roots.

Not all weeds found commonly in coffee plantations are injurious to the coffee plant when they grow in between rows. Low growing, spreading ground covers with shallow root systems are actually beneficial to the coffee plant since they

- impede establishment of injurious weeds
- serve as living mulch to conserve water during dry spells
- prevent soil erosion produced by heavy rainfall and runoff
- diversify the vegetation, providing benefits to natural enemies

Coffee farmers in Honduras, El Salvador and Nicaragua have been trained through a CATIE-led IPM program to differentiate between injurious and beneficial weeds and to use both selective weeding practice and a combination of mechanical weeding and herbicides to favorably change species composition over time. Benefits to the farmer have included reduced costs in weeding in future years as injurious weeds are eliminated and better soil fertility and insect pest management. (Guharay, et al., 2000)

Case Example 9: Mechanical removal: «solarization» of seedbeds removes plant pathogens and nematodes.

Plant pathogens causing damping-off and other seedling diseases, and root-knot nematodes will devastate vegetable transplants and fruit tree nursery stock if they are not eliminated from the seedbed and nursery soil. Soil fumigants applied under plastic much to the soil, such as methyl bromide, are not only environmentally dangerous but are too expensive for small holder growers. Nematicides and fungicides include some of the most dangerous compounds for small holder conditions.

The sun's heat has been found to be an effective sterilizer of soil when it is correctly harnessed. The method of «solarization» of soil is even recommended to large growers as a somewhat less effective, but acceptable, alternative to the use of methyl bromide, which is being phased out of use by international agreement.

To sterilize soil, small holder farmers in many Latin American and Caribbean countries have been taught to mound up the soil to an appropriate depth and in an exposed site, add water to thoroughly soak the soil, cover tightly with plastic sheeting and use the sun's energy to steam the soil, raising it to temperatures that pathogenic organisms and nematodes cannot survive.

for changes and large numbers are not usually caught (Figure 63).

Pheromones, chemicals produced by the insect itself to attract individuals of the opposite sex, have been synthesized only rarely for pests of tropical crops. This trapping alternative, very effective for many pest species and commonly used in the developed world, is practically unknown to small holder farmers in the developing countries.

5.2 Pesticides

A ***pesticide*** is any substance designed and used deliberately to kill or impede the development or reproduction of organisms considered pests. The broadest classification system for pesticides distinguishes them by origin as either synthetic or natural (biological).

Figure 62. Red alcohol-baited traps attract and kill coffee berry borer, Hypothenemus hampei, *that fall into soapy water in bottom cup.*

Figure 63. Yellow sticky traps were designed to monitor whitefly, Bemisia tabaci, *populations, but farmers sometimes use dense concentrations of them for control in seedbeds.*

5.2.1 Biological pesticides

Biological pesticides are comprised of living organisms or their by-products that are applied or released in large numbers or amounts into a pest population for immediate control purposes. Biological pesticides may consist of large numbers of parasitoids or predators for insect or mite control, or of herbivores for weed control, botanical extracts, or microbes such as bacteria, fungi, and insect viruses. While the same organisms may occur naturally in a farmer's environment, and he or she may take steps to conserve them and increase their numbers over time, the deliberate liberation of these organisms is considered the use of a biological pesticide.

Parasitoids, predators and weed herbivores

Parasitoids, predators and ***weed herbivores*** are insects and mites that are released live, usually in very large numbers, to actively search for the pest. A parasitoid is a wasp or fly that kills the pest by using it as food for its offspring. The adult female parasitoid lays one or many eggs on, in or near the pest and parasitoid larvae emerging from the eggs slowly consume the pest from within or externally, killing it within a few days (Figure 64).

Figure 64. A parasitoid wasp, Trichogramma pretiosum, *has parasitized this* Helicoverpa *egg. The egg will produce only a new wasp.*

Figure 65. Chrysoperla carnea *is one of the few predator species mass reared for use as a biological insecticide.*

A predator, by comparison, is an adult or immature invertebrate (or vertebrate, but rarely used as a biological insecticide) that kills the pest much more rapidly by consuming it directly (Figure 65). A parasitoid larva uses just one prey individual to develop to the adult stage, while a predator generally consumes many prey before completing its life cycle. Predatory species will usually consume a range of prey species, while many species of parasitoids are specialists on the pest and will have evolved very efficient searching behavior in order to find it.

Herbivorous insects or mites can be used to control weeds, especially foreign invasive species. They are tested rigorously by entomologists in laboratory settings to ensure that they feed only upon the weed species before they are used in the wild.

Use pattern among small holder farmers

Living biological pesticides as described above are rarely used by individual resource-poor small holders in developing countries, even though they may be used on large holdings, or cooperatives in the same area. Why is this? Production constraints, lack of a distribution system and the economy of scale explain much of the phenomenon of differential use.

Small holders rarely plan the use of pesticides in advance. Unless the pest is chronically present, and even still, it makes more economic sense to wait than to invest in products that may not be used. Businesses producing live organisms for sale, unless the demand is very large, produce predators and parasitoids according to advance contracts directly with the farmer so as to guarantee adequate quantity of the appropriate life stage when the farmer needs it.

Living parasitoids and predators cannot be stored (they have no ***shelf-life***), rather, they must be released within days or even hours of purchase. The producing facility therefore cannot produce an excess of living organisms and maintain cost-effectiveness. This basic contradiction between the smallholders decision-making and purchasing behavior and the constraints of producing live organisms means that small holders are usually excluded from liberating biological pesticides in the form of predators and parasitoids even though they may be an effective alternative for his/her pest problem.

There are exceptions to this generalization. Where the in-country industry for raising and marketing predators and parasitoids is big enough, surplus product can be used by those small holders who can get access to it. Farmer associations may be able to make contracts with suppliers on the behalf of groups of resource-poor farmers; still, advance commitment to pest control is often economically not rational. Finally, highly local production of predators or parasitoids tied directly to farmer associations, (Figure 66) has been shown to work where the demand for predators or parasitoids can be created and sustained.

Effectiveness

Predators and parasitoids can reduce and maintain pest populations below economically damaging levels when the numbers released are sufficient, the timing of application is correctly done and when the weather, especially wind and rain, is not adverse. They are more complex to use than are synthetic

Figure 66. Sugar cane producers association in Costa Rica produces the parasitoid Cotesia flavipes *for use as a biological insecticide.*

Figure 67. Marine toad, Bufo marinus.

pesticides because, as living organisms, they are more subject to mortality factors and may attack only certain life stages of the pest. An important advantage of predators and parasitoids is that they do not cause induced pest outbreaks nor are there long-term problems with resistance.

Human safety

These biological pesticides present practically no risk for human beings. Their safety derives from their specificity for a particular pest species or group of related species and their lack of biological activity against vertebrates.

Environmental safety

Predators, parasitoids and weed herbivores pose a potential environmental risk if they can continue to live and reproduce in the environment after they are released. If the species or geographic race used is not native to a particular geographic area, negative impacts on native species or strains theoretically may result. In developing countries, biological pesticides have been used extensively and negative impacts have been virtually undetected or at least unreported. After more than 50 years of releasing predators, parasitoids and weed herbivores around the world, it can be said that many more known environmental problems have ensued after the introduction of vertebrate predators, such as the marine toad *Bufo marinus*, than have from the release of insect agents (Figure 67).

Microbial pesticides

Microbial pesticides are pesticides whose active ingredient is a living microorganism or its by-product. Microbial pesticides cause disease in insects, weeds, mites, or nematodes or kill them through toxins liberated by the microbe. Four groups of microorganisms, fungi, bacteria, protozoa, and viruses, and one group of larger organisms grouped with them, the non plant-parasitic nematodes, are used in microbial insecticides (Figure 68).

Microbial control agents are formulated live in water, in emulsifiable oil, or as powders. The species of microorganisms most commonly used in microbial pesticide products are the bacterium *Bacillus thuringiensis*, (*B.T.*), the insect-killing fungi *Beauveria bassiana*, *Metarhizium anisopliae,* and *Verticillium lecanii* and insect viruses known as nuclear polyhedrosis viruses (NPV) and granulosis viruses (GV).

Use pattern among small holder farmers

Microbial pesticides do have a shelf life. A resistant stage of the infectious agent, such as a spore or

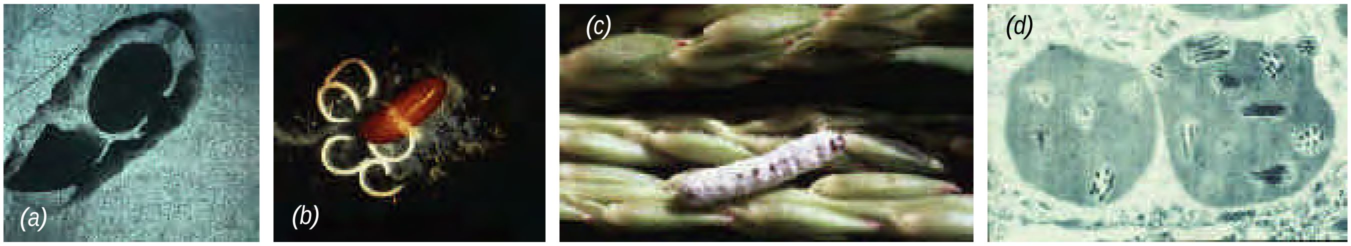


Figure 68. Pathogens and nematodes used in microbial pesticides: bacteria (a), nematodes (b), fungi (c), viruses (d) and protozoans (e).

conidium (Figure 69), is formulated in a life-sustaining medium. For this reason, and because they are applied with the same equipment as are synthetic pesticides, microbial pesticides, unlike biologicals based on parasitoids and predators, are used sometimes by small holder farmers.

Two factors limit the use of microbial pestticides by small holders: availability and cost relative to the cheap, older-generation synthetic pesticides. Due to environmental concerns and regulatory pressures, the demand for microbials is increasing among larger farmers who produce, especially for export, in the developing world. As pesticide suppliers respond, the variety of microbial products should increase for the benefit of the small holder in the future.

Manufacturers of microbial pesticides range from large commercial enterprises to small scale, home «factories». Production units may be public institutions (universities and research centers), large or small private businesses, or mixed ventures (Figure 70). The success of a microbial pesticide-producing enterprise depends upon product purity and viability, which in turn depends upon managerial capacity and facilities. In some countries, high-quality cultures of microbial control agents are successfully produced in larger, well-organized cooperatives or farmer associations. A key to success is the development and implementation of quality control procedures at all stages of production, formulation and packaging.

Figure 69. Conidium of insect pathogenic fungus, Beauveria bassiana.

Figure 70. Cooperative Union of Miraflor in Nicaragua produces Beauveria bassiana *for its members who grow coffee and cabbage.*

Effectiveness

Microbial pesticides are effective for their target pests but slower to act than synthetic pesticides. The fastest-acting microbials such as *B.t.* will halt insect feeding, and therefore damage, within a day or two. Slower acting fungi may have no effect for several days and therefore must be used on early, scant generations or on very young pests. Farmers need to be educated about mechanisms by which microbials work so that they don't misinterpret slowness as a lack of effectiveness. Education about proper timing of application is essential for success as microbials are frequently only useful on certain pest life stages.

Microbial pesticides are sensitive to environmental factors such as sunlight, which will deactivate some microbes, and humidity which will foment fungal reproduction if high and impede it if low. One advantage of microbial pesticides over synthetic pesticides is that microbials, with a few exceptions, do not engender resistance in the pest over time.

Human safety

Use phase

Microbial pesticides produced and registered in developed countries comply with a modified set of testing requirements that measure human health and environmental effects. They are considered to have little or no effect on the health of the person who applies them or on consumer health, but protective clothing is recommended for the applicator.

Production phase

Most of the species of microorganisms produced in the developing world are the same as those produced in the developed world and have been shown to be safe to for the applicator. However, the production process itself presents several health risks, such as inhalation of dry spores and the development of allergies, which must be addressed in any program that promotes the development of small-scale production of microbial pesticides.

Environmental safety

As do predators and parasitoids, microorganisms continue to live and reproduce in the environment after they are applied and potentially pose a risk to native species. The species of living microorganisms most commonly found in microbial pesticides are naturally distributed throughout the globe, although geographic differences in genetic makeup will lead to ***strain differences*****.** The fate of foreign strains in the new environment and their impact on native strains is poorly understood.

Most fungi will have effects on ***non-target organisms*** within the same families or orders as the target pest. NPV viruses, by comparison, are highly specific to their insect target species and do not have outside impacts (Figure 71). *Bacillus thuringiensis* toxins from commercial products, will, if ingested kill other species closely related to the pest.

Botanical pesticides

The use of plant extracts as pesticides, commonly called ***botanical pesticides*** or ***botanicals,*** is considered a traditional or indigenous method of pest

Figure 71. NPV virus for Spodoptera frugiperda *(a) will not kill closely related* Spodoptera sunia *(b).*

Figure 72. Farmer in the Dominican Republic amid his stand of neem trees.

management throughout the developing countries of Latin America and the Caribbean. Extracts and dry preparations of seeds, leaves, bark and roots mixed on the farm to kill pests are also a satisfying extension of a rich cultural tradition of plant-based medicines for human and animal ailments.

Not all botanical insecticides used in Latin America result from extensions of traditional knowledge. Since the early 1980's, millions of neem trees, *Azadirachta indica,* native to the Far East, have been planted throughout tropical America and their seeds and leaves are being processed into home-made and commercial botanical insecticides and nematicides (Figure 72). In addition to neem-based products, a few other compounds are available as commercial botanical pesticides.

For purposes of discussion and analysis, botanical pesticides may be grouped into three categories:

- commercially produced and registered botanical pesticides such as neem tree (*Azadirachta indica*) compounds, rotenone, sabadilla, and pyrethrum
- foodstuffs such as chili pepper, garlic, citrus extracts, coffee grounds, cinnamon, wheat flour and starch used at high concentrations to kill or repel pests.
- extracts from native plants, untested and unregistered

Use pattern among small holder farmers

During the last decade, the promotion of home-made botanicals and of commercial botanical products by organizations working among small holder farmers has increased dramatically. Botanical pesticides are favored over synthetic pesticides by extension personnel because they are expected to:

- cost less
- lead to self-reliance when home-made
- have equal or superior efficacy
- have low human health impact
- have low environmental impact
- conserve beneficial insects and other non-target organisms

Effectiveness

Commercial botanical pesticides may often be as effective as synthetic pesticides when used according to their labels for vulnerable target pests. Many of them are registered as repellents, not insect «killers» and should only be depended upon for repelling. Others have quite specific mechanisms of action and are only effective against a certain range of pest species or life stages. In their eagerness to use botanical pesticides, small holders may overstep correct and effective use.

One of the greatest doubts about the wisdom of promoting home-made botanicals, either based on foodstuffs or on unregistered native plant extracts, is rooted in the question of effectiveness. The systematic development of robust recommendations as to vulnerable target species, timing of application, and effective dose is a long experimental process that has been frequently short-circuited with this group of pesticides, even if many of them have been widely used in practice. Farmers may try botanicals and record their results, but the effects they observe are highly dependent upon the particular circumstances of the trial. If a pest population was not close to damaging levels when a botanical was applied, the pesticide may have looked effective but in fact served as nothing more than a placebo.

Consistent quality of home-made botanical pesticides is difficult if not impossible to achieve. We know that the pH of water, genetic variability among plant populations and individuals of and degradation of extracts over time can lead to a wide range of biological activity among batches of home-made botanical pesticides. Pesticides that don't work are a credibility disaster for the extension agent that recommended them and an economic disaster for the small holder farmer.

In order to be truly useful, those botanical pesticides determined to be good options should be introduced as a curative pest management tactic, whose use is determined by sampling pest populations and integrating population size information with other decision-making criteria.

Human safety

Commercially produced and registered botanical pesticides have been subjected to testing requirements somewhere. Human and wildlife toxicity profiles for their active ingredients are available. Botanical pesticides based on foodstuffs are exempt from registration as pesticides by the USEPA because they are known to be safe as foods.

While these two groups of compounds are considered safe for farmers who apply them and for people who eat the food applied, questions remain about risks to those who prepare some of the insecticides from raw materials at home. Farmers who extract compounds from food are exposed to much higher concentrations during that process than during the act of application of a diluted product. These risks are not measured during conventional testing because this process does not occur in testing countries nor do the requirements apply to products that are not bought and sold.

A third group of botanicals comprises extracts from plants, often locally known only, for which little or no formal safety testing has been done. The active ingredient compound in plants in this group is most likely even unknown.

For compounds extracted from plants in this last group, we need studies of short and long-term effects on human health, modes of action, and entry pathways to the human body before they can be used safely, even at an experimental level. A few compounds have taught us already the danger of extracting plant compounds: extract of tobacco has one of the greatest acute toxicities of any insecticide and tobacco leaf veins are sometimes used for insect control in El Salvador and Nicaragua. Extracts of «paraiso tree» leaves prepared as homemade botanical insecticides have killed several people, including children, in Central America.

Experimentation with unknown plant extracts

The idea of concocting even a well-known and safe botanical insecticide such as garlic extract inevitably leads to discussion about other interesting, possibly biologically active plant species. Innovative farmers will want to experiment. An important task for any extension agent is to make the risks of experimentation very clear without at the same time generally inhibiting a healthy tendency toward discovery. Plants thought to have pesticide properties should be brought to the attention of professional researchers who can isolate the active ingredients and design a thorough battery of tests for health effects and efficacy. Farmer experimentation with unknown plant extracts should be categorically avoided.

Environmental safety

Except in the case of registered compounds, the environmental fate of botanical pesticides has not been investigated. It could be logically argued that the compounds extracted from native plants are present in the environment anyway, albeit bound up in plant tissue.

Depending upon its mechanism of action, a botanical insecticide can be as likely to kill natural enemies and non-target organisms, especially invertebrates, as the pest itself. Some botanicals, such as neem extracts, have been shown to be innocuous for parasitoid populations. Many foodstuffs applied as pesticides or repellents are broad-spectrum.

Guidelines for promoting home-made botanical pesticides

- The home-production and/or use of registered botanicals and botanicals based on foodstuffs can be a valuable part of a small holder farmer's pest management program, but should include only those few plant compounds whose:
  - efficacy has been demonstrated for a particular pest
  - human health risks are known and acceptable during both the preparation phase and the application phase
  - quality can be assured among batches
  - environmental impact can be considered low-risk
- The use of a botanical pesticide should form part of a coherent management strategy, where use is based upon assessment of pest population size and probable plant damage response.
- Botanicals should be promoted using empowering methodology, not recipe substitution.
- Experimentation with unknown botanicals should not be encouraged and furthermore the risks of this should be made clear to farmer partners.

5.2.2 Synthetic pesticides

Synthetic pesticides are manufactured through a process of chemical synthesis. Synthetic pesticides produced and commercialized in all countries in the developed world and most in the developing world have been subjected to required tests on human toxicity and environmental fate and impact. The company that sells a pesticide product registers it with the national authorities responsible for pesticide regulation, who have reviewed the results of those tests. Most developing world countries use the results of tests performed in pesticide-producing countries as the basis for registration decisions.

Formulations

Commercially produced synthetic pesticides are usually mixtures, or ***formulations***, of several substances that perform specific functions.

- the ***active ingredient*** (a.i.) is the biologically active component
- ***auxiliary substances*** of organic or mineral origin optimize the effect of the active ingredient during and after the field application. Among these are:
  - ***inert carriers:*** the medium in which the active ingredient is diluted or mixed. Carriers may be solid or liquid ***diluents***, or ***solvents*** and account for a large proportion of the formulated product.
  - ***adjuvants:*** compounds that improve efficacy and stability of the active ingredient. Adjuvants are present in small quantities in the formu-

lated product. Common adjuvants are acidifiers, activators. adherents, foam suppressants, attractants, deposition agents, buffers, dispersing agents, emulsifiers, moistening, agents, penetrants, and surfactants

- ***synergists:*** compounds that increase the efficacy of two substances beyond the summed efficacy of the two substances acting alone

There are three major classes of commercial pesticide formulations: *liquid formulations*, *dry formulations* and ***fumigants***. The particular formulation of a compound will influence the compound's effects on human toxicity, toxicity to wildlife and environmental fate. Formulations that are approved for certain uses may be very dangerous to the applicator or to wildlife if they are used in non-approved ways. Small holder farmers frequently use wettable powders, designed to be mixed with water, as powders for insect control in storage units or for household pests such as ants and cockroaches. They may also use granular pesticides outside the soil environment for which they are intended.

Important properties of the most common formulations are presented in Table 3.

Names

Any given pesticide has several names associated with it:

The ***chemical name*** refers to the molecule comprising the active ingredient of the pesticide, for example, «1-napthyl N-methylcarbamate».

The ***approved common name*** *is* authorized by an international or national regulatory organization, such as the American National Standards Institute and the International Organization for Standardization. Common names always begin with a small letter, for example, «methamidophos». These names are used in everyday conversation.

The ***trade name*** (brand name, proprietary name) is given by the product's manufacturer. Commercial names begin with a capital letter, for example «Sevin».

Important properties

Toxicity

• *To human beings*

Pesticides enter the human body via four ***entry points***: skin (dermal), mouth (ingestion), nose (inhalation) and the eyes. Once in contact with susceptible tissues, a pesticide's active ingredient can have one or more toxic effects.

- Acute effects

Acute, or immediate, effects are those that cause immediate health damage after one or several short-term exposures. Acute effects include death, nausea and vomiting, dizziness and severe headache, and skin rashes.

Acute toxicity is the property most easily measured in experimental animals and is therefore most often used to describe the human health risk of a given pesticide. ***Acute toxicity rating*** is based on the pesticide's calculated ***median lethal dose (LD50)***, the dose (mg/kg body weight) administered via mouth (***oral LD50***) or skin (***dermal LD50)*** to laboratory rats that is capable of killing one half of the study population during a determined period of exposure. The ***median lethal concentration (LC50)*** is a measure used for exposures in air or water. The lower the LD50 or LC50 is, the more acutely toxic the pesticide.

- Chronic effects

Chronic effects are those that appear long after exposure to a pesticide. They may result from single or repeated exposures and low doses of pesticides

Table 3. Common formulations of synthetic pesticides used by small holder farmers.

Class	Type	Abbrev.	Description	Use by small holders
Liquid	Emulsifiable Concentrate	EC E	• liquid active ingredients, petroleum-based solvent and an agent that permits mixing in water • easily absorbed through skin	common
	Concentrate Solution	C LC	• diluted with a liquid solvent before being applied.	common
	Ultra-low Volume	ULV	• very high percentage of active ingredient • used without dilution or diluted with very small quantities of solvent. • applied with equipment that generates very small droplets, resulting in a very high probability of ***pesticide drift*** away from the target area	rare
	Flowable	F L	• finely ground solid active ingredients suspended in the liquid with inert materials • mixed with water	
Dry	Dust	D	• ready to use from package • low percentage of active ingredients • very fine dry inert carrier made from talc, chalk, clay, or ash • high level of pesticide drift	rare
	Granule	G	• similar to dusts, but the granular particles are larger and heavier • usually registered to be incorporated into the soil for weed, nematode, or insect control • picked up by birds as food	few, but very commonly used
	Wettable Powder	WP W	• finely ground formulations that look like dusts • mixed with water for spray application • high risk of inhaling the pesticide while pouring and mixing the concentrated powder	common
	Microencapsulated Pesticides	M	• particles of active ingredient (liquid or dry) surrounded by a plastic coating.	rare
Fumigant			• solids or liquids that form toxic gases when released· highly toxic to all organisms	rare except for grain storage structures

may be involved. Because effects in people may occur many years in the future, it has been difficult to definitively connect them to pesticide exposure. The chronic effects documented among pesticide applicators, farm workers, and consumers that have been linked to chronic effects with sufficient evidence are listed in Table 4.

Two important parameters governing pesticide effects on human health are ***risk*** and ***exposure***. The probability that an adverse effect will result from a given exposure to a pesticide is known as the ***risk***. Certain factors, known as ***risk factors***, can greatly influence the overall risk. Among these factors are characteristics (e.g., race, sex, age, weight) or variables (e.g., smoking, exposure).

The toxicity of a given pesticide is fairly constant for people in developing countries vs developed countries. The reason that a given pesticide produces far more adverse effects among the population of users and consumers in the developing world

Table 4. Classification system for chronic effects of pesticides.

Category	**Effect**	**Pesticide Examples***
I. Carcinogenicity	Carcinogens act on living tissue to cause malignant growth.	Probable carcinogens (IARC or USEPA): captafol captan mancozeb thiodicarb toxaphene
II. Neurological damage	Neurotoxicity: damage to nervous tissue	chlorpyriphos methamidophos
III. Reproductive and Developmental Effects	Birth defects, infertility, sterility	DBCP dinoseb endrin mancozeb
IV. Endocrine disruption	Pesticides mimic natural estrogens, disrupting the functioning of reproductive organs and causing miscarriage, male sterility, infertility, sexual hormone disbalance	DBCP mancozeb toxaphene
V. Organ damage A. Eyes	Eyes, liver, lungs, etc. are irreversibly damaged	methyl bromide
B. Liver		arsenic DDT mirex
C. Lungs		paraquat

** classification as of Sept. 2003. Classifications change constantly and can be checked on USEPA website.*

is that ***exposure*** to the pesticide is much higher. Exposure occurs when pesticides come into contact with the body through the skin, mouth, or by inhalation.

The reduction of exposure in developed countries involves the use of impermeable packaging and containers, closed systems for filling applicators, and barriers such as masks, goggles, respirators, rubberized clothing, boots and gloves, and sealed tractor cabins. Farmer literacy also reduces exposure as the farmer understands the dangers incurred when handling pesticides and takes rational steps to avoid them.

The idea that through education, exposure among small holder farmers in the developing world can be reduced resulted in the «Safe Use of Pesticides» paradigm promoted especially vigorously by the pesticide industry. Unfortunately, education campaigns alone do not appear to have changed farmer behavior in most of the developing world and there has been harsh criticism of the paradigm.

• *To non-target organisms*

Non-target organisms are those living creatures found on the farm or in surrounding agricultural or wild lands and bodies of water that are exposed to pesticides but are not the target of the application. The devastating effects of pesticides on non-target wildlife was brought to the world's attention by Rachel Carson in the early 1960's (Carson, 1962).

Economically important non-target species of fish, crustaceans such as shrimp, birds, pollinating and honey-producing bees, and parasitoids and predators of pests respond differently to pesticides than do human beings since they are, in most cases, only distantly related. Acute effects on fish are known for many pesticides since testing of such is required for registration in many developed countries. Some pesticides, such as insect growth regulators, may have little effect on human health but be devastating for some non-target species.

Persistence in the environment

The ***persistence*** of a pesticide in the environment after being applied refers to its capacity to resist degradation over time. Persistence is measured as the time required for 50% of the original quantity of active ingredient applied to degrade to other compounds. The statistic resulting from the measurement is known as the pesticide's ***half life.***

In soil, very persistent pesticides have half lives of decades, moderately persistent pesticides have half lives of 6 - 12 months, and pesticides with low persistence have half lives of < 6 months. On exposed plant parts, half-lives are much shorter. Pesticides degrade in the environment via oxidation, reduction, and hydrolysis processes once they come into contact with water, air, soil minerals and microorganisms.

The final products of pesticide degradation are usually carbon dioxide, water, mineral salts, and metabolites. The metabolites may be more dangerous than the original pesticide. For example, acephate, with an LD50 of 945 mg/kg degrades into methamidophos, which has an LD50 of 30 mg/kg.

A high persistence value is advantageous in pest control but is at the root of most environmental problems associated with pesticides. If the toxic compounds degrade slowly, they accumulate in ground water, soils and animal and human body tissues, this last process known as ***bio-accumulation***. Chemical compounds that accumulate in body tissue and are not excreted are found at higher concentrations in predatory species at the top of food chains, a phenomenon known as ***bio-magnification***.

Even pesticides with low persistence in the environment can contaminate superficial and subterranean water. Run-off from sprayed fields that are linked closely to waterways can result in fish kills. In very permeable, sandy soils, low-persistence pesticides can leach quickly into shallow water tables. Wildlife can be killed by eating pesticides directly, especially granular formulations, or by eating killed or weakened prey.

Environmental Mobility

Pesticides move away from the site of application through soils, through water and through the air at different rates depending upon solubility in water and oil, adsorption to soil particles, and persistence. How fast and far a pesticide particle will move is described by its ***environmental mobility.*** Pesticides that are water-soluble can move quickly into water systems. Others with high adsorbtion in soil become tightly attached to soil particles and are not likely to move into water systems.

The more persistent a pesticide, the more time it has to move through soil layers or to be transported in air currents or in water to distant destinations. It is now known that highly persistent pesticides applied in the tropical countries can accumulate in other regions of the globe where they are carried by winds aloft. Food chains well-removed from the site of application are not safe; even in polar regions, very high concentrations of toxins have been measured in polar bears, seals and the Eskimo people who hunt them. Pesticide contamination has become a truly globalized problem requiring a global solution and international cooperation.

Selectivity

Selectivity of a pesticide describes the range of pest species that it is designed to kill. ***Narrow-spectrum*** pesticides affect a few species or families, while ***broad-spectrum*** pesticides affect many families or even orders of pests.

The more highly selective a pesticide is, the fewer non-target effects it has. Pesticides with extreme selectivity, such as certain microbials, tend to have very little negative environmental or human health impact.

Development of resistance

Pest populations develop ***resistance*** to most classes of synthetic pesticides after they are used repeatedly. Resistance develops when a few individuals in a population are able to survive exposure to the pesticide because of genetic differences in their physiology, even though the pesticide is fatal to the vast majority of individuals. The survivors reproduce, and pass along their resistant genes and, if there is little immigration of non-exposed individuals into the population, the percentage of resistant types increases over time. When the first control failures occur because of resistance, the reaction of farmers is often to increase the dosage and frequency of sprays, exacerbating the problem by setting a higher bar for selection.

Resistance in a pest population develops at different speeds according to the intensity and consistency of the pesticide use, dose, genetic variability in the pest population, and the pesticide's mode of action. Some classes of pesticides provoke the development of resistance very quickly because their modes of action are more easily overcome, evolutionarily speaking, by pest physiological mechanisms.

Resistance results in losses from uncontrollable pests, increased costs from increased usage, and high environmental and health costs from desperate attempts to manage pests by overusing pesticides.

Classification

Any synthetic pesticide may be classified according to several schemes.

Classification by target organism

Table 5. Classes of pesticides according to the type of organism controlled.

Class	*Type of target organism*
Insecticide	insects
Acaricide	mites and ticks
Herbicide	weeds
Nematicide	nematodes
Rodenticide	rodents
Fungicide	fungi
Bactericide	bacteria
Molluscicide	mollusks

Classification by chemical structure of the active ingredient

In this classification scheme, pesticides are grouped into families in which all members have active ingredients with similar chemical structures.

Organochlorines are synthetic organic products whose active ingredient molecule contains chlorine. Most are very persistent in the environment and biomagnify in the food chain since they are stored in fat tissues. The majority of organochlorines are insecticides with low acute toxicity but have known chronic effects. Among these products are DDT, heptachlor, mirex, and clordane. Almost all organochlorines, with the notable exceptions of endosulfan and lindane, have been prohibited in most countries.

Most of the organochlorines found now in soil, sediment and water samples are residual deposits laid down decades ago when these pesticides were legally and widely used. Now most of them are banned from production and use in most developing countries, but they continue to be used for mosquito control and are also repackaged and sold illegally in small quantities for urban and household pests. They may be particularly dangerous in these situations, since children play in household yard soil and domestic animals such as chickens scratch up soil-dwelling insects.

Organophosphates are organic derivatives of phosphoric acid developed as insecticides. They are degraded relatively quickly in the environment but nevertheless have frequently been found in surveys of groundwater and superficial bodies of water in tropical America.

In the developing countries of Latin America and the Carribbean, organophosphates such as malathion, chlorpyriphos, and methamidophos are the group of insecticides most widely used among small holder farmers, mainly because they are cheap. Many of the most commonly used have high acute toxicity. Organophosphates inhibit the activity of cholinesterase, the enzyme required for nerve functioning. In the developing world, most insecticide poisonings related to agriculture are due to organosphophate exposure.

Carbamates are insecticides derived from carbamic acid. They have low environmental persistence but relatively high acute toxicity. They are very toxic for bees and parasitoid wasps. Carbamates act upon nerve pathways in the same way as organophosphates, but their effect is less persistent. Carbofuran, aldicarb, methomyl, and thiram are carbamates.

Pyrethroids are synthetic compounds with insecticidal action that are structurally related to the compound pyrethrum found in the flowers of a species of *Chrysanthemum*. Examples include cypermethrin, deltamethrin and permethrin.

Pyrethroids have very low persistence in the environment. Their toxicity to human beings is generally low but depends greatly on the carrier; in oil the same compound may have an LD50 level significantly below (more toxic) that of a water-based formulation.

Pyrethroids tend to be less widely used by small holder farmers for insect control than are organophosphates. They are more expensive and insects have developed resistance to them more often than they have to organophosphates.

Bipyridyls are widely used herbicides that are very soluble in water. Chemically they are classified as cationic compounds of quaternary ammonium of the molecule piridine. The most well-known bipyridyls are paraquat and diquat.

Triazines are herbicides. The most well-known compounds are atrazine and simanzine. Triazines have low systemic toxicity but are important contaminants of groundwater.

Chloroalkylthio compounds are fungicides and include captan, captafol, and folpet. Another member, thalidomide, is a notorious ***teratogen***, or deformity causing substance***.*** This characteristic is apparently not shared by other members of this class.

Dithiocarbamates are mostly fungicides, including thiram, maneb, and zineb. They are of moderate to low acute toxicity. Some are suspected carcinogens.

Others: there are other compounds used as pesticides that comprise smaller pesticide families, or are individually classified. Newer compounds, such as imidacloprid, a chloronicotinyl, are not classified within larger groups of pesticides. Imidacloprid has a moderate acute toxicity and is unlikely to be a carcinogen. Other new compounds have diverse origins, such as spinosad, which is derived from fermentation processes of fungi.

Classification by Mode of Action

A pesticide can be classified by its ***mode of action***, or method by which it contacts the vulnerable tissues of the target pest. Many misuses of pesticides occur because small holder farmers select pesticides with inappropriate modes of action for the pest he or she is confronting.

Modes of action for different types of pesticides are given in Table 6.

Classification by Mechanism of Action

The mechanism of action describes in physiological terms how a pesticide acts upon the target tissue once it has been contacted. The kinds of damage that pesticides do to pests are described in Table 7.

Classification by Acute Toxicity

WHO has recommended a classification scheme for each pesticide according to its acute toxicity (Table 8).

Table 6. Pesticide modes of action

Type of pesticide	*Mode of action*	*How it works*
insecticides and nematicides	contact	act upon contact with the cuticle
	ingestion	act upon stomach tissues once ingested.
	systemic	absorbed by the plant part in contact with the pesticide, then ***translocated*** in the plant in sufficient quantities to be effective in another location
	fumigant	penetrate as a gas into cryptic parts of the plant, but are not translocated to or stored in more distant organs or tissues
herbicide	contact	act upon contact and are not translocated in the plant. example: paraquat
	systemic	may be picked up in the soil and translocated to parts of the plant which have not been in directcontact with the herbicide example: glyphosate.
fungicide	superficial protectants	contact the pathogen's reproductive structures and impede their development

Table 7. Pesticide mechanisms of action.

Type of pesticide	*Vulnerable tissue or organ*	*Mechanism*
insecticide	central nervous system	interfere with the flow of cations along the membranes of nerve cells.
		inhibit acetyl cholinesterase, the enzyme responsible for the destruction and termination of the biologicalactivity of the neurotransmitter, acetyline
	cuticle	inhibit growth by preventing the cuticle from forming
	endocrine system	interfere with hormonal metabolism
herbicide	seed	germination inhibitors inhibit the process of protein synthesis in the seed
	leaf, stem	photosynthesis inhibitors prevent photosynthesis
	leaf, stem, root	plant growth inhibitors produce deformations in the weed or interfere with the process of cell division
	leaf, stem, root	cell respiration inhibitors: affect the enzymatic activity of the reactions that transport electrons, or interfere with ATP synthesis.
fungicide	all	lipid synthesis inhibitors: provoke changes in the quantities and nature of essential lipids found in membranes and cell walls
	all	protein synthesis inhibitors: impede the normal synthesis of certain essential proteins
	all	interfere with nuclear functioning: inhibit mitosis.

Table 8. WHO classification by acute toxicity rating.

CLASS	*ORAL LD50*		*DERMAL LD50*	
	*SOLIDS**	*LIQUIDS**	*SOLIDS**	*LIQUIDS**
Ia Extremely hazardous	5 or less	20 or less	10 or less	40 or less
Ib Highly hazardous	5-50	20-200	10-100	40-400
II Moderately hazardous	50-500	200-2000	100-1000	400-4000
III Slightly hazardous	>500	>2000	>1000	>4000

**Physical state of the ingredient or formulation classified.*

Because they tend to be cheap and broad-spectrum, Class Ia and Class Ib pesticides are very commonly used by small holder farmers in Latin America and the Caribbean, especially those listed in Table 9. Most of the pesticides requiring special vigilance are insecticides, but a few herbicides and fungicides are also represented in this group

Table 9. Most dangerous commonly used pesticides in small holder crops in tropical Latin America and the Caribbean.

WHO Class	*Type of pesticide*	*Compound*
Ia	insecticide	aldicarb
		mevinphos
		parathion
		parathion-methyl
		terbufos
	fungicide	captafol
Ib	insecticide	azinophos-methyl
		carbofuran
		methomyl
		methamidophos
		monocrotophos
		oxamyl
II	insecticide	carbaryl
		carbosulfan
		chlorpyrifos
		dimethoate
	herbicide	paraquat
		bromoxynil

Mitigating human health effects

Who is at risk?

Many members of a community are exposed to pesticides:

- The farmer who mixes and applies the pesticides with a backpack sprayer or by hand
- Field hands, including children and women, who contact plants and soils containing pesticide residues
- Children and women who wash contaminated field clothing
- All household members who live within reach of pesticide drift
- All household members who share their homes with stored pesticides or eat and drink from empty pesticide containers
- Consumers who eat produce contaminated with pesticide residues
- Community members who drink pesticide contaminated water

For many years «mitigation of human health risk from pesticides» was synonymous with «safe use of pesticides». Programs promoting «safe use» followed this logic:

- small-holders need pesticides to prevent losses.
- pesticides present certain health risks, but these risks can be mitigated if small-holders correctly handle, transport, store, apply and dispose of pesticides.
- thus small-holders need to be educated about handling, storage, disposal and the use of personal protective clothing and equipment (masks, gloves, boots, sprayers etc.) to prevent exposure to pesticides.

Despite the best efforts of the pesticide industry and the investment of millions of dollars in developing countries on «safe pesticide use» campaigns, one has only to visit the countryside in most parts of the developing world to witness their effectiveness: field hands spray dangerous pesticides barefoot, without shirts, and with a backpack sprayer leaking product down the applicator's back. Without hesitation, farmers mix synthetic pesticides in water with a bare arm. Fields are too close to homes and streams and there are few disposal facilities or recycling programs for used containers.

Small holder farmers are often not sufficiently impressed by the warning labels on pesticide containers or not sufficiently aware of chronic as well as acute toxic effects. No governments monitor ***re-entry times*** in small-holder fields or ***safe harvest intervals*** that assure minimal residues on food. Some countries are beginning to fine farmers who wash of backpack sprayers in streams and industry is beginning some pilot recycling of empty containers but these measures have limited impact so far.

In developing countries with vast numbers of semi-literate or illiterate small holder farmers lacking all but the most essential resources and subject to few regulations, unilateral focus on the «safe use» paradigm is at best a waste of resources and at worst a perpetuation of a dangerous myth, focusing attention and resources on a mitigation approach that will contribute only minimally to solving the exposure problem. Safe and effective pest management must begin by reducing synthetic pesticide applications to those needed as a last resort. Preventive pest control measures based on understanding of pest ecology and behavior should be implemented first, then synthetic pesticides should be substituted by mechanical and biological control where efficacious and safe, and finally, dangerous Class I and II pesticides should be substituted by less acutely toxic compounds used minimally and rationally according to pest population estimates.

If the use of synthetic pesticides is unavoidable, as it is for certain crop/pest combinations, a mitigation strategy for human health effects of synthetic pesticides can focus training for farmers on:

- *reducing risk*: understanding the risks presented by different products and selecting less dangerous pesticides. Visual examples of health effects have a bigger impact than the written word.
- *reducing exposure*: storing pesticides away from people and disposing safely of empty containers
- *reducing exposure*: maintaining application equipment in good shape
- *reducing exposure*: using clothing acceptable to the farmer in his/her environment
- *reducing exposure*: using pesticides only as a last resort and using lowest effective doses

Mitigating environmental impacts

More than 97% of an applied pesticide does not reach its target. Rather it moves into and through the soil, water or the air where it may degrade into another compound, or persist in its original state. It contacts non-target organisms in all environments that it enters, and may affect them or not, depending on the pesticide's mechanism of action.

Mitigating the environmental impact of pesticides begins with minimizing their use. Less pesticide applied results in less environmental impact.

Pesticides vary in the degree to which they impact the environment. Programs should campaign vigorously against the lingering use of any organochlorines prohibited by law since their impacts will be felt for generations into the future. Granular formulations in areas important for birds should not be recommended and pesticides toxic to fish should be avoided where fish populations are at risk. Where pyrethroids or imidachloprid are usable, they represent an environmentally preferable alternative to more persistent pesticides.

The way in which sprayed fields are embedded in the landscape affects environmental impacts. Run-

Case Example 10. Education on safe use of dangerous pesticides is often not enough.

Nicaragua's Pacific Plain produced thousands of hectares of highly pesticide dependent cotton until the mid 1980's. Pesticide poisonings among workers laboring in the fields and on airstrips where pesticides were loaded into crop dusters were all too common.

McConnell et al. (1992) studied the exposure of workers loading planes with organophosphate and carbamate pesticides. They compared airstrips with closed mixer-loader systems and where personal protective equipment (masks, gloves, overalls) was available to airstrips with open loading systems, no protective clothing and no training. Workers on airstrips with closed systems and protective clothing had significantly lower erythrocyte cholinesterase, indicating increased exposure to pesticides, than workers on airstrips with presumably higher exposure rates. The equipment had been used in unexpected and inappropriate ways and coveralls and impermeable gloves and boots did not prevent exposure.

off of pesticide-laden soils and sediments to streams and lakes is one of the most important routes by which surface water becomes contaminated with pesticides (Figure 73). Runoff can be slowed, even in steep regions subject to torrential tropical rains, with soil conservation practices such as sediment-trapping trenches and dense live barriers (Figure 74).

When a project has the opportunity to counsel farmers on developing new land, great care should be taken to respect minimum distances from superficial waterways such as springs, streams, rivers, lakes and estuaries. Gallery forest must be left in place and its understory vegetation conserved as a buffer between farmland and the water (Figure 75). Pesticide runoff can be minimized with broad bands of vegetation that absorb run-off water.

Surface water is directly contaminated by pesticides and fertilizers where farmers wash sprayers and empty containers, or process harvested products, in stream water. These practices should be discussed in light of the damage they do to an important resources shared by all.

Resistance management

Resistance by a pest to a pesticide occurs often and is perceived by a farmer as a change over time in the pest population that renders it uncontrollable with conventional pesticide applications, even when attacked with ever-increasing doses. Farmers generally recognize resistance when it occurs but most do not know how to avoid it.

Resistance by pests to pesticides can be avoided in theory. If a product is not used continuously through time and is used at prescribed dose levels it is difficult for a pest organism to evolve resistance to it.

The basic principle of resistance management is the rotation of pesticides between different families of

Figure 73. Sediment load clearly visible in satellite photo of the Gulf of Fonseca in Central America.

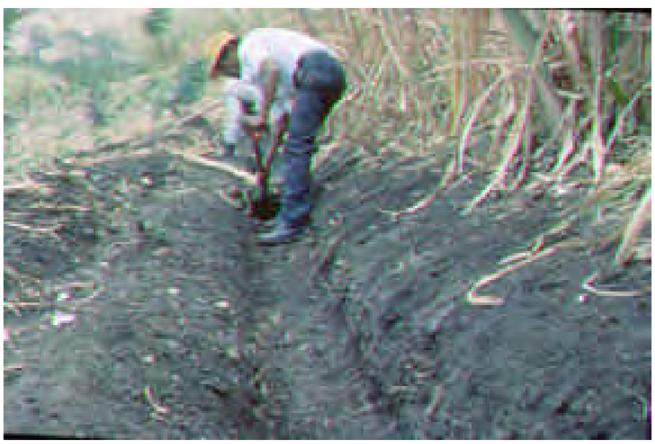


Figure 74. Sediment-trapping trench.

Figure 75. Lack of gallery forest along this river will increase run-off of pesticides into the water.

Case Example 11. Municipal actions can provide motivation to reduce pesticide impacts in the environment.

Municipal authorities who by ordinance can restrict activities that cause local, small scale environmental damage, can be important allies for a program promoting change in farmer behavior with respect to pesticides.

The small town of Conchagua, El Salvador, on the shore of the Gulf of Fonseca, has proposed a municipal ordinance that prohibits the washing of backpack sprayers in streams and rivers. This motivator works hand in hand with farmer training to improve the quality of natural resources and mitigate pesticide impacts. Eliminating direct pesticide contamination from streams flowing down the slopes of Conchagua Volcano not only improves potable water quality, but reduces fish and crustacean kills and residues in marine waters of the neighboring Gulf of Fonseca.

pesticides since mechanisms of resistance are likely to differ between families. Farmers should apply dosages recommended on the label and their application equipment should be calibrated so that the desired dose is actually applied.

In practice, among small-holders insect resistance to pesticides is a huge problem. Especially where many small plots of high value, high pesticide-use crops such as vegetables are cultivated by different farmers in close proximity, pesticide use is not coordinated and pest populations can rapidly develop resistance. Adding to the problem is a lack of cheap alternative pesticides from different families that can be rotated over a crop cycle.

Resistance management among small-holders in areas where it is a problem requires organization and cooperation among farmers. Plans for substituting biological pesticides where possible should be agreed upon and the use of synthetic pesticides where they are unavoidable should be managed by product rotation to avoid resistance.

5.2.3 Soaps, Oils and Miscellaneous Substances

Some soaps have insecticidal properties, especially toward soft-bodied insects. Commercial products based on soap are usually not available in the developing world, but the small holder may use the soap, manufactured for cleaning and washing, that he or she has at home.

The human toxicity of soaps applied as insecticides is unlikely to be a concern since the same substances are used to wash clothes or dishes, and are used at similar concentrations when applied as insecticides. Effectiveness, however, and the possibility of ***phytotoxicity***, or toxicity for the crop plant itself, is a matter for concern.

The ability to control a particular insect species will depend in part upon the type of soap, which may be potassium-based or sodium-based. Ease of application varies according to the fat base and the presentation of the soap (powder versus solid); soaps made with animal fats can produce a sticky mass that is difficult to spray. Phytotoxicity must be tested for each brand of soap and crop combination, limiting the ability to generally recommend soaps for pest control.

Oils, of mineral or vegetable origin or petroleum derivatives, can be used to suffocate soft-bodied insects such as scales or aphids, or to stop up their mouthparts. Commercial insecticidal oils are rarely available in the developing world, therefore small holders are limited to adapting locally available oils used for other purposes. Acceptable oils must meet cost, efficacy, human and environmental health, and phytotoxicity criteria. Oils used for cooking are too valuable to be used on a large scale. Kerosene is somewhat cheaper and is used for ground-dwelling pest ants, but economics reduce its use to a very limited scale. Used motor oil poured into the ground for ant control is a dangerous carcinogen and should not be handled by small holder farmers. All oils are potentially phytotoxic and must be tested at used concentrations for each crop before they can be recommended.

Other substances such as ashes, lime, steam and boiling water are very widely used by small holder farmers to manage soil-borne diseases, especially in seedbeds and nurseries. Their safety to the environment and to the people who handle them has not been questioned seriously. Limited but valuable efficacy has been documented for these substances against some pathogens when properly used.

Chapter 6
Programming Guidelines

6.1 The policy framework

Just as a small holder farmer's economic and social context influences decisions about pest management, so do policies, laws and regulations. It can be argued that enlightened policies are the most powerful tool for changing small holder pest management practices and regressive policies constitute the most difficult obstacle to change.

The costs of pesticide contamination to society have rarely been completely estimated. Such an effort requires placing monetary values on loss of life and work-time, loss of biodiversity, loss of economically important wildlife such as fish, and health effects from contaminated drinking water. In the few cases where such efforts have been made, the costs to society have been found to be steep. Pimentel and Grenier (1997) estimated that pesticide contamination in the United States costs society $8.346 billion per year. For every $1 that farmers spend in direct costs for pesticides, society pays an additional $1-$1.5. In other words, pesticide costs are subsidized by 100-150%.

Policies create a framework of incentives and disincentives that influence pesticide users in their choices and regulations implement the policies.

6.1.1 National policies and regulations

Pesticide registration

Every country regulates pesticide importation, manufacture, labeling, and sale through a process of registration. Pesticide registration regulations are designed in part to limit use of pesticides considered too dangerous for the farmer, the consumer or the environment. In most developing countries the registration authority lies within the productive sector, usually the Ministry of Agriculture. The participation of the health and environmental sectors in the decision-making process is usually, but not always, quite limited. As such, societal costs are often *not* considered in product registration regulations.

Pesticide registration decisions in developing countries usually track decisions made in the developed world. Toxicological and environmental data are too expensive to be generated in country, and so the probable impact of pesticides must be extrapolated to different climates and social settings. Toxicological risk varies little but the probability of exposure certainly does. Many products legally used in the developed world with few consequences are too dangerous to be used by small holder farmers.

Regulation of agronomic practices

Regulations that mandate particular agronomic practices are used in area-wide pest management programs. These include ***plow-down dates***, or dates by which crop residues must be incorporated into the soil in order to eliminate habitat for insect pests. Crop bans by region or by date are also mandated when it is deemed essential to break up uncontrollable population increases. To be successful, these practices require political will to face the unpopular, and financial resources for enforcement and for massive public education. In Latin America and the Caribbean, they have been successfully used in crops susceptible to devastating outbreaks of whitefly, such as tomato and pepper, and in cotton.

Some policies work toward the reduction of pesticide use in a straightforward way. The development of national standards for organic production and organic goods labeling often include funding for promotion of organic production. By its nature, the institutionalizing of organic standards facilitates the marketing of organically produced goods.

Quarantine regulations

Quarantine regulations regulate, the movement of pest-bearing foodstuffs, soil, and plant parts between countries or between regions within a country. They are designed to prevent the introduction of new pests.

Enforcement of quarantine regulations requires public education campaigns, inspections and fumigations at borders and a system of permits for legal introductions. Undoubtedly, quarantine efforts have been a very powerful preventive pest management tool for many pests.

Tax policy

Economic policy instruments include taxes on pesticides. Some developed countries, such as Sweden, apply taxes on pesticides to «internalize the externalities», so that farmers face the real cost that society incurs for pesticide contamination. The case in developing countries is frequently the contrary; because farmers are the poorest segment of society, government policy is often to subsidize agricultural inputs, including pesticides, believing in addition that subsidies will boost yields, reduce food insecurity and poverty.

Other indirect subsidies include preferential exchange rates for pesticides and subsidies on inputs like pesticide application equipment.

Credit policy

Certain credit policies are subtle but powerful promoters of pesticides. Programs designed to boost agricultural production through subsidized rural credit are quite common. Often such programs tie the subsidized credit to the use of certain technology packages, sometimes including heavy use of pesticides. Farmers may face penalization for deviating from the package, guaranteeing the use of pesticides by those who sought credit on favorable terms.

Other policies

Giveaway programs as part of national production policy may have international donor money behind them, in the form of subsidized credit or the direct provision of pesticides for distribution. Most donors have desisted in direct provision of pesticides during the last ten years, with several notorious exceptions.

During and after natural disasters such as hurricanes, earthquakes or floods, the policies ordinarily employed by relief agencies and their donors and by national governments may be suspended and unusual flows of pesticides to affected areas can occur. Vector control and an emergency boost to recover agricultural production are rationale but, for years after the disaster has passed, warehouses remain stocked with dangerous pesticides which make their way into small holder farmer hands.

6.1.2 International Agreements

A number of important international agreements or conventions contribute to limiting pesticide hazards in participating and ratifying developing countries. The agreements cover information exchange, trade issues related to pesticide residues, and trade of pesticides dangerous to human health or to the environment. They provide a framework for national policies and compliance can be monitored by civil society.

Prior Informed Consent Procedure

The ***Prior Informed Consent (PIC)*** procedure was developed chiefly by the United Nations Environment Program (*UNEP*) and the Food and Agriculture Organization (*FAO*) of the United Nations (*UN*). It improves safeguards for health and the environment, needed because of global trade in pesticides and industrial chemicals, especially in those substances banned or severely restricted in the manufacturing country and exported to countries with weak information or regulatory systems. The PIC Procedure became a legally-binding convention in March, 1998.

Under the procedure, a participating country notifies the Joint UNEP/FAO Secretariat of its domestic actions banning or severely restricting the use of a particular chemical. UNEP/FAO then notifies participating importing countries, and the importing country indicates whether, or under what conditions, it would accept further shipment of the chemical.

Currently there are five industrial chemicals, 17 pesticides (active ingredients) and five pesticide formulations on the PIC list.

Codex Alimentarius

The ***Codex Alimentarius*** is a joint FAO/WHO program designed to protect the health of consumers and to ensure fair practices in food trade. It develops and updates international food safety standards, including maximum residue limit (MRL) recommendations. These limits recommend permissible levels for pesticide residues on food.

National governments can choose whether or not to use the Codex MRL in food quality monitoring programs.

Stockholm Convention on Persistent Organic Pollutants (POPs)

Over 100 countries negotiated the *Stockholm Convention,* mandating actions to reduce contamination from ***persistant organic pollutants*** **(POPS),** some of which are organochlorine pesticides. The Convention subscribers agree to stop producing persistent pesticides and industrial chemicals; the initial list named twelve POPs: aldrin, chlordane, DDT, dieldrin, dioxins, endrin, furans, heptachlor, hexachlorobenzene, mirex, polychlorinated biphenyls (PCBs) and toxaphene.

Basil Convention on Transport of Hazardous Substances

The Basil agreement covers the movement of pesticides across borders. It has been important in recent years when removal of stocks of POPs and outdated pesticides required transporting those pesticides through several countries in order to reach ports.

6.1.3 Donor Policies

Many institutions donating funds or implementing sustainable agriculture programs with farmers have developed policies regarding pesticides and pest management. Among them are the United States government's *Regulation 216* (Annex 1), policies used by the governments of Switzerland and The Netherlands and by the World Bank, and CARE's *Pesticide and Pest Management Policy* (Annex 2). These policies reflect institutional commitment to reducing the hazards of pesticides used in developing countries, while seeking to encourage the use of better, alternative crop protection tactics. Some are quite proscriptive (lists of banned pesticides), while others provide comprehensive orientation toward safe and effective pest management.

6.2 Building capability in pest management

Pest management is a specialized field of work. Non-governmental programs that engage the small holder in pest management improvement activities will need to establish and maintain partnerships with researchers and research institutions, NGO's confronting similar problems, and educators in order to build expertise for particular problems. Time invested in networking over pest management problems and solutions pays off.

Before engaging in a sustained collaboration, it is important to discuss pest management goals. A partner institution's vision and mission will influence its views of what constitutes «better» pest management. Most discussion will probably center upon the issue of self-reliance, as it is manifested in the use of tools such as botanical pesticides versus purchased inputs. A self-reliance based paradigm may conflict with another that prioritizes increasing net returns to farmers, while reducing health and environmental risks.

Knowledge should flow both ways in any relationship with the national extension service. While the extension service has its finger on the pulse of farmer practices and needs, its personnel may need updating on management tools, pest biology and ecology and on innovative and effective adult education techniques. Whenever possible, programs should work with the permanent national extension service to strengthen agents skills. Extension agents are often bypassed in an effort to work directly with farmers, yet their influence is considerable.

Health and environment sector actors are natural allies for agricultural programs that include the reduction of synthetic pesticide use and mitigation activities in their agendas. Interdisciplinary programs in which pest management is improved while safeguarding occupational health and protecting the environment are important mechanisms for change.

Alliances with government and university researchers who investigate better pest management options should ideally be developed from the outset of any intervention with small holder farmers. Funding for research is usually approved only after a long development, revision and review process.

6.3 Effective activities for improving pest management

The only actor who can implement safe and effective pest management on the farm, albeit within limits governed by policy and regulations, is the farmer. If the farmer is not convinced of the need to change pest management practices for the better, he/she will not do it. It is incumbent upon the promoting institution to work with the farmer not only so that he/she knows how to manage pests in a way best for all involved but furthermore so that he/she will want to do that. Certain program approaches and activities have been found to best result in the desired outcome, implementation.

Facilitated Learning

Traditional small holder farmers generally have a great capacity to observe and interest in their environment. Learning by discovery has been found to be stimulating and satisfactory for farmers, as it is for most other people. It does not mean that the trainer never provides answers, but that the major findings are often based on farmer observations and interpretations. Pest biology, parasitism and predation, alternate hosts, pest identification, disease symptoms, sampling for population size, seedbed preparation are examples of concepts that can be understood best by collection, practice, and observation in the field rather than in the classroom. Group activities that encourage interpersonal dynamics create a good climate for open discussion and learning.

The facilitator should understand his or her role as a promoter of participation, self-esteem, critical thinking, and decision making among the farmers. On the other hand, the facilitator is also an educator; he or she must be careful to ensure that wrong information does not propagate itself simply because it was offered by a farmer. Farmers should leave the sessions more knowledgeable about their agroecosystems than they were at the outset.

Successful learning-by-discovery sessions require preparatory effort on the part of the facilitator. Facilitators will need training in order to successfully carry out their missions. Guided sessions will work if the trainer knows what the farmer will find ahead of time, and materials and living organisms may need to be collected.

Continuity in learning throughout a growing season leads to higher rates of change in small holder practices. The ***farmer field school (FFS)*** model of small holder learning in pest management, developed first in Asia for rice (Matteson, 2000) and now implemented throughout Asia and in parts of Latin America and Af-

Case Example 12. Farmer Field School efforts for potato farmers in the Andean countries.

Farmers in the Andean countries Bolivia, Peru and Ecuador must combat numerous insect pests and diseases of potatoes in the field and in storage. In an effort to reduce dependence on pesticides and implement IPM, Farmer Field Schools (FFS) have been supported by the International Potato Center (CIP) in collaboration with national organizations and the FAO over the past decade. The tools that FFS facilitators have developed to teach IPM concepts and practices include simple experiments, role-playing, and learning-by-doing exercises. The tools have been collected in a guidebook, titled «*Herramientas de Aprendizaje para Facilitadores*», published in 2000 by INIAP (Ecuador) and CIP. It is an excellent sourcebook for working with potato farmers in particular and is a model for capturing teaching tools for future needs applicable to all crops around the world.

rica, successfully builds its program upon farmer discovery of pest ecology and guides farmers in ecologically-based management through hands on application.

Training activities: choosing and handling pesticides

Small holder farmers need training on pesticides, even if a program's goal is low or zero use. Farmers will undoubtedly find themselves at some point in a situation in another crop, or as paid laborers, in which contact with pesticides is hard to avoid.

The most important material to cover with farmers consists of:

- the dangers of synthetic pesticides to human health
- how to interpret a pesticide label
- how to correctly choose an effective synthetic pesticide for a particular pest problem
- how to choose a less dangerous pesticide
- when to use synthetic pesticides, and when not to
- proper ways to store products and dispose of containers
- how to maintain sprayers and other application equipment
- best clothing options for reducing exposure
- how to reduce exposure in the farmer household

Formation and support of small holder groups

Discussions among small holders confronting similar problems can be very useful for debating relative success with different pest management methods. Maintaining group attendance can be a challenge but especially when financial, (e.g. credit) issues are involved, small-holders may see them as frankly necessary.

Some pests can only be effectively managed over a wide area. Management coordination among farmers can be promoted on a local scale and groups can also collaborate with eradication programs such as those for screw-worm, Mediterranean fruit fly, and boll weevil.

Small-holder participation in on-farm research

Improvements in pest management through time will stall without research. Farmers can and should be involved in the research process in order to increase the chances of high adoption rates. The best model for research development appears to depend upon a three way interaction between the farmer, the extension agent, and the professional researcher.

Importance of the problem to investigate

The extension service is the eyes and ears in the field and the funnel through which many farmer opinions are collected. The relative magnitude of different problems can best be understood through their insight and the collection of national and regional statistics.

Developing ideas for new pest management solutions

All actors contribute the basic research plan

- the farmer contributes a personal and local view toward tactics that could be researched, especially as concerns economic and social acceptability
- the researcher brings to the table an ecological and economic analysis of the pest problem that helps to predict the effectiveness of possible solutions, success stories from elsewhere and knowledge of ideas that have not worked

- the extension agent contributes an opinion of regional or national acceptability and will in the end be responsible for dissemination.

Conducting the research

Small holder farmers are more and more commonly involved in data taking in the field research phase and their continuous input throughout the process has been found to be useful.

Validation

Validations of pest management methods conducted with the participation of small holder farmers on their own land are more cost-effective than the traditional «demonstration plot» managed entirely by an extension agent. Simple comparisons between management strategies related by the small holder him/herself are highly useful for convincing key members of a community.

Didactic materials

There are now extensionist-oriented IPM guides for almost all tropical New World crops. Since pests vary from place to place, the best of these will be written within country or in a neighboring country.

Basic written and photographic guides to pest identification and simple, crop-based pest management guides for small holders may well need to be published or updated. Pamphlets documenting quantitative details such as doses and sampling methods are important tools.

Videos documenting pesticide effects on people and the environment are a powerful tool for motivating change. Farmers participating in an IPM program in Chinandega- Leon, Nicaragua, stated that they were deeply affected by videotaped interviews with people suffering the effects of pesticides and by graphic pictures of the results of intoxication and chronic exposure among farmer peers.

Formal education for small holder youth

Rural youth attending technical schools can be a good conduit for technical information within their communities. Support for attendance and support for improving the quality of their training in safe and effective pest management are effective project activities.

Land tenure stabilization programs

The more stable the relationship between the small holder farmer and the land he/she works, the more likely that long-term land use planning will occur and preventive strategies such as plant diversification will be implemented. Any activities that strengthen titling programs will contribute to better pest management in the long term.

Credit programs

Credit programs often facilitate funds for pest management. Monetary loans can be tied to a «technological package» that pays for labor needed for mechanical pest control. In-kind credit programs can promote biological pesticides, pruning implements, non-chemical disinfectants, seeds for diversification, fertilizers, and irrigation equipment. A truly progressive, albeit more expensive, credit program oriented toward improving pest management would offer access to soil testing and diagnostic tests for unknown diseases in order to rationalize pesticide use.

Timely and stable access to credit in general facilitates a more diversified and ecologically based approach to pest management in that farmers can plan their activities in advance and employ more preventive action.

Niche-marketing

Programs can work directly with farmers to obtain financial rewards for zero synthetic pesticide use.

Case Example 13: CARE Nicaragua program influences government pesticide policy.

The CARE Nicaragua project described in Case Example 4 influenced not only farmer knowledge and practice regarding pesticides and pest management, but also pesticide policy in Nicaragua and throughout Central America. The project staff engaged government officials on the issue of pesticide policies. In the late 1980s project staff pointed out the overuse of pesticides by resource-poor farmers, due in large part to the policies that made pesticides virtually free to farmers (Hruska 1989). The concern about overuse of pesticides was overweighed by the pressing economic and social situation in the country at the time. Not all the efforts were successful, but the discussions helped raise the profile of the pesticide/IPM project among the Nicaraguan government and staff members were invited to join the national Pesticides Commission.

The CARE staff members brought to the Commission a valuable perspective, along with new information and data from the field project. These contributions helped shape the drafting of a new Pesticide Law, which grew out of the Commission's work. The new law provided the Ministry of Health a role in the pesticide registration process for the first time. The Ministry could deny registration based on evidence of important human health risks posed by the pesticide. Before this change in the law, the Ministry of Agriculture decided unilaterally about pesticide registration, and based their decisions only on product efficacy.

The CARE experience influenced practices in other Central American countries. The CARE project was used as a model for the development of a regional pesticides program, PLAGSALUD. CARE staff were invited to help design the project and the Public Health Specialist for the CARE project later became the country coordinator for PLAGSALUD in Nicaragua. Many of the lessons learned and best practices developed by the CARE project were adopted by PLAGSALUD and applied across the region.

The certified organic niche-market motivates the elimination of synthetic pesticides and the development and use of alternative tactics by paying premium prices for zero pesticide and synthetic fertilizer use. Farmers working in the certified organic niche develop and validate zero pesticide management technology, some of which can be adopted by a broader base of conventional farmers who cannot commit their farms entirely to organic production.

Stakeholder meetings to establish lo/notox goals and pathways

Stakeholder meetings resulting from acutely felt problems around pesticide contamination can lead to establishing goals shared by the inhabitants of a community or a watershed. Strategies for successful meetings are promoted by the FAO IPM Facility.

Advocacy and national and international policy

Program efforts to empower small-holders to make better pest management choices can be undermined by policies that promote or facilitate pesticide use. On the other hand, successful pesticide reduction and replacement programs can positively influence the development of policy either through results or by combining work with farmers and policymakers.

Program activities with impact at the policy level include:

- lobbying against pesticide giveaway programs and subsidies for synthetic pesticides.
- funding and implementing studies to determine the true costs and benefits of pest management tactics, to be used as basic information for policy development
- educating decision-makers about the true costs of pesticides.
- lobbying donors to ensure that their aid programs don't promote pesticides
- providing expert input to the formulation of laws related to pesticide issues.
- publishing statistics indicating pesticide use patterns and intoxication patterns that can be used to support policy decisions.
- supporting associations of institutions concerned with pesticide issues and fora for the interchange of opinion.

Where programs have sought to contribute to the formation of national or international policy, their impact may be measured by final products or progress toward

- well-wrought policies based on the societal costs and benefits of pesticide use and safe pest management options
- policy-maker understanding of the issues
- policy-maker commitment to suitable solutions

Publish results in widely-distributed media

Poor access to published information on pest management is a serious limitation for professionals. Research plans do not benefit from gleaning the experiences of related activities published in neighboring countries or even neighboring institutions. Access to the internet solves only part of the problem.

The only widely available and permanent source of information for researchers are reviewed journals, available with some difficulty but available, through university library linkages. The «gray literature», reports and meeting summaries, may be highly relevant because it is generated more locally, but because limited copies are printed, it is collected by individuals and local libraries and access is difficult.

An important contribution to promoting the goals of safe and effective pest management worldwide is the publication of results of research and implementation among small holder farmers. Convincing studies are the only viable tool available to counter the myths that small holder farmers will not or do not give up the use of synthetic pesticides and that there are no viable alternatives to synthetic pesticides for pest management..

6.4 Pest management program evaluation

Effective pest management programs rely on constant evaluation in order to improve. Policy contexts and social and economic constraints vary among crops, markets, and nations; as such, no formula guarantees that small holder farmers will reduce and rationalize synthetic pesticide use and implement alternative effective methods. A climate of open questioning, self-evaluation, reflection and modified action based on results must be continuously nurtured.

Well-designed programs will have conducted a ***baseline study*** that describes the «before» state of small holder pest management practices and their economic and social well-being. In the absence of a baseline study, groups «with» and «without» participation in a program can be compared, but an adequate design controlling for the many independent factors is necessary.

The indicators of program impact will depend ultimately on the objectives and pest management paradigm developed by the promoting institution. Generally speaking, we expect that a program will help the small holder

- manage pests more effectively to reduce losses and maximize net income
- use new knowledge to make wiser decisions
- develop a broadened attitude toward management options
- obtain in the short and long term, economic, social and environmental benefits.

The final, measurable indicators of economic impact include change in:

- pest management costs
- marketable yield
- net income
- risk of yield loss

Final measurable indicators of environmental and social impact at a community level include change in:

- the number of acute intoxications per unit time
- pesticide residue levels in food and fiber
- pesticide residue levels in soil and water

Intermediate indicators of program impact on knowledge, attitude and practices can be

- ability to
  - identify pests and natural enemies and relate important aspects of their biology and ecology.
  - understand the relationship between the crop and the pests, including concepts of critical periods of infestation, types of damage, damage thresholds and plant response to infestation.

- awareness of the dangers of pesticides
- adoption of alternative control tactics
- confidence in decision-making
- dependence on recommendations from extension agents or pesticide salesmen
- skill in analyzing threatening pest situations and responding correctly to them
- best choice in the use of pesticides

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Glossary

abiotic mortality factor: environmental factor, such as rain, wind, excessive temperature or radiation from the sun, that reduces a pest population.

active ingredient: biologically active component of a pesticide formulation.

acute effect: immediate health damage after one or several short-term exposures to a pesticide.

acute toxicity: property of a pesticide related to its capacity to result in acute effects.

acute toxicity rating: measurement of a pesticide's acute toxicity based on its calculated median lethal dose.

adjuvant: compound that improves the efficacy and stability of a pesticide's active ingredient

alley cropping: pattern of planting in which the areas between crop rows (alleys) are used to produce a useful plant as a crop or for fertilization and mulching purposes.

agroforestry system: polycultural planting pattern that combines crops and trees for forestry products.

antagonist: beneficial microorganism that competes with or otherwise limits plant pathogen population growth.

antagonistic soil: soil in which antagonistic microorganisms have built up and are capable of limiting soil pathogen population growth and activity.

approved common name: pesticide name authorized by an international or national regulatory organization

area-wide management: programs implemented in situations requiring broad operational arenas, including pest eradication and crop-free mandated periods, and localized control of migratory species.

auxiliary substance: substance of organic or mineral origin that optimizes the effect of pesticide's active ingredient during and after the field application

bio-accumulation: process by which pesticides accumulate in body tissues, especially fat.

bio-magnification: phenomenon in which pesticides are found at higher concentrations in predatory species at the top of food chains.

biological pest control: strategy that uses living organisms (plants, animals, or pathogens) or their byproducts or components to suppress or repel pest populations.

biological pesticide: living organisms or their by-products that are applied or released in large numbers or amounts into a pest population for immediate control purposes.

botanical pesticide: plant extract or other plant preparation used as a pesticide.

broad-spectrum pesticide: pesticide that affects a large number of pest species and families.

chemical name: name of the molecule comprising the active ingredient of a pesticide.

chronic effect: health damage related to a pesticide that appears long after exposure.

chronic pest: pest that always or almost always finds and affects the host plant in a particular field.

chronic toxicity: property of a pesticide related to its capacity to result in chronic health effects.

clinical eye: ability to quickly and representatively estimate pest population density by eyeballing the crop.

conidium: spore-like reproductive and dispersal unit of an insect pathogenic fungus.

conservation of natural enemies: actions taken by the farmer to avoid harming naturally occurring populations of pest natural enemies or to encourage increases in their population size or effectiveness.

cover crop: plant used in a cropping system to suppress weeds.

critical period: sensitive period during the crop plant life history during which economically important pest damage occurs.

crop-free mandated period: period of time (usually months) during which the planting of a certain crop or group of related crops is prohibited by law.

cultural pest management: manipulation of the productive environment carried out to make it less favorable for pests.

curative tactic: action that the farmer takes when a pest population is already present at levels sufficient to cause economic damage or soon to pass an economic injury level.

direct damage: discoloration or other cosmetic damage, perforations, or rotting in the product that we directly consume.

economic injury level: population density for a pest species at which the value placed on crop losses caused is greater than the cost of control.

entomopathogenic fungus: fungus that infects and kills insects.

entry points: orifices or organs through which pesticides enter the human body: skin (dermal), mouth (ingestion), nose (inhalation) and eyes.

environmental mobility: property of a pesticide that describes how fast and far it will move once applied in the environment.

exposure: pesticide contact with the human body through the skin, eyes, mouth, or by inhalation.

farmer field school: model of small holder learning in pest management based upon farmer discovery of pest ecology and learning ecologically-based management through hands on, continuous application.

formulation: mixture of several substances that perform specific functions.

fumigant: class of pesticide formulation, members of which are used to gasify and sterilize closed areas.

generalist pest: : pest with a broad host range.

genetically-based resistance: inherited capability of a crop plant to resist or tolerate pest damage.

half life: time required for 50% of the original quantity of pesticide active ingredient applied in the environment to degrade to other compounds.

host range: restricted number of plant species that a pest species has evolved to consume or otherwise use during all stages in its life cycle.

indirect damage: damage to parts of the plant not directly consumed; caused by pests that feed on or infect the foliage, stem or root.

induced pest: an organism that under previous conditions was not a pest; usually caused by an excessive or misdirected use of synthetic pesticides that has eliminated the regulating natural enemy complex.

inert carrier: medium with no biological activity in which a pesticide's active ingredient is diluted or mixed.

intercrop: pattern of planting more than one crop together in the same field in alternating rows or similar variation.

invasive pest: pest organism that colonizes the crop suddenly in massive numbers with usually very destructive results.

key pest: within a complex of various pests affecting a single crop or system, the species that consistently causes the most economic damage.

life cycle: all stages in the life of an organism.

limiting factor: abiotic or biotic factor that curbs the limitless growth of a population that would occur in its absence.

live barrier: facing on terrace, field division, or windbreak made with densely planted grasses or shrubs. Used to prevent movement of water, wind, soil or pests.

live fence: fence in which living trees are used as posts.

mechanical control: removal of a pest by hand or with some kind of implement.

mechanism of action: physiological means by which a pesticide acts upon the target tissue once it has been contacted.

median lethal concentration (LC50): the pesticide dose that is capable of killing one half of the study population in aquatic testing conditions or in inhalation studies during a determined period of exposure.

median lethal dose (LD50): the dose (mg/kg body weight) administered via mouth (oral LD50**)** or skin (dermal LD50) to laboratory rats that is capable of killing one half of the study population during a determined period of exposure.

microbial control agent: active ingredient in a microbial pesticide or naturally occurring microbial natural enemy. Agents can be fungi, bacteria, protozoa, viruses or nematodes.

microbial pest control: strategy that uses living microbial organisms (bacteria, viruses, fungi, protozoa, or nematodes) or their byproducts or components to suppress or repel pest populations

microbial pesticide: pesticide whose active ingredient is a living microorganism or its by-product. Microbial pesticides cause disease in the pest or kill it with toxins produced by the microorganism.

migratory pest: pest that travels over long distances to establish itself in the host crop.

mode of action: method by which a pesticide contacts the vulnerable tissues of a target pest.

monoculture: pattern of planting only one type of crop or crop variety in a field.

monophagous: feeding pattern in which only one plant species is consumed.

narrow-spectrum pesticide: pesticide that affects a few pest species usually in the same family.

natural control: component of pest control exercised by natural enemies and abiotic factors, without the intervention of the farmer.

natural enemy: organism that consumes, infects or competes with a pest organism.

non-target organism: organism in the crop environment or outside of it that is not the object of pest control.

parasitoid: wasp or fly that kills a pest by using it as food for its offspring. The offspring develop in or on the pest.

persistence (environmental): capacity of a pesticide applied in the environment to resist degradation over time.

persistent organic pollutants*:* internationally recognized and scrutinized group of compounds with excessive persistence in the environment, including but not limited to most organochlorine pesticides.

pest: any insect, mite, mollusk, rodent, bird, mammal, weedy or parasitic plant, plant pathogen, or nematode that negatively affects crop yield.

pesticide: any substance or entity designed and used deliberately to kill or impede the development or reproduction of organisms considered pests.

pesticide drift: movement of an applied pesticide through the air to areas outside the crop.

pesticide treadmill: syndrome in which pesticide resistance develops, ever higher doses are needed, and new pests are induced from the background species mix.

pheromone: chemical produced by an insect to attract individuals of the opposite sex.

phytoplasma: microscopic pathogens that enter the plant via the mouthparts of insect vectors or through seed.

phytotoxicity: property of a pesticide that causes a negative effect on a crop plant.

plow-down dates: mandated dates by which crop residues must be incorporated into the soil in order to eliminate habitat for pests.

polyculture: system of planting in which more than one crop species and other plant species are combined in the same field.

polyphagous: feeding pattern in which many species of host plants are consumed.

predator: adult or immature invertebrate or vertebrate that kills the pest by consuming it directly.

preventive management: pest management strategy that builds upon a biological and ecological knowledge base to implement cultural management, genetic resistance, and the protection and nurturing of a pest's natural enemies.

primary damage: damage caused by a pest directly to the crop.

quarantine regulations: regulations prohibiting or regulating the movement of pest-bearing foodstuffs, soil, and plant parts between countries or between regions within a country.

random sample: subset of a population selected without prejudice which, if large enough, should accurately represent the whole population.

re-entry time: period of time between a pesticide application and the point at which field laborers should be allowed to re-enter the sprayed field. Residues are considered to be non-hazardous to human health at this point.

resistance: capability of a pest population to escape a pesticide's killing ability.

restricted use pesticide: category of pesticides designated by USEPA. Pesticides classified as restricted use can only be used by licensed applicators for specific uses.

risk: probability that an adverse effect will result from a given exposure to a pesticide.

risk factor: characteristic of a person or variable in a person's behavior known to influence the risk attributed to a given pesticide.

safe harvest interval: period of time between last pesticide application and harvest during which it is considered that pesticide residues have diminished to levels safe for the consumer.

sampling unit: life stage of the pest that is vulnerable to the management tactics available (eg. small larvae, egg, weed seedlings) or other indicator of its presence in the crop.

saprophyte: organism consuming dead plant material.

sampling: process of observing a crop regularly to determine pest population density and status of other variables in the agroecosystem.

secondary damage: damage caused by a pest that can affect the plant only after primary damage has been caused by another organism

secondary pest: pest that causes economically minor damage, relative to the key pest.

selectivity: property of a pesticide that describes the range of pest species that it is designed to kill.

shelf-life: period of time during which a packaged product remains viable.

solarization: use of the sun's radiation to sterilize soil.

specialist pest: pest with a very narrow host plant range.

sporadic pest: pest that attacks the crop in an irregular fashion, not always present.

strain differences (in microbial control agents): geographic differences in genetic makeup.

strip-crop: pattern of planting in which groups of rows of one crop (strips) are alternated with strips of another crop. Several crops may be involved.

synergist: compound that increase the efficacy of two substances beyond the summed efficacy of the two substances acting alone.

synthetic pesticide: compound for killing pests that is manufactured through a process of chemical synthesis.

teratogen: substance that causes deformities.

trade name: pesticide name given by the product's manufacturer.

transgenic crop variety: variety containing genetic material natural to another species. In pest resistant transgenic crops, the genetic material confers resistance to insects, weeds or pathogens.

trap crop: strips or areas of crop plants that are more attractive to the pest than is the principal crop.

trap vegetation: strips or areas of non-crop plants that are more attractive to the pest than is the crop.

trophic relationships: the links between organisms at different levels in the food chain, eg between predator and prey, herbivore and plant.

List of Acronyms and Abbreviations

BT	*Bacillus thuringiensis*
CATIE	International Center for Tropical Agricultural Research and Education
CIAL	Local Agricultural Research Committee
CIAT	International Center for Tropical Research
CIP	International Center for the Potato
CIBC	Commonwealth Institute for Biological Control
COSUDE	Swiss Agency for Development Cooperation
EIL	economic injury level
EPA	Environmental Protection Agency
FHIA	Honduran Foundation for Agricultural Research
FAO	Food and Agriculture Organization (of the UN)
FFS	Farmer Field School
GV	granulosis virus
GMO	genetically modified organism
IARC	International Agency for Research on Cancer
IPM	integrated pest management
MRL	maximum residue limit
NPV	nuclear polyhedrosis virus
PAN	Pesticide Action Network
PIC	prior informed consent
POPS	persistent organic pollutants
PVO	private volunteer organization
RUP	restricted use pesticide
UN	United Nations
UNEP	United Nations Environment Program
WHO	World Health Organization

Annexes

Annex 1. Sections of regulation 216 relevant to pesticide use in the developing world (sections 216.3(a)(10)(b)).

(b) Pesticide Procedures

(1) Project Assistance. Except as provided in §216.3 (b)(2), all proposed projects involving assistance for the procurement or use, or both, of pesticides shall be subject to the procedures prescribed in §216.3(b)(l)(i) through (v).

These procedures shall also apply, to the extent permitted by agreements entered into by A.I.D. before the effective date of these pesticide procedures, to such projects that have been authorized but for which pesticides have not been procured as of the effective date of these pesticide procedures.

(i) When a project includes assistance for procurement or use, or both, of pesticides registered for the same or similar uses by USEPA without restriction, the Initial Environmental Examination for the project shall include a separate section evaluating the economic, social and environmental risks and benefits of the planned pesticide use to determine whether the use may result in significant environmental impact. Factors to be considered in such an evaluation shall include, but not be limited to the following:

(a) The USEPA registration status of the requested pesticide; (b) The basis for selection of the requested pesticide;

(c) The extent to which the proposed pesticide use is part of an integrated pest management program;

(d) The proposed method or methods of application, including availability of appropriate application and safety equipment;

(e) Any acute and long-term toxicological hazards, either human or environmental, associated with the proposed use and measures available to minimize such hazards;

(f) The effectiveness of the requested pesticide for the proposed use;

(g) Compatibility of the proposed pesticide with target and nontarget ecosystems;

(h) The conditions under which the pesticide is to be used, including climate, flora, fauna, geography, hydrology, and soils;

(i) The availability and effectiveness of other pesticides or nonchemical control methods;

(j) The requesting country's ability to regulate or control the distribution, storage, use and disposal of the requested pesticide;

(k) The provisions made for training of users and applicators; and

(l) The provisions made for monitoring the use and effectiveness of the pesticide.

In those cases where the evaluation of the proposed pesticide use in the Initial Environmental Examination indicates that the use will significantly effect the human environment, the Threshold Decision will include a recommendation for the preparation of an Environmental Assessment or Environmental Impact Statement, as appropriate. In the event a decision is made to approve the planned pesticide use, the Project Paper shall include to the extent practicable, provisions designed to mitigate potential adverse effects of the pesticide. When the pesticide evaluation section of the Initial Environmental Examination does not indicate a potentially unreasonable risk arising from the pesticide use, an Environmental Assessment or Environmental Impact Statement shall nevertheless

be prepared if the environmental effects of the project otherwise require further assessment.

(ii) When a project includes assistance for the procurement or use, or both, of any pesticide registered for the same or similar uses in the United States but the proposed use is restricted by the USEPA on the basis of user hazard, the procedures set forth in §216.3(b)(1)(i) above will be followed. In addition, the Initial Environmental Examination will include an evaluation of the user hazards associated with the proposed USEPA restricted uses to ensure that the implementation plan which is contained in the Project Paper incorporates provisions for making the recipient 191 government aware of these risks and providing, if necessary, such technical assistance as may be required to mitigate these risks. If the proposed pesticide use is also restricted on a basis other than user hazard, the procedures in §216.3(b)(l)(iii) shall be followed in lieu of the procedures in this section.

(iii) If the project includes assistance for the procurement or use, or both of:

(a) Any pesticide other than one registered for the same or similar uses by USEPA without restriction or for restricted use on the basis of user hazard; or

(b) Any pesticide for which a notice of rebuttable presumption against reregistration, notice of intent to cancel, or notice of intent to suspend has been issued by USEPA, The Threshold Decision will provide for the preparation of an Environmental Assessment or Environmental Impact Statement, as appropriate (§216.6(a)).

The EA or EIS shall include, but not be limited to, an analysis of the factors identified in §216.3(b)(l)(i) above.

(iv) Notwithstanding the provisions of §216.3(b)(l)(i) through (iii) above, if the project includes assistance for the procurement or use, or both, of a pesticide against which USEPA has initiated a regulatory action for cause, or for which it has issued a notice of rebuttable presumption against reregistration, the nature of the action or notice, including the relevant technical and scientific factors will be discussed with the requesting overnment and considered in the IEE and, if prepared, in the EA or EIS. If USEPA initiates any of the regulatory actions above against a pesticide subsequent to its evaluation in an IEE, EA or EIS, the nature of the action will be discussed with the recipient government and considered in an amended IEE or amended EA or EIS, as appropriate.

(v) If the project includes assistance for the procurement or use, or both of pesticides but the specific pesticides to be procured or used cannot be identified at the time the IEE is prepared, the procedures outlined in §216.3(b)(i) through (iv) will be followed when the specific pesticides are identified and before procurement or use is authorized. Where identification of the pesticides to be procured or used does not occur until after Project Paper approval, neither the procurement nor the use of the pesticides shall be undertaken unless approved, in writing, by the Assistant Administrator (or in the case of projects authorized at the Mission level, the Mission Director) who approved the Project Paper.

(2) Exceptions to Pesticide Procedures. The procedures set forth in §216.3 (b)(l) shall not apply to the following projects including assistance for the procurement or use, or both, of pesticides.

(i) Projects under emergency conditions.

Emergency conditions shall be deemed to exist when it is determined by the Administrator, A.I.D.. in writing that:

(a) A pest outbreak has occurred or is imminent; and

(b) Significant health problems (either human or animal) or significant economic problems will occur without the prompt use of the proposed pesticide; and

(c) Insufficient time is available before the pesticide must be used to evaluate the proposed use in accordance with the provisions of this regulation.

(ii) Projects where A.I.D. is a minor donor, as defined in §216.1(c)(12) above, to a multi-donor project.

(iii) Projects including assistance for procurement or use, or both, of pesticides for research or limited field evaluation purposes by or under the supervision of project personnel. In such instances, however, A.I.D. will ensure that the manufacturers of the pesticides provide toxicological and environmental data necessary to safeguard the health of research personnel and the quality of the local environment in which the pesticides will be used. Furthermore, treated crops will not be used for human or animal consumption unless appropriate tolerances have been established by EPA or recommended by FAO/ WHO, and the rates and frequency of application, together with the prescribed preharvest intervals, do not result in residues exceeding such tolerances. This 192 prohibition does not apply to the feeding of such crops to animals for research purposes.

(3) Non-Project Assistance. In a very few limited number of circumstances A.I.D. may provide non-project assistance for the procurement and use of pesticides. Assistance in such cases shall be provided if the A.I.D. Administrator determines in writing that:

(i) emergency conditions, as defined in §216.3(b)(2)(i) above exist; or (ii) that compelling circumstances exist such that failure to provide the proposed assistance would seriously impede the attainment of U.S. foreign policy objectives or the objectives of the foreign assistance program. In the latter case, a decision to provide the assistance will be based to the maximum extent practicable, upon a consideration of the factors set forth in §216.3(b)(l)(i) and, to the extent available, the history of efficacy and safety covering the past use of the pesticide the in recipient country.

§216.4 PRIVATE APPLICANTS Programs, projects or activities for which financing from A.I.D. is sought by private applicants, such as PVOs and educational and research institutions, are subject to these procedures. Except as provided in §216.2(b), (c) or (d), preliminary proposals for financing submitted by private applicants shall be accompanied by an Initial Environmental Examination or adequate information to permit preparation of an Initial Environmental Examination.

The Threshold Decision shall be made by the Mission Director for the country to which the proposal relates, if the preliminary proposal is submitted to the A.I.D. Mission, or shall be made by the officer in A.I.D. who approves the preliminary proposal. In either case, the concurrence of the Bureau Environmental Officer is required in the same manner as in §216.3(a)(2), except for PVO projects approved in A.I.D. Missions with total life of project costs less than $500,000.

Thereafter, the same procedures set forth in §216.3 including as appropriate scoping and Environmental Assessments or Environmental Impact Statements, shall be applicable to programs, projects or activities submitted by private applicants. The final proposal submitted for financing shall be treated, for purposes of these procedures, as a Project Paper. The Bureau Environmental Officer shall advise private applicants of studies or other information foreseeably required for action by A.I.D.

Annex 2: CARE pesticide policy

CARE's Pesticide Policy provides clear guidelines for the selection and use of pesticides on CARE projects. The term «pesticide» is herein used in the generic sense, and refers to all chemical agents applied to reduce or eliminate pest outbreaks, including but not exclusive of insecticides, herbicides, fungicides, rodenticides, nematicides, and commodity or space fumigants. The text of the policy is as follows:

«CARE's Pesticide Policy aims to control crop and forest pests on a sustainable basis with minimal short and long term detriment to humanity and the physical environment. We will promote non-chemical pest control methods as the preferred control strategy. CARE will permit the use of chemical pesticides not prohibited under this policy in cases where non-chemical alternatives prove to be either unavailable or ineffective, and where measures have been taken to provide appropriate training and personal protection equipment, as specified below.

Use of the following categories of chemical pesticides in CARE-administered or financed projects will be prohibited:

(1) Pesticides the use of which is prohibited in the country in which the project is being implemented;

(2) Pesticides prohibited by the project's donor agency;

(3) Pesticides classified by the World Health Organization as 'extremely hazardous' or 'hazardous' (WHO Classes IA and 1B); and

(4) Pesticides demonstrated to cause adverse long term health effects, reproductive effects, and environmental damage.

For 'hazardous' pesticides (WHO Class 1B) currently in use within CARE-administered and financed projects, a strategy and time frame to phase out their use will be required.

To determine which pesticides fall into category (4), CARE will draw upon both the body of research generated by national and international agencies dealing with pesticide safety and its own project experience. CARE has a serious concern for and will give special attention to pesticides either withdrawn from registration or not registered with a CARE member's national government.

In addition, CARE will publish a bi-annual listing of pesticides in categories (3) and (4).

When pesticides that are not prohibited by the policy are used, the following applies:

(1) CARE projects will apply all restrictions for the pesticides in use as listed in the 'Consolidated list of products whose consumption and/or sale have been banned, withdrawn, severely restricted or not approved by governments', published by the United Nations.

(2) Preference will be given to the effective chemical that is considered to be the least toxic to

the person applying it, to the eventual consumers of the crop, and to the environment.

(3) Pesticides will not be used unless training of the user on safe pesticide handling and application has been completed.

(4) Pesticides will not be used unless the pesticide user is provided with adequate personal protection equipment, and

(5) Pesticides will not be used unless ongoing monitoring of use by CARE staff demonstrates that the appropriate training has been carried out and that safe-use measures have been adopted and are effective.

To facilitate an optimal exchange of information about pesticides and restrictions on their use, CARE missions will provide a list of all pesticides in use on an annual basis. CARE-New York will provide missions with a bi-annual status report on all pesticides prohibited by this policy and any restrictions that may apply to those pesticides permitted.

CARE will provide project staff, counterparts, and project beneficiaries with sufficient instruction on pest management methodologies to allow them to make informed choices among pest management alternatives. Where indicated, training will be modified in order to guarantee achievement of the above prerequisites for use of a pesticide in CARE-sponsored activity. Training in pesticide use will be consistent with literacy standards and local cultural conditions.

CARE's Pesticide Policy will directly target project participants both within and outside of CARE activities, in all phases of a project (design, implementation, and monitoring). We will initially concentrate on addressing pest management practices of counterparts, farmers and other agricultural workers within CARE's sphere of influence, as well as the practices of organizations collaborating on CARE projects.

The CARE mandate compels us to extend our policy to encompass active support for and encouragement of the adoption of optimal pest management methodologies and policies in all countries with CARE operations.

Chemical pesticides prohibited under this policy which are located at CARE project sites will be disposed of according to the United Nations Food and Agricultural Organization's 'Guidelines for the Disposal of Waste Pesticides and Pesticide Containers on the Farm.'»

In order to implement the Pesticide Policy, CARE will launch a coordinated effort among all appropriate sectoral and regional units, as well as between CARE New York and all CARE missions. Implementation will consist of specific strategies for information collection and dissemination, training, health improvement and monitoring, and pest control methodology selection. All activities will be subject to the availability of financial and other necessary resources.

Annex 3: Web sites for information on pesticides, pest management:

Hundreds of WEB sites provide information about pesticides and pest management. The user should pay careful attention to the source since anyone can post information on the internet and many sites are used to promote products or points of view.

Pesticides are substances regulated by national and international agencies. These organizations provide accurate and reliable information on pesticides.

Pest management beyond the use of pesticides is a virtually unregulated endeavor: few «official» agencies post information. Some of the best sites for pest management ideas and background information are posted by the very few international and national programs and institutions with mandates to promote safe and sustainable pest management, such as FAO and universities.

Pesticides

www.who.int/pcs

Site for the WHO International Programme on Chemical Safety. The most authoritative site on human health effects of pesticides. Not all documents are online yet, but the WHO Recommended Classification 2000-2002 is, one of the most cited sources of acute toxicity information.

www.chem.unep.ch

The UNEP pesticides website. An excellent source of authoritative information on international agreements, especially PIC and POPs.

www.fao.org/waicent/afoinfo/economic/esn/codex/codex.htm

The FAO´s Codex Alimentarius site.

www.epa.gov/pesticides

The U.S. EPA site on pesticides is a goldmine of information. Thousands of technical documents are available online. A limited Spanish version is available. Current regulatory status of every pesticide registered in the US may be checked as needed for compliance with Regulation 216.

www.pesticideinfo.org

Probably the best «one-stop shopping» for information on specific pesticides. The Pesticide Action Network (PAN) has brought together many sources of information and assembled easy to read tables, including their own «bad actors» composite rating.

ace.ace.orst.edu/info/extoxnet

EXTOXNET: The Extension Toxicology Network. Another excellent source if you need information by substance.

www.ijoeh.com

The International Journal of Occupational and Environmental Health brings important articles on occupational and environmental health research, teaching, and public policy to developing countries. It has had Special Series in recent years on the Precautionary Principle, Human Rights, International Pesticide Use, and Integrated Pest Management

Pest Management

www.fao.org/globalipmfacility

Provides the latest information on worldwide application of the Farmer Field School approach to farmer education, organization and policy development.

www.communityipm.org

An excellent source of information on the FAO Asia «Farmers' Field School» methodology. Many interesting and valuable downloadable documents.

www.wisard.org

Global IPM Facility's site listing experts in pest management by crop, pest, and geographical base.

www.ipmworld.umn.edu

Radcliffe's IPM World Textbook. A great resource text constantly updated and improved. Excellent for students, teachers, and extension agents who want a concise presentation of thematic areas, or the state of the art in IPM by crop, according to the authors. Many articles in Spanish.

www.nysaes.cornell.edu/ent/biocontrol

Biological Control: A Guide to Natural Enemies in North America. An excellent guide to natural enemies. Limited geographically, but useful photos and summary of biology and ecology.

www.ipm.ucdavis.edu/pmg

The University of California Pest Management Guide. Very complete and useful guides by crop. Some a bit dated. Pest management program development as applied in the US.

www.ipmnet.org

Consortium for International Crop Protection produces a monthly newsletter , *IPM News*, summarizing what's new in the world of IPM around the world. The best calendar of IPM events anywhere The website indicates how to subscribe to the newsletter.

www.ncsu.edu/cicp/IPMnet_News

All back issues of IPM News

www.agrobiologicals.com

Search by pest for targeted biological products. Contact information for 2600 companies selling biological inputs for pest management

www.cabi-bioscience.org

Commonwealth Agricultural Bureau's International branch site with searchable databases on fungi, and information on their international projects; especially useful in biological control and sustainable agriculture.

www.isaaa.org

International Service for the Acquisition of Agribiotech Applications site; pro-GM crops. Useful for current information by country on the commercial production of GM crops.

About the authors

Sarah Gladstone has been professor and researcher since the mid 1980's at the National Agriculture University in Nicaragua, the Autonomous National University of Nicaragua, and Zamorano in Honduras. An agricultural ecologist, she has worked in Central America on developing biological and integrated pest management programs for insect pests of corn, melons, coffee, multi-use tropical tree species, and sugar cane. She manages «*Hacienda El Nisperal*» an organically-certified coffee farm in Nicaragua. She holds a Ph.D. in zoology from Duke University in the United States.

Allan Hruska has worked for the past 15 years to implement safe and sustainable pest management among small holder farmers in Central America. He coordinated CARE International's IPM Program in Nicaragua during the late 1980's and later served as CARE Nicaragua Assistant Country Director, was Head of Zamorano University's Department of Plant Protection in Honduras, and directed the Zamorano/COSUDE IPM training program in Central America. He has taught and directed research at the National Agriculture University in Nicaragua and Zamorano University. Currently he is Executive Director of NicaSalud, a Federation of 22 NGOs working in community-based health in Nicaragua. He holds a Ph.D. in Entomology and Economics from North Carolina State University.