Agriculture and Human Values **17:** 49–63, 2000.

Traditional knowledge and pest management in the Guatemalan highlands

Helda Morales[1] and Ivette Perfecto[2]
[1]*Departamento de Agroecología, El Colegio de la Frontera Sur. San Cristóbal de Las Casas, Chiapas, México;* [2]*School of Natural Resources and Environment, The University of Michigan. Ann Arbor, Michigan, USA*

Accepted in revised form May 5, 1999

Abstract. Adoption of integrated pest management (IPM) practices in the Guatemalan highlands has been limited by the failure of researchers and extensionists to promote genuine farmer participation in their efforts. Some attempts have been made to redress this failure in the diffusion-adoption process, but farmers are still largely excluded from the research process. Understanding farmers' agricultural knowledge must be an early step toward a more participatory research process. With this in mind, we conducted a semi-structured survey of 75 Cakchiquel Maya farmers in Patzún, Guatemala, to begin documenting their pest control practices. Their responses revealed that their understanding of biological and curative pest control is limited. However, their broad knowledge of cultural preventive pest control practices could explain why they had faced few pest problems in their traditional *milpa* (intercrop of corn, beans, and other edible plants). The majority of these preventive practices are probably efficient and environmentally innocuous.

Key words: Cakchiquel, Corn, Cultural control, Curative practices, Guatemala, Local knowledge, Pest management, Preventive practices, Traditional knowledge

Abbreviations: CATIE = Centro Agronómico Tropical de Investigación y Enseñanza (Center for Research and Education in Tropical Agronomy); COCADI = Coordinadora Cakchiquel para el Desarrollo Integral (Cakchiquel Coordinating Group for Integrated Development); DIGESA = Dirección General de Servicios Agrícolas (General Office of Agricultural Services); CRSP = Collaborative Research Support Program; ECOSUR = El Colegio de la Frontera Sur; IPM = Integrated pest management; USAID = United States Agency for International Development

Helda Morales *trained in biology in her native Guatemala, and in integrated pest management in Costa Rica, focused on the social aspects of pest control for her doctorate at the School of Natural Resources and Environment (The University of Michigan). She is now a Research Associate in the Agroecology Department of El Colegio de la Frontera Sur (ECOSUR) in San Cristobal de Las Casas, Chiapas, Mexico. Her research ranges from traditional Mayan knowledge to tri-trophic interactions for pest control.*

Ivette Perfecto *is an Associate Professor at the School of Natural Resources and Environment at The University of Michigan, where she teaches courses in agroforestry, tropical ecosystems, and field ecology. Her research interests include tropical forest disturbance and biodiversity in agroecosystems. She divides her time between Ann Arbor, Nicaragua, Costa Rica, Mexico, and her native Puerto Rico.*

Introduction

As in other Third World countries, the use of synthetic pesticides in Guatemala is alarming. From 1990 to 1994, US inspectors retained 3,081 shipments of produce from the Guatemalan highlands because of pesticide residues (Thrupp et al., 1995). Still more alarming, 70.4% of farmers surveyed reported symptoms consistent with pesticide poisoning (Hoppin, 1991). Recognizing the major environmental disruptions caused by synthetic pesticides, agricultural planners now commonly use ecological knowledge in developing pest management strategies (Vandermeer and Andow, 1986; Andow and Rosset, 1990). Nevertheless, despite the many efforts to introduce integrated pest management (IPM) technologies in the Guatemalan highlands (Fisher, 1994; Murray, 1995; IPM-CRSP, 1996), the prevalence of pesticide-related problems (Hoppin, 1991; Morales et al., 1994; Conroy et al., 1996) is proof that IPM adoption is far from widespread.

One of the shortcomings of the traditional diffusion-adoption approach to agricultural extension is its failure to incorporate participatory and multidisciplinary research. Nelson (1994), in her work with Nicaraguan farmers and IPM scientists, demonstrated that when farmers participate in the research process, they are more willing to adopt IPM technology. The lesson seems simple, and has been promoted by the participatory research movement since the early 80s: change agents should ask their clients what they want, and include them in the whole research process (Chambers, 1983).

Understanding farmers' traditional agricultural knowledge must be an early step in participatory research. By traditional agricultural knowledge we understand the cultural and technical knowledge that farmers in a specific area have. Farmers inherit part of this knowledge from their ancestors and build upon it constantly based upon other sources of information and their own experiments and experience. The richness of this knowledge is often enormous (Gliessman, 1981; Altieri, 1984; Oldfield and Alcorn, 1987; Posey and William, 1989; Gómez-Pompa and Kaus, 1992). Major development institutions, such as the World Bank and the United States Agency for International Development (USAID), now include traditional knowledge in their discourse (Warren, 1991). In Guatemala, recuperation of traditional agricultural knowledge among the Quekchís in the northeastern highlands (Altertec, 1996), and among the Quichés in the northwest (Aguilar, 1993) is underway. However, efforts to document traditional knowledge are in their infancy and are not part of mainstream agricultural research and extension programs in Guatemala or elsewhere.

In addition to documenting the traditional knowledge of the farmers, it is important to understand the ecological mechanisms behind their practices (Gliessman, 1981; Vanek, 1989; De Walt, 1994). This is vital to application of traditional practices to new situations. For example, understanding the mechanisms involved in the utilization of vetiver grass (*Vetiveria zizanioides*) for soil and moisture conservation in India, allowed farmers around the world to adopt and benefit from this traditional practice (Greenfield, 1989).

Furthermore, and more importantly, the understanding of the traditional practices by outsiders may be useful for the empowerment of farmers at the local level (Freire, 1968; Patton, 1990; De Walt, 1994; Barzman et al., 1996; Sillitoe, 1998). Empowerment through the understanding of traditional knowledge has been essential for the organization of grassroots projects in Bolivia, Chile, México, and Nigeria (Altieri, 1984). Thrupp (1989) argues that farmers' knowledge, with or without scientific validation, can serve as a basis for their empowerment. She also argues that the value of traditional knowledge may not be understandable by Westernized scientists taking a reductionist approach. We contend, however, that when "experts" in countries like Guatemala treat indigenous farmers as ignorant and stubborn (e.g., García, 1994; Santízo et al., 1996), traditional agricultural knowledge is inevitably degraded. In such cases, validation of traditional knowledge is necessary both for empowerment of farmers and education of research and development workers. The strengths and weaknesses of traditional knowledge should be presented to agricultural scientists and policy makers in a language that they understand: "the language of science" (Moles, 1989). This should, theoretically, improve communication between farmers and agronomists (Slikkerveer, 1989; Nelson, 1994).

In the highlands of Guatemala, traditional farmers have, until recently, faced few pest problems. The apparent lack of pests may be due to cultural practices used for centuries by Mayan farmers. The recent increase in pest populations is likely due to application of pesticides to the non-traditional crops that have been introduced over the last two decades (Morales et al., 1994). Traditional practices could present sustainable alternatives to the use of pesticides in both traditional and non-traditional crops.

Here, we initiate the documentation and validation of traditional farming practices in Patzún, a Cakchiquel Maya town in the Guatemalan highlands. Farmers in Patzún, fearful that their knowledge will disappear because even their children disrespect their traditional practices (Board of Directors, Cooperativa San Bernardino, personal communication), welcomed scientific validation of those practices. We catalog the religious, environmental, and agricultural factors that farmers in Patzún cite as controlling pests in their fields. We also evaluate the agricultural practices from an agroecological perspective with an eye to their potential application in other agroecosystems.

Methods and study site

Patzún is a community with a rich agricultural heritage, but its abrupt integration into the global economy is eroding the traditional agricultural knowledge of its Mayan inhabitants. The village is located in the western Department of Chimaltenango, at an altitude of 2,235 m. Ninety-three percent of the 36,000 habitants are Cakchiquels.

Since before the conquest, agriculture in the region has centered on the traditional *milpa*, a polyculture of maize with some combination of climbing beans, fava beans, and different varieties of squash. In the early 1980s, the basis of the local economy shifted to production of non-traditional export crops (broccoli, snow peas, and zucchini). The non-traditional crops were introduced under a USAID program along with a technological package of synthetic pesticides and fertilizers. Nonetheless, many farmers are still growing maize using low-input, traditional technology. Between August, 1994 and March, 1997 one of us (H. M.) lived in Patzún for approximately 15 months. We conducted individual and group surveys, complemented by field observations, in order to document and assess traditional pest management practices among Cakchiquel farmers.

Surveys allow broad population coverage but can yield misleading information. Researchers and respondents may, without realizing it, understand questions in different ways (Clark and Schober, 1992). Furthermore, respondents' perceptions of the perspective of the interviewer's beliefs or goals may influence their responses (Clark and Schober, 1992). Investigators must also take care in choosing the format of the questionnaire. In preliminary research, an open-response format can reveal the full range of responses, but informants may not provide information they perceive as self-evident or irrelevant (Schwarz et al., 1992). Furthermore, a particular answer may not occur to an informant answering an open-response question although he or she believes it to be true, making quantitative conclusions suspect (Schwarz et al., 1992). Taking into account these potential stumbling blocks, one of us (H. M.) conducted an exploratory survey about traditional pest control practices to evaluate comprehension and interpretation by Cakchiquels and a few members of other Maya language groups. She interviewed eleven individuals and conducted two focus groups in August, 1994. The first focus group was comprised of seven members of the board of directors of an agricultural cooperative in Patzún whom H. M. had met during a previous study. The second was a group of four former farmers who are her friends and members of the Pastoral Indígena of the Catholic Church in Guatemala City. The Pastoral Indígena works within the Guatemalan Catholic Church to promote inclusion of some aspects of Mayan religion in the Catholic liturgy. She also interviewed eleven individual farmers as she walked with them through the streets of Patzún or in the nearby fields. She asked farmers how they control pests in the *milpa*, and who gives them agricultural advice.

The exploratory survey revealed several problems with the questions. Difficulties inevitably arose because the interviews were conducted in Spanish, the second language of the interviewees, who all speak Mayan languages. For example, the majority of the farmers in the individual interviews said that they do not have *gallina ciegas* (white grubs); however, when asked if they had *ican* (the Cakchiquel word for white grubs), they all agree that white grubs were common. The focus groups also revealed that farmers have practices to "avoid" insect attacks, but that they do not volunteer this information when asked how to "control" them. Finally, according to the focus groups, one of the most important practices to avoid insect attacks is to plant and to harvest when the moon is full. The majority of the farmers did not volunteer this information until they were asked directly if they organize their activities around the lunar cycle. They explain that they hesitate to mention it as an agricultural practice because some people consider it to be a superstition and make fun of them. This exploratory survey allowed us to redesign the questions, and to be conscious of the possible problems with the survey.

We began using the modified survey in May, 1995, conducting most of the interviews in the fields around Patzún. We used a semi-structured interview with open-ended questions to ask growers about practices they believe to be effective against insect pests, and to describe those practices. When farmers did not mention practices already recorded, they were asked their opinion on those practices as well. The questions of the interview were:

- Do you have pests in your *milpa*?
- Are there insects that eat the *milpa*?
- Which insects eat the *milpa*?
- Do insects cause economic losses in the *milpa*?
- Why you do not have problems with insects in your *milpa*?
- What should be done to avoid insects or insect damage in the *milpa*?
- What do you do when insects are eating your *milpa*?
- Are there animals that kill the insects that eat the *milpa*?
- Who taught you how to plant?
- Who gives you agricultural advice?

We selected interviewees who plant *milpa* and were willing and available to participate. We tried to include an equal number of traditional and non-traditional farmers, those older and younger than 40, and men and women. By "traditional" and "non-traditional" farmers we mean people who grow just *milpa*, as opposed to those who also grow non-traditional crops such as broccoli and snow peas.

In total, we interviewed 75 people, 30 traditional farmers and 45 non-traditional ones, 38 people younger than 40, 37 older than 40, 58 men and 17 women. The reason for the disparity between men and women is that the majority of the older women could not speak Spanish or did not feel confident enough in Spanish to be interviewed. Also some of them did not want to talk with us. At the time that the interviews were conducted, there was a rumor that *gringas* were kidnapping children in the area. Unfortunately, despite being Guatemalan, H. M. was perceived as a foreigner, and women with small children were afraid of her. Furthermore, some women thought that she could learn more about agriculture by talking with men, and they called their husbands even though she insisted that she wanted to know their own opinions.

The first interviewed farmers were members of the board of directors of the Cooperativa San Bernardino. The cooperative gives credit to plant broccoli, provides inputs such as fertilizers and pesticides, and negotiates sales to export companies. The board of directors is formed of leaders from Patzún and the surrounding villages, who gave H. M. advice and put her in contact with other farmers that they thought would give her valuable information. Thus, the majority of the early interviews were with "non-traditional farmers." However, the community of friends that H. M. made in Patzún helped us with the interviews by teaching her basic entomological Cakchiquel, helping us interpret the results of the interviews, and introducing her to their neighbors, friends, family members, and the elders. These social links gave us the opportunity to interview a range of people that we believe provide a good representation of the whole community. Among them were full-time farmers, landless farm workers, the director of a development project, agricultural export company workers, Catholic priests and catechists, Protestant ministers, and teachers, all of whom plant *milpas*.

The percentage of farmers' providing particular responses was calculated for each question to indicate the relative importance of each practice among Patzuneros. These percentages likely underestimate the actual fraction of farmers employing each practice, as a given practice may not have occurred to all interviewees at the moment of the interview. The number of farmers answering each question (n), may differ from question to question, since in some cases, not all the questions were asked in an interview. Some of the most representative answers are cited as a direct quote in Spanish, with an English translation.

Given the inevitable problems associated with surveys, the first author also made direct observations of the agricultural practices of some growers. She spent several hours in the fields with four farmers. As she watched them at work, they had long conversations about their agricultural practices and those of their neighbors.

Results and discussion

The concept of pests

> *Plagas quiere estudiar usté? La milpa no tiene plagas seño* (Guillermo Teleguario).
> You want to study pests? The *milpa* does not have pests, miss.

When H. M. started interviewing farmers in Patzún to assess their traditional pest control practices she was surprised by the answer of Guillermo Teleguario. *Don* Guillermo, former mayor of Patzún, was at that time the president of Cooperativa San Bernardino. Although he likely thought her ignorant, he introduced her to several of the farmers that she interviewed, because he believes in the importance of the validation of traditional knowledge. The answer was the same, from the 75 interviewed farmers, 54% said that they do not have pests in their *milpa*. We did not understand. It was impossible that the majority of the farmers had not noticed the insects we had seen eating their crops.

Of course they had noticed. Because Spanish is the second language in Patzún and we do not speak more than 10 words of Cakchiquel, we were painfully aware of the language barrier. We suspected that the problem was with the word *plaga* (pest). We noticed a problem with the word *plaga* since the pre-survey, but we decided that it would be interesting to see if the response was the same among all the farmers. Nevertheless, after talking with Guillermo Teleguario, we added another question and asked if there were "insects" that eat the *milpa*. Ninety-nine percent of the farmers said that in fact there were.

The interviewed farmers mentioned 18 different groups of insects (Table 1). The insects mentioned most commonly were weevils, white grubs, moths, beetles, caterpillars, and aphids. Some farmers also mentioned wireworms, mites, crickets, scales, flies, leafhoppers, and ants. The list of insects that they mentioned is similar to the one developed by IPM experts (CATIE, 1990). IPM scientists recognized 22 species of insects and mites as the main pests that attack corn in Central America. Among the four families that farmers did not mentioned, three of them are difficult to observe without actively searching for them. Cydnidae bugs are less than 8 mm long and hide among roots, Pyralidae larvae bore into the stalks of corn, and Eriophyidae mites are impossible to see without lenses (Borror et al., 1989). Farmers may recognize the fourth family, but they only mentioned *gorgojos* (weevils). They do not seem to differentiate between Curculionidae and Bostrichidae. On the other hand, IPM scientist did not mentioned wooly bear caterpillars, aphids, crickets, white scales, and flies as important corn pests in Central America. Nevertheless

Table 1. Herbivorous arthropods in corn mentioned by farmers (N = 64) in Patzún, Guatemala, (1994–1996), compared with herbivorous insects recognized as pests by IPM scientists in corn in Central America (CATIE, 1990).

Mentioned by farmers	Mentioned by scientists	English name	% of farmers
Gorgojos	Curculionidae: *Sitophilus*, Bostrichidae: *Rhizopetha*	Weevils	63.2
Ican	Scarabaeidae: *Phyllophaga*	White grubs	47.1
Jut	Noctuidae: *Agrotis, Mocis*	Hairless caterpillars	23.5
Gusano del elote	Noctuidae: *Heliothis*	Corn earworm	23.5
Cogollero	Noctuidae: *Spodoptera*	Fall armyworm	23.5
Chomochí	∗	Wooly bear caterpillars	23.5
Tortuguillas	Chrysomelidae: *Diabrotica*, *Cerotoma*	Leaf beetles	19.1
Pulgón	∗	Aphids	13.2
Hormiga negra	Formicidae: *Acromyrmex*, *Atta*, *Solenopsis*	Ants	4.4
Palomillas	Gelechiidae: *Sitotroga*	Grain moths	3.7
Gusano alambre	Elateridae: *Aeolus*	Wireworms	2.9
Grillo	∗	Crickets	2.9
Sak	Acrididae: *Schistocerca*	Grasshoppers	2.9
Aradores, acaros	Tetranychidae: *Oligonychus*, *Tetranychus*	Spider mites	2.9
Salta hoja	Cicadellidae	Leafhoppers	1.5
Escama blanca	∗	White scales	1.5
Mosca	∗	Flies	1.5
∗	Cydnidae: *Cyrtomenus*	Burrower bugs	0
∗	Pyralidae: *Elasmopalpus*, *Diatrea*	Snout/grass moths	0
∗	Eriophyidae: *Eriophyes*	Gall mites	0

∗ = not mentioned.

corn has been reported as a host of all these insects elsewhere (Saunders et al., 1983). In sum, we can say that farmers can recognize at least the majority of the insect families identified by scientists.

Besides knowing the herbivorous insects in the *milpa*, the farmers also know the Spanish word *plaga*. While listing the insects that eat the *milpa*, the farmers often mentioned for comparative purpose the *plagas* in the non-traditional crops. Their Spanish was not the problem with our first question. The problem was our concept of pest: "every herbivorous arthropod in a crop is a pest or potential pest." For the farmers in Patzún, the concept is more sophisticated: An herbivore that does not cause economic damage is not a pest. They do not classify the insects as pests because they do not cause economic losses in the *milpa*. Their approach is in some ways similar to the IPM central concept of "economic threshold." Under the IPM philosophy, the application of a control is not justified if the "pest" does not reach the economic threshold. In other words, if pest control would cost more than the decrease in yield that the pest would cause, control is not recommended (Horn, 1988).

What controls pests?

Understanding the Patzunero concept of "pest" helped us recover from our worries. We realized that although our preconception of the outcome of the surveys was flawed, we would actually learn something much more important than we had imagined before we started interviewing. We had expected to compile a list of traditional practices such as the application of botanical insecticides and incense burning to control and/or repel insects. We understood then that such curative pest control activities were largely unnecessary in the traditional *milpa*, since sixty percent of them mentioned that the insects do not cause economic losses in the *milpa*. The important question to address was why the herbivorous insects do not reach pest status in the first place.

Farmers in Patzún explain the absence of pest problems by the weather and soil conditions in the area, their tolerance of insect damage, their religious beliefs, and the agricultural methods that they practice (Table 2). Farmers mentioned that the weather and soil conditions in Patzún are favorable for corn, and for this same

Table 2. Patzún farmers' opinions on why insects in the *milpa* do not reach economic levels (N = 37).

Explanations	% of farmers
Damage is avoided with agronomic practices	64.9
Insects do no eat much	24.3
Milpa is strong	18.9
Damage is accepted	16.2
Cold weather	13.5
God protects the *milpa*	8.1
Soil is appropriate for the *milpa*	2.7

reason herbivorous insects are almost non-existent. They mentioned that on the Pacific coast of Guatemala the *milpa* is often attacked by insects because of the warm weather.

Their observations on the effect of abiotic factors over insects are supported by the literature that reports experiences in other areas. For example, it has been reported that the fall armyworm, (*Spodoptera frugiperda*) causes much more severe damage in the lowlands of Central America than in the highlands (King and Saunders, 1984). In the lowlands of Mexico as well, *milpas* cultivated using practices similar to those used in Patzún can have serious problems with insect pests (Ucán Ek et al., 1982). Apparently, the lower temperatures in the highlands are a shield that Patzuneros have against herbivorous insects.

Soil can be another important factor that influences insect development. For example, the observations of Wightman and Wightman (1994) in Africa that sandy or loamy soils favor white grubs seem to corroborate the observations of some farmers in Patzún: "crops growing on sandy soils suffer more pest attacks."

So, as Patzuneros affirm, temperature and soil in Patzún contribute to the apparent lack of insect problems in the *milpa*, but they are not the only explanation. The principal evidence that abiotic factors are not enough to control pests are the severe problems that farmers in the area have with herbivorous insects in the non-traditional crops (Morales et al., 1994; Thrupp et al., 1995; Conroy et al., 1996).

Their tolerance of pest damage and the fact that corn is part of farmers' religion also explain in part the lack of pest attacks in the *milpa*, contrasting with the non-traditional crops. Cakchiquel religion determines the care that farmers give to their *milpas*, but no religious guidelines exist for non-traditional crops. Non-traditional crop management is directed by outsiders, who are not as tolerant of cosmetic damage as Cakchiqueles. Most of the farmers mentioned that they share their corn with the animals, and for some of them to share with the animals is part of their religious beliefs:

> *El maíz tiene gusanos pero yo no lo rechazo, no soy como las compañías que rechazan el brócoli porque lleva gusano* (Fabián Teleguario).
> The corn has worms but I do not reject it, I am not like the export companies that reject the broccoli because it has a worm.

> *Aunque las gallinas ciegas se coman algunas plantas lo que se pierde es un quintal de maíz. Hay que compartir con los animales* (Hipólito Miculax).
> Even if the white grubs eat some plants, we lose only 100 pounds of corn. We should share with the animals.

> *Llamamos a Monseñor Julio para que viniera a bendecir a los insectos. La gente no quiere destruir los animales. Hay que evitarlos, cada animal tiene su función* (Angela López).
> We call on Bishop Julio to come pray for the insects. We do not want to destroy the animals. We should avoid them. Each animal has its function.

> *El maíz es sagrado, incluso si hay un maicito tirado se recoge, se le habla al tamal, y a la tortilla, porque va a ser parte del hombre. Se siembran los tres colores: blanco, amarillo, negro. La abuela Ixmucané los mezcló. Cuando se cosecha se le echa incienso. Todos se levantan a las 5 de la mañana y se encienden velas y se reza* (Jacinto Pelicó).
> Corn is sacred; even if there is only one small grain on the ground, we pick it up; we talk with the tamal (cornmeal, that may or may not be mixed with a sauce made with ground squash seeds, roasted peppers, tomatoes and meat, wrapped in corn husks or plantain leaves, and cooked by steaming) and the tortilla because they will become part of our own bodies. We plant the three colors: white, yellow, and black. The goddess Ixmucané mixed them. For the harvest we burn incense. Everybody wakes up at 5 AM and we burn candles and we pray.

Jacinto explained that according to the Mayan religion, humans are made from corn dough, and the three colors of corn represent all the peoples' colors. By mixing them in the *milpa*, they venerate the goddess Ixmucané who will "let all the races be together." As Jacinto, eight percent of the farmers interviewed mentioned that corn is not attacked by insects because it is protected by God.

Since the fact that corn is central to Mayan religion and culture has already been well documented (Asturias, 1949; Ucán Ek et al., 1982; Aguilar, 1993; Terán and Rasmussen, 1994), we, as ecologists, will now focus on the merit of Patzuneros' agricultural practices according to agroecological theory and experiences in other geographical areas.

Agronomic practices

The majority of the farmers mentioned that they prevent insect attacks by using agronomic practices. They mentioned 26 preventive practices that help repel insects or make plants resistant to insect attacks in the field and in storage (Table 3). The rest of this section will describe these preventive practices as well as some reactive ones and, where possible, evaluate the practices based on the agroecological literature.

Preventive practices in the field

In the field, preventive practices start with the selection of the appropriate terrain and finish with management of crop residues. According to the farmers, it is important to choose the appropriate land to plant since characteristics of the soil and its previous management may affect insect populations. For example, one farmer mentioned that in muddy terrain, white grubs could destroy entire cornfields, while in drier soils they are not a problem. However, other farmers have observed more pest attacks in sandy soils.

Since the introduction of the non-traditional crops in the area, farmers often rotate the *milpa* with broccoli or snow peas. Some farmers recommended not planting fava beans in the *milpa* in fields from which non-traditional crops have just been harvested to avoid aphid attacks.

Once they have selected the appropriate site, it is time to prepare the soil. Some farmers let their hens in the field for two or three days to allow them to eat the insects from the up-turned soil and help diminish insect attacks later. A few farmers mentioned that before planting they applied lime or ashes to the soil to reduce ants, wireworms, and white grubs. The application of lime or ashes to the soil to reduce soil pests is a very common practice among indigenous groups in America (Altieri and Trujillo, 1987; Aguilar, 1993; Altertec, 1996). Lime, ashes, and other inert powders obstruct insect tracheas and damage their cuticles and have been used successfully to control pests in the field and in the storage (Golob, 1997). Lime applications to the soil are effective to control white grubs (Vittum, 1984; Potter et al., 1996). Ashes also have been used successfully to control a leaf miner (*Liriomyza huidrobensis*) in potatoes (Raymundo and Alcazar, 1983).

Planting dates also are very important for avoiding insect damage in Patzún. Most of the farmers plant at the end of March or beginning of April. According to Abelardo Martínez, they cannot plant before March because of frost: “*Si siembro antes lo mata la helada*.” The corn cycle in Patzún is very long, around nine months from planting to harvest. Farmers strive to be the first to harvest and get the best prices. Planting at the beginning of March would allow them to do it. Nevertheless, they wait until the end of March, when everybody is ready to plant more or less at the same time. According to their experience all the animals are attracted to their plots if they plant ahead of time: “*Mi papá sembró los primeros días de marzo y solo la mitad del elote encontró*” (my father planted during the first days of March and he found only half of the

Table 3. Preventive agricultural practices that avoid insect economic damage, according to farmers in Patzún (N = 51).

	% of farmers mentioning practice
I. Preventive practices in the field	
Choose the appropriate terrain for corn: non-flat, non-muddy, sandy	5.9
Do not plant fava beans in the *milpa* after non-traditional crops	2.0
Let the hens into the field before planting, so that they can eat the worms	3.9
Apply ashes and/or lime to avoid ants, wire-worms, and white grubs	6.0
Use organic fertilizer	15.7
Good soil nutrition	4.0
Disinfect organic fertilizer	9.8
Respect planting dates	11.8
Plant when the moon is full	23.5
Plant more than needed	2.0
Plant corn with beans to avoid beetles	2.0
Plant *miltomate* (*Physalis* sp.) in the *milpa*	2.0
Harvest when the moon is full	21.6
Do not bury the corn stalk (to avoid white grubs)	11.8
Bury the corn stalk to feed the white grub	2.0
Protect the natural enemies	3.9
Plant trees to attract birds that eat the worms	2.0
II. Preventive practices in storage	
Do not over dry the corn before putting it in storage	9.8
Do not cover the storage with tin roof, use tile or straw	15.7
Save husk to avoid weevils in the storage	1.4
Store corn in a silo	2.0
Apply lime in storage to avoid weevils	2.0

corn in the cob) (Mariano Jocholá). This observation is related to the ecological theory of predator satiation (Heliövaara et al., 1994; Kelly, 1994). The mass emergence of corn plants creates peaks in food availability for herbivores that are able to consume only a small fraction of the plants, keeping overall herbivore populations low because of low food availability the rest of the time. In fact, this concept has been applied in IPM programs with the establishment of mandatory harvest and planting dates (Horn, 1988; Hruska and Gómez, 1997).

Farmers also recommend not to plant after San Antonio's day (June 13th), since it is God's will, and it will be impossible to harvest anything. Guillermo Teleguario has another explanation for this:

> *Es mejor sembrar antes por que cuando vienen las lluvias salen los insectos y se comen a la milpa y si está chiquita no aguanta, no crece la mata ni los jilotes*.
> It is better to plant before because when the rains come, the insects appear and they eat the milpa and if it is small it does not bear up. Neither the plant nor the ears grow.

As a result of the climatic characteristics of the area and insect ecology, all the farmers in Patzún plant their corn over a period of two months. The exact date to plant is chosen according to the lunar cycle. To plant when the moon is full was the practice most often mentioned to avoid insect attacks; twenty-four percent of the farmers said that if they plant when the moon is full, the plants grow stronger and resist insect damage. Many cultures use lunar agricultural calendars (Ucán Ek et al., 1982; Altieri and Trujillo, 1987; Thrupp, 1989; Aguilar, 1993). Beliefs about the moon's effect on farming are so widespread that it is reasonable to hypothesize that the moon's cycle may have an effect on crops and animals, but no ecological or physical mechanism to explain this practice has been demonstrated. It is possible that lunar planting and harvesting dates permit farmers to synchronize their activities to the day across a landscape, potentially maximizing predator satiation. In this sense, lunar planting and harvesting may be related to planting synchrony as used in integrated pest management programs (see above).

Besides planting at the right moment, another strategy used to avoid insect damage is to plant more than is needed. The majority of the farmers plant 4 corn seeds per hole: *"Una para el pájaro, una para la hormiga, una para mi, y una para el vecino"* (one seed is for the bird, one for the ant, one for me, and one for the neighbor). This is related to the concept of sharing the food and accepting insect damage mentioned before. Jacinto Pelicó explained that many problems in the Mayan community started with capitalism:

> *Antes ni se vendía el maíz, solo compartir, ahora todo se comercializó y por eso las cosechas están malas. Ahora el dinero es más importante*.
> In the past corn was not even sold, just shared, now everything is commercialized and that is why harvests are bad. Now money is the most important thing.

The practice of sharing the crops and planting more than needed may not be economically efficient. In fact, the economic net revenue in the traditional *milpa* in the area is very low (Hildebrand et al., 1977), but the majority of the farmers are able to produce enough corn for their own consumption. As Jacinto Pelicó explained, trying to be "efficient" is the reason of their economic problems. An analysis of the agricultural commercialization in the Guatemalan highlands shows that in fact this has been detrimental for the economy and food security of the farmers (Immink and Alarcón, 1993). The authors blame the lack of market access, the fluctuating prices, and the inefficiency of the marketing institutions. Furthermore, planting more than needed is a practice recommended by IPM scientist to minimize economic losses due to pests such as *Spodoptera frugiperda* (King and Saunders, 1984; CATIE, 1990).

In addition to planting more corn than they need, farmers plant 2 bean seeds in the same hole. Sometimes fava beans or squash are planted in between. Much of the rest of the remaining space is filled by volunteer, edible or medicinal plants, such as *miltomate* (tomatillo, *Physalis* sp.), *quilete* (nightshade, *Solanum nigrum), chipilín* (*Crotalaria longitostrata*), *colinabo* (yellow turnip, *Brassica napus*), and *mostaza* (turnip, *Brassica rapa*), that farmers foster. The importance of intercropping to avoid insect attacks has been demonstrated by many researchers (for reviews see Risch et al., 1983; Andow, 1991), but although all the farmers in Patzún intercrop, it was only mentioned as a practice to avoid insect attacks by two farmers. One of them said that it is impossible to grow beans without corn because of beetle attacks. Angela López said that she plants *miltomate* to repel insects in the *milpa*. This is in accordance with Thurston's (1991) finding that many traditional farming practices act to control plant disease, but it is doubtful that farmers use them specifically for disease control. It is interesting that farmers in Patzún do deliberately use cultural practices for insect pest management, but not polycultures that are so popular among agroecologists. The majority of farmers may never have noticed the importance of polycultures in pest management because they have never planted corn in monoculture.

The second-most-mentioned practice to avoid pests was the use of organic fertilizers. They affirm that organic fertilization avoids insect damage in their *milpa*. Farmers in Patzún argue that organic fertilizer limits insect attacks because it is good for the soil and therefore for the plant. Fourteen percent of the farmers mentioned that organic fertilizers, compared with synthetics, “are moist, they have more nutrients, they are not washed away by the rain, and they last longer.” As a consequence of these characteristics, farmers explain that organic fertilizers are better for the plant because they “do not burn them, they do not make them grow too much, and for that reason plants can resist wind and pests.” Traditionally, farmers in Patzún use whatever materials they have available for compost. The favorite materials are kitchen scraps and cow manure. They also use harvest residues, straw, horse manure, herbs, lime, ashes, and when they have access to them, chicken manure and forest leaves. Some farmers also use sheep, goat, and rabbit manure.

Although management of soil fertility is the most important practice to prevent pests attacks according to 20% of the farmers, we do not have enough information to evaluate conclusively this practice. Organic farming promoters around the world often argue that organic fertilizer reduces pest populations, but evidence for this in the literature is scant and contradictory (Culliney and Pimentel, 1986; Eigenbrode and Pimentel, 1988; Costello and Altieri, 1995; Phelan et al., 1995; Letourneau et al., 1996). However, controlled experiments that we conducted in Patzún show that corn plants treated with organic fertilizer for at least two years host fewer aphids than those treated with synthetic fertilizer (Morales, 1998). According to farmers, organic fertilizers are better for plants because they make them resistant. The idea that a healthy plant can resist insect attacks is popular among farmers and scientists around the world but agricultural scientists are just beginning to investigate this belief (Phelan et al., 1995).

On the other hand, the conservation of natural enemies of pests, a practice that is well know to the scientific community, and frequently employed in IPM programs does not seem to be part of the agricultural knowledge of most farmers in Patzún. Some farmers mentioned that it is important to protect the natural enemies of pests (4%), and plant trees to attract birds that eat insects (2%). Nevertheless, the majority of the farmers in Patzún did not express awareness of natural enemies that eat herbivorous insects in the *milpa*. When asked if there are animals that kill the insects that eat the *milpa*, only 10% of the farmers indicated that other insects (Cicindelidae and Coccinellidae), lizards, toads, and birds are beneficial for the control of herbivorous insects. The lack of knowledge of natural enemies seems to be common among farmers in Central America (Bentley, 1989, 1992). In his study with farmers in Honduras, Bentley (1989, 1992) concludes that one reason for this gap in traditional knowledge is that natural enemies are difficult to observe. In fact, farmers from another village interviewed in a previous study (Morales et al., 1994) had a similar explanation. They said jokingly that before they attended workshops presented by Altertec (a non-governmental organization promoting organic agriculture in Guatemala), they could only recognize organisms bigger than a rat. The use of natural enemies is one of the most important tools in IPM, and farmers’ knowledge gap in this area could be remedied with another important tool of Western science: the microscope or hand lens. Unfortunately, farmers do not have access to such tools.

Finally, according to Patzuneros, the management of crop residues is also important for prevention of insect attacks. Twelve percent of interviewees said that to avoid white grub attacks, the corn stalk should not be buried but should be burned or removed from the field. In fact, Dix and colleagues (1995) found that white grubs are more numerous near buried corn stalks. Furthermore, many IPM textbooks (e.g. Horn, 1988) stress elimination of crop residues as a preventive practice for pest management. However, one farmer mentioned that he buries the stalks to feed the insects. He explained that otherwise the white grubs would eat the corn roots.

Preventing pests in storage

Preventing pest problems in storage is also important to farmers. Patzuneros’ preventive pest management practices for stored grains can also be explained by agroecological theory and results from scientific experiments. Twenty-one percent of the farmers mentioned that they harvest when the moon is full to avoid weevils and moths in the stored grains. After the harvest in December or January, Patzuneros leave the grain in their courtyard to dry. Ten percent of the farmers mentioned that it is necessary not to over-dry the corn before they put it in storage to avoid weevil attacks. This observation could possibly be explained by the behavior of the natural enemies of the maize weevil (*Sitophilus zeamais*). Populations of *Anisopteromalus calandrae*, a parasitoid of the maize weevil, increase when humidity increases (Smith, 1993). Furthermore, IPM scientists in Central America have recognized that letting corn dry in the field for too long increases the exposure to weevil infestations, thereby increasing economic damage (CATIE, 1990).

Sixteen percent of them mentioned that it is also necessary to store the grains in a cool place. H. M.

asked a woman who owns a pesticide store in Patzún which product she recommends for control of weevils and moths. The woman looked at her in a funny way and said that the granary should be covered with tile or straw, not with tin roof because the latter makes the room very hot, which increases insect attacks. Finally, explaining her odd look, she emphasized that she does not recommend "products" for the control of weevils, since they are not worthwhile. It is interesting that even local pesticide dealers recommend storing the grains in a cool place instead of an insecticide. In fact, scientists (Birch, 1953; Throne, 1994) have long recognized the importance of the manipulation of humidity and temperature to manage pests in stored grains. According to Throne (1994), the maize weevil will not develop at relative humidity levels below 43% and at temperatures below 15 °C or above 35 °C.

A few farmers also mentioned that they keep the husk covering the ear to avoid weevils in the granary. However, other farmers argue that this practice should be avoided because of rat attacks. Several farmers said that it is very effective to use a silo instead of a granary to avoid insect attacks, but since most cannot afford silos ($50), only a few farmers (2%) in Patzún use them to store their grain.

Finally, 11% of those interviewed think that organic fertilizers reduce pest attacks not only in the field but also in storage. They said that beans and corn fertilized with organic manure or compost suffer fewer weevils and moth attacks in the granary. To our knowledge, this has not been studied. The same mechanisms that reduce pest attacks in plants fertilized with organic fertilizer in the field may be responsible for pest reduction in the granary.

In sum, farmers in Patzún employ a broad array of methods to prevent insect attacks in their *milpas* and stored grains. The majority of these practices are popular among promoters of sustainable, ecological agriculture, but some of them have not been studied or are poorly understood by scientists. That is the case for the most popular practices among the people in Patzún: The use of the lunar calendar and the use of organic fertilizers to prevent insect attacks. Given the importance that farmers in Patzún attribute to these two practices, the possible mechanisms involved merit further study. With this in mind, we conducted the experiment to evaluate the impact of traditional fertilization practices on corn pests, which we mentioned above (Morales, 1998).

Curative practices

Despite their vast agroecological knowledge, and although the majority of farmers do not consider insects pests a problem, one-third of the farmers think that pests are becoming more prevalent and that they should do something to eliminate them. To manage insect pests in the *milpa*, Patzuneros use mechanical controls as well as botanical and synthetic pesticides (see Table 4).

Table 4. Practices used to control insect damage in the *milpa* and stored grains in Patzún (N = 45).

	% of farmers
I. Mechanical practices	
Lime for white grubs and/or weevils	8.9
Hoe for white grubs	2.2
II. Botanical pesticides	
Chysanthemum (*Chrysanthemum parthenium*)	6.7
American worm seed (*Chenopodium ambrosioides*)	2.2
Rue (*Ruta* sp.)	2.2
Coriander (*Coriandum sativum*)	2.2
Marigold (*Tagetes erecta*)	2.2
III. Synthetic pesticides	
Powdered poison for wireworms	2.2
Lorsban for white grubs	4.4
Folidol for ants	2.2
Fumigol for everything	2.2
Poison for aphids	4.4
Pesticide for beetles	15.6
Poison for treehoppers	2.2
Poison for weevils	15

Lime is sometimes used to control white grubs in the field and weevils in stored grains (9% of farmers). Honduran farmers also successfully use lime to control pests in stored grains (Hoppe, 1986). As discussed earlier, inert powders such as lime can control insects by mechanically damaging their tracheae and cuticles (Vittum, 1984; Potter et al., 1996).

Another mechanical control mentioned by a few farmers (2%) is to kill with the hoe the white grubs found while working the soil.

More popular than the mechanical practices is the use of pesticides. Botanical pesticides such as *altamisa* or *pirulillo* (*Chrysanthemum parthenium*), *apazote* (*Chenopodium ambrosioides*), *ruda* (*Ruta* sp.), *culantro* (*Coriandum sativum*), and *flor de muerto* (*Tagetes erecta*) are applied by 15% of the farmers. All of the plants that they mentioned have been recognized as effective insect repellents and insecticides by scientists, and are used by farmers around the world. Extracts of *Chrysanthemum* spp. were the active ingredient in some of the first commercialized insecticides in the late 1800s (Hansen, 1987). The botanical insecticide extracted from *Chrysanthemum* spp., pyrethrum, has been replaced in modern agriculture by synthetic pyrethroids (Hansen, 1987). *Chenopodium* spp. toxicity has also been determined for several species of insects, like seed beetles (*Callosobruchus maculatus*), the rice weevil (*Sitophilus oryzae*), and the Japanese beetle (*Popillia japonica*) (Leach and Johnson, 1925; Su, 1991). Farmers in Rwanda use this plant as an insect repellent to protect beans in the granary (Munyemana, 1986). Extracts of *Coriandrum* spp. seeds are also toxic for *T. confusum*, and *S. oryzae* (Su, 1986). Organic farming promoters have long recognized the insect repellent effect of *Ruta* spp. (Maffia, 1981). *Ruta* repels a broad range of insect pests, such as *P. japonica*, fleas and flies. Among the plants mentioned by Patzuneros, perhaps the most popular around the world for its insecticidal properties is *Tagetes* spp. (Morallo-Rejesus and Decena, 1982). The main advantage of these botanical insecticides is that farmers can grow the plants themselves, avoiding dependence on external inputs.

Nevertheless, the most common curative practice used in *milpas* is the application of synthetic insecticides. Although their use seems to be widespread in the area, 40% of the farmers that use pesticides could explain that they apply a “poison” or an “insecticide,” but they could not remember the names or they did not know what they applied. It is very common to ask for advice for pest control in the local pesticide stores, and to get just a few ounces of the product without any label. Among the insecticides that farmers remember having used are Lorsban (Clorpirifos), Folidol (Parathion), and Malatión (Malathion). The majority of these insecticides are organo-phosphates that are not very toxic, but some farmers mentioned that they need to apply them regularly to control beetles in beans and storage pests. Farmers do not have many problems in the *milpa*, but they do have problems in storage. Furthermore, many of these applications are preventive. In the field, they apply pesticides only sporadically to eliminate ants, wireworms, leafhoppers and aphids, if the populations are high.

In sum, Patzuneros’ knowledge of curative practices is not as broad or as ecologically grounded as their knowledge of preventive practices. The main reason why Patzuneros do not have a broad knowledge of curative pest management practices is that the majority of them do not consider insects to be pests in the milpa. Insect pests are a new problem for them, one that arose with the advent of non-traditional crops.

Sources of agricultural advice

Patzuneros’ lack of knowledge in reactive pest management practices is also understandable by looking at how their knowledge is gained. The farmers interviewed claim that their agricultural knowledge and practices in the *milpa* are part of their Mayan traditions. These practices have been transmitted from one generation to the next by parents and other community members. Some farmers mentioned that they also learned some agricultural practices in workshops and from agronomists (9%), but the majority (75%) is like Guillermo González who is very proud to have learned everything from his father and by himself:

> *Mi papá me daba consejos desde que yo era niño. Nunca me mandó a la escuela porque me vio que era bueno y inteligente para trabajar. Nadie me ha tenido que decir como hacer las cosas después, y solo sé como y me ha ido bien*.
> My father gave me advice since I was a child. He never sent me to school because he saw that I was good and intelligent for working. Nobody told me how to do things after that, I just know how and I have done well.

The few traditional farmers that have received advice about their growing pest problems in *milpas*, mentioned workshops organized by foreigners and/or by the General Office of Agricultural Services (DIGESA), the governmental agricultural extension office that no longer exists. Although farmers experiment and adapt to new situations, the process of developing new knowledge to deal with pests is slow. Apparently, given their lack of access to information, farmers are unable to keep up with the rapid changes induced by globalization.

Policy implications

To reduce the use of pesticides in the Guatemalan highlands, policy makers should encourage and support organizations that recognize farmers’ deep ecological knowledge, as well as their limitations. Since the focus of IPM programs in the area is on curative practices (insecticides with low persistence in the environment, biological and other selective insecticides, parasitoids and predators), the deficiencies in farmers’ knowledge of natural enemies and curative practices for pest control should be addressed. However, the emphasis should be on preventive, cultural practices that farmers are already familiar with and usually do not require costly inputs. Furthermore, bottom-up programs for pest management are necessary in the Guatemalan highlands. Some organizations like Altertec and the Cakchiquel Organization for Integrated Development (COCADI) are doing an impressive job, but they lack support. The Farmer's IPM Field Schools in Indonesia (Kenmore, 1991) and the Crop Management Project in Nicaragua (Falguni Guharay, Centro Agronómico Tropical de Investigación y Enseñanza (CATIE)-Proyecto Manejo Integrado de Plagas-Nicaragua, personal communication) are examples of the success of this bottom-up approach to the reduction of pesticide use at the national level.

An important lesson to be taken from our experiences is that scientists (and agricultural planners) must not take for granted that farmers use words the same way that they do. Identifying these discrepancies in meaning can help "experts" understand how farmers think, and can help them learn how to communicate more successfully with farmers.

Our interviews of a small subset of Patzunero farmers may provide just a suggestion of what they know and do not know about pest management in their *milpas*. Nevertheless, our data support the growing body of literature affirming the value of traditional agricultural knowledge from around the world. This knowledge should be taken into account by agricultural planners and may even be applicable to other agroecosystems.

Conclusions

Farmers in Patzún have a vast knowledge of preventive agricultural practices for pest management. These practices include soil management, plant nutrition, and strict sowing and harvesting schedules. The efficacy of some of these practices is corroborated by agroecological theory and published agronomic experiments, and seem to be environmentally innocuous. One of the most interesting findings of this study is Cakchiquel farmers' concept of a pest; if an insect does not cause economic damage, it is not a pest. This explains why the majority of the farmers in Patzún affirm that they do not have pests in their *milpa*.

The knowledge that farmers have of curative practices for pest control is much more limited than their knowledge of preventive practices. The main reason for this gap is that pest problems are relatively new in the area and farmers do not have access to information on curative practices. Another knowledge gap that this study identified is their lack of knowledge of biological control. This may also explain the failure of the adoption of curative practices and biological control recommended by IPM projects in the area.

The preventive pest management knowledge of the Cakchiquel farmers merits consideration by pest management planners and researchers. This seems especially important now that farmers are confronting new pests, and using synthetic pesticides. Both scientists and farmers stand to benefit from understanding why pests are a growing problem in the area and whether the environmentally-sound, traditional practices for pest management could be applied to a changing agroecosystem.

Acknowledgments

We want to express our gratitude to all the people and institutions that allowed us to complete this work: to the farmers that shared their knowledge with us, especially to Jacinto Pelicó, Angela López, Alejandro Cipac, Guillermo Teleguario, and José Raquec; to Bruce Ferguson for his criticism and his patience editing this article; to John Vandermeer, John Witter, Roger Williams, and the New World Agricultural and Ecology Group, for providing insightful ideas and criticism; to Fulbright-LASPAU, IPM-CRSP/USAID, the Latin American and Caribbean Studies, the Rackham School of Graduate Studies, and the School of Natural Resources and Environment at The University of Michigan for providing funds through grants for Helda Morales; and to the anonymous reviewers for providing constructive criticism.

References

Aguilar, E. (1993). *Sistematización del conocimiento agrícola campesino en comunidades seleccionadas del departamento de El Quiché, a base de tecnologías campesinas*. División de Ciencia y Tecnología del Centro Universitario de Occidente, Universidad de San Carlos de Guatemala, Guatemala: Tésis de Licenciatura.

Andow, D. (1991). "Vegetational diversity and arthropod population response." *Annual Review of Entomology* 36: 561–586.

Andow, D. and P. Rosset (1990). "Integrated pest management." In R. Carroll, J. Vandermeer, and P. Rosset (eds.), *Agroecology* (pp. 413–440). New York: McGraw-Hill, Biological Resources Management Series.

Altertec (1996). "Rescate del conocimiento campesino, Salamá, Purulha, Baja Verapaz." *Boletín Permacultural: Alternativa* 1(2): 2.

Altieri, M. (1984). "Towards a grassroots approach to rural development in the Third World." *Agriculture and Human Values* 1(4): 45–48.

Altieri, M. and J. Trujillo (1987). "The agroecology of corn production in Tlaxcala, México." *Human Ecology* 15(2): 189–220.

Asturias, M. A. (1949). *Hombres de Maíz*. Buenos Aires, Argentina: Editorial Losada, S. A.

Barzman, M., N. Mills, and N. Thi Thu Cuc (1996). "Traditional knowledge and rationale for weaver ant husbandry in the Mekong Delta of Vietnam." *Agriculture and Human Values* 13(4): 2–9.

Bentley, J. (1989). "What farmers don't know can't help them: The strengths and weaknesses of indigenous technical knowledge in Honduras." *Agriculture and Human Values* 6(3): 25–31.

Bentley, J. (1992). "Alternatives to pesticides in Central America: Applied studies of local knowledge." *Culture and Agriculture* 44: 10–13.

Birch, L. (1953). "Experimental background to the study of the distribution and abundance of insects. I. The influence of temperature, moisture and food on the innate capacity for increase of three grain beetles." *Ecology* 34: 698–711.

Borror, D., C. Triplehorn, and N. Johnson (1989). *An Introduction to the Study of Insects*. Fort Worth: Saunders College Publishing.

CATIE, Proyecto Regional Manejo Integrado de Plagas (1990). *Guía para el manejo integrado de plagas del cultivo del maíz*. Turrialba, Costa Rica: Centro Agronómico de Investigación y Enseñanza (CATIE).

Chambers, R. (1983). *Rural Development: Putting the Last First*. New York: Longman.

Clark, H. and M. Schober (1992). "Asking questions and influencing answers." In J. Tanur (ed.), *Questions about Questions* (pp. 15–48). New York: Russel Sage.

Conroy, M., D. Murray, and P. Rosset (1996). *A Cautionary Tale: Failed US Development Policy in Central America*. Boulder, Colorado: Lynne Rienne Publishers.

Costello, M. and M. Altieri (1995). "Abundance, growth rate and parasitism of *Brevicoryne brassicae* and *Myzus persicae* (Homoptera: Aphidae) on broccoli grown in living mulches." *Agriculture, Ecosystems and Environment* 52: 187–196.

Culliney, T. and D. Pimentel (1986). "Ecological effects of organic agricultural practices on insect populations." *Agriculture, Ecosystems and Environment* 15: 253–266.

De Walt, B. (1994). "Using indigenous knowledge and natural resource management to improve agriculture and natural resource management." *Human Organization* 53(2): 123–131.

Dix, A., R. Carroll, M. Dix, and G. Dal Bosco (1995). *Corn Stalks Influence Patchy Distribution of White Grubs in Broccoli Fields*. Virginia Tech, Blacksburg: IPM-CRSP Working Paper 95-5.

Eigenbrode, S. and D. Pimentel (1988). "Effects of manure and chemical fertilizers on insect pest populations on collards." *Agriculture, Ecosystems and Environment* 20: 109–125.

Fisher, R. (1994). "Sostenibilidad ecológica en cultivos no-tradicionales de exportación para pequeños productores de Guatemala: Algunas consideraciones y experiencias en la protección ambiental y el manejo integrado de plagas y plaguicidas." In *Sostenibilidad de la producción agrícola no-tradicional de exportación por pequeños productores en Guatemala, Memorias*. Guatemala: Instituto de Nutrición de Centro América y Panamá (INCAP).

Freire, P. (1968). *Pedagogy of the Oppressed*. New York: The Seabury Press.

García, A. (1994). "Sostenibilidad ambiental: Responsabilidad del sector privado y del sector productor." In *Sostenibilidad de la producción agrícola no-tradicional de exportación por pequeños productores en Guatemala, Memorias*. Guatemala: Instituto de Nutrición de Centro América y Panamá (INCAP).

Gliessman, S. (1981). "The ecological basis for the application of traditional agricultural technology in the management of tropical agroecosystems." *Agro-Ecosystems* 7: 173–185.

Golob, P. (1997). "Current status on future perspectives for inert dust for control of stored product insects." *Journal of Stored Products Research* 33(1): 69–79.

Gómez-Pompa, A. and A. Kaus (1992). "Taming the wilderness myth." *BioScience* 42(4): 271–279.

Greenfield, J. (1989). *Vetiver Grass* (*Vetiveria* spp.): *The Ideal Plant for Vegetative Soil and Moisture Conservation*. Washington, DC: The World Bank.

Hansen, M. (1987). *Escape from the Pesticide Treadmill: Alternatives to Pesticides in Developing Countries*. New York: Institute for Consumer Policy Research Consumers Union.

Heliövaara, K., R. Väisänen, and C. Simon (1994). "Evolutionary ecology of periodical insects." *Trends in Ecology and Evolution* 9(12): 475–480.

Hildebrand, P., S. Ruano, T. López Yos, E. Samayoa, and R. Duarte (1977). *Sistemas de cultivos para los agricultores tradicionales del occidente de Chimaltenango*. Guatemala: Instituto de Ciencia y Tecnología Agrícolas, Ministerio de Agricultura.

Hoppe, T. (1986). "Storage insects of basic food grains in Honduras." *Tropical Science* 26(1): 25–38.

Hoppin, P. (1991). *Pesticide Use on Four Non-Traditional Crops in Guatemala: Policy and Program Implications*. Baltimore: School of Hygiene and Public Health, Johns Hopkins University, Doctoral Dissertation.

Horn, D. (1988). *Ecological Approach to Pest Management*. New York: The Guilford Press.

Hruska, A. and M. Gómez Peralta (1997). "Maize response to corn leafhopper (Homoptera: Cicadellidae): Infestation and achaparramiento disease." *Journal of Economic Entomology* 90(2): 604–610.

Immink, M. and J. Alarcón (1993). "Household income, food availability, and commercial crop production by smallholder farmers in the western highlands of Guatemala." *Economic Development and Cultural Change* 41(2): 319–342.

IPM-CRSP (1996). "Integrated pest management in non-traditional export crops." In *II Seminario de Manejo Integrado de Plagas en Cultivos No-Tradicionales de Exportación* (p. 90). Guatemala: IPM-CRSP/Guatemala.

Kenmore, P. (1991). *How Rice Farmers Clean up the Environment, Conserve Biodiversity, Raise More Food, Make Higher Profits: Indonesia's IPM-a Model for Asia*. Jakarta, Indonesia: FAO Inter-country program for Integrated Pest Control in Rice in South and Southeast Asia.

Kelly, D. (1994). "The evolutionary ecology of mast seeding." *Trends in Ecology and Evolution* 9(12): 465–470.

King, A. and J. Saunders (1984). *Las plagas invertebradas de cultivos anuales alimenticios en América Central*. London: Overseas Development Administration.

Leach, B. and J. Johnson (1925). *Emulsion of Worm Seed Oil and of Carbon Disulfide for Destroying Larvae of the Japanese Beetle in the Roots of Perennial Plant*. Washington, DC: US Department of Agriculture Bulletin 1332.

Letourneau, D., L. Drinkwater, and C. Shennan (1996). "Effects of soil management on crop nitrogen and insect damage in organic vs. conventional tomato fields." *Agriculture, Ecosystems and Environment* 57: 179–187.

Maffia, N. (1981). *Companion Planting and Intensive Cultivation*. Emmaus: Rodale Press.

Moles, J. (1989). "Agricultural sustainability and traditional agriculture: Learning from the past and its relevance to Sri Lanka." *Human Organization* 48(1): 70–78.

Morales, H. (1998). *Pest Control and Soil Management in the Guatemalan Highlands: Understanding Traditional Agricultural Practices*. School of Natural Resources and Environment, The University of Michigan, Ann Arbor: Doctoral Dissertation.

Morales, H., R. Pérez, and C. MacVean (1994). *Impacto ambiental de los cultivos no tradicionales en el altiplano de Guatemala*. Guatemala: Asociación para el Avance de las Ciencias Sociales (AVANCSO), Textos para Debate No. 5.

Morallo-Rejesus, B. and A. Decena (1982). "The activity, isolation, purification and identification of the insecticidal principles from *Tagetes erecta*." *The Philippine Journal of Crop Science* 7(1): 31–36.

Munyemana, P. (1986). *Essai de préservation du haricot* (*Phaseolus vulgaris* L.) *contre Acanthoscelides obtectus Say en utilisant les produits d'origine végétale*. Memoire présenté en vue de l'obtention du grade d'ingénieur agronome (UNR-Butare). Cited by J. Kayitare and L. Ntezurubanza (1991). "Evaluation de la toxicité et de l'effet repulsif de certaines plantes du Rwanda contre les bruches du haricot: *Acanthoscelides obtectus* Say et *Zabrotes subfasciatus* Boheman." *Insect Science and Its Application* 12(516): 695–697.

Murray, D. (1995). *Cultivating Crisis: The Human Cost of Pesticides in Latin America*. Austin: The University of Texas Press.

Nelson, K. (1994). *Participation and Empowerment: A Comparative Study of IPM Technology Generation in Nicaragua*. School of Natural Resources and Environment, The University of Michigan, Ann Arbor: Doctoral Dissertation.

Oldfield, M. and J. Alcorn (1987). "Conservation of traditional agroecosystems." *Bio Science* 37(3): 199–208.

Patton, M. (1990). *Qualitative Evaluation and Research Methods*. London: Sage Publications.

Phelan, P., J. Mason, and B. Stinner (1995). "Soil-fertility management and host preference by European corn borer, *Ostrinia nubilalis* (Hubner), on *Zea mays* L.: A comparison of organic and conventional chemical farming." *Agriculture, Ecosystems and Environment* 56: 1–8.

Posey, D. and B. William (1989). *Resource Management in Amazonia: Indigenous and Folk Strategies*. New York: New York Botanical Garden, Advances in Economic Botany Series No. 7.

Potter, D., A. Powell, P. Spicer, and D. Williams (1996). "Cultural practices affect root feeding white grubs (Coleoptera: Scarabaeidae) in turfgrass." *Journal of Economic Entomology* 89(1): 156–164.

Raymundo, S. and J. Alcazar (1983). "Dusting with ashes to reduce leaf-miner fly damage on potatoes (*Liriomyza huidrobensis*)." *Appropriate Technology* 10(3): 17.

Risch, S., D. Andow, and M. Altieri (1983). "Agroecosystems diversity and pest control: Data, tentative conclusions, and new research directions." *Environmental Entomology* 12(3): 625–629.

Santízo, E., J. Sandoval, and E. Calderón (1996). "Transference of technology on snow peas." In *Integrated pest management in non-traditional export crops. II Seminario de Manejo Integrado de Plagas en Cultivos No-Tradicionales de Exportación* (p. 72). Guatemala: IPM-CRSP/Guatemala.

Saunders, J., A. King, and C. Vargas (1983). *Plagas de cultivos en América Central*. Turrialba, Costa Rica: Centro Agronómico de Investigación y Enseñanza (CATIE).

Schwarz, N., H. Hippler, and E. Noelle-Neumann (1992). "A cognitive model of response-order effects in survey measurement." In N. Schwarz and S. Sudman (eds.), *Context Effects in Social and Psychological Research* (pp. 187–201). New York: Springer-Verlag.

Sillitoe, P. (1998). "The development of indigenous knowledge." *Current Anthropology* 39(2): 223–252.

Slikkerveer, L. (1989). "Changing values and attitudes of social and natural scientists towards indigenous peoples and their knowledge systems." In D. Warren, L. Slikkerveer, and S. Titilola (eds.), *Indigenous Knowledge Systems for Agriculture and International Development* (pp. 121–137). Ames: Technology and Social Change Program, Iowa State University, Studies in Technology and Social Change No. 11.

Smith, L. (1993). "Effect of humidity on life history characteristics of *Anisopteromalus calandrae* (Hymenoptera: Pteromalidae) parasitizing maize weevils (Coleoptera: Curculionidae) larvae in shelled corn." *Environmental Entomology* 22(3): 618–624.

Su, H. (1986). "Laboratory evaluation of the toxicity and repellency of coriander seed to four species of stored-product insects." *Journal of Entomological Science* 21(2): 169–174.

Su, H. (1991). "Toxicity and repellency of Chenopodium oil to four species of stored product insects." *Journal of Entomological Science* 26(1): 178–182.

Terán, S. and C. Rasmussen (1994). *La milpa de los Mayas*. Mérida, Yucatán, Mexico: Danida.

Throne, J. (1994). "Life history of immature maize weevils (Coleoptera: Curculionidae) on corn stored at constant temperature and percentage of humidity." *Environmental Entomology* 23(6): 1457–1471.

Thrupp, L. A. (1989). "Legitimizing local knowledge: From displacement to empowerment for third world people." *Agriculture and Human Values* 6(3): 13–23.

Thrupp, L. A., G. Bergeron, and W. Water (1995). *Bittersweet Harvest for Global Supermarkets: Challenges in Latin America's Agricultural Export Boom*. Washington, DC: World Resources Institute.

Thurston, D. (1991). *Sustainable Practices for Plant Disease Management in Traditional Farming Systems*. Boulder, Colorado: Westview Press.

Ucán Ek, E., M. Narváez, A. Puch, and C. Chan (1982). "El cultivo del maíz en el ejido de Mucel, Pixoy, Valladolid, Yucatán." In *Nuestro Maíz* (pp. 243–287). México, D.F.: Dirección general de culturas populares.

Vandermeer, J. and D. Andow (1986). "Prophylactic and responsive components of an integrated pest management program." *Journal of Economic Entomology* 79(2): 299–302.

Vanek, E. (1989). "Enhancing resource management in developing nations through improved attitudes towards indigenous knowledge systems: The case of the World Bank." In D. Warren, L. Slikkervear, and S. Titilola (eds.), *Indigenous*

Knowledge Systems for Agriculture and International Development. Ames: Technology and Social Change Program, Iowa State University, Studies in Technology and Social Change No. 11.

Vittum, P. (1984). "Effect of lime applications in Japanese beetle (Coleoptera: Scarabaeidae) grub populations in Massachusetts soils (*Popillia japonica*)." *Journal of Economic Entomology* 77(3): 687–690.

Warren, D. (1991). *Using Indigenous Knowledge in Agricultural Development*. Washington, DC: The World Bank, World Bank Discussion Paper No. 127.

Wightman, J. and A. Wightman (1994). "An insect, agronomic and sociological survey of groundnut fields in Southern Africa." *Agriculture, Ecosystems and Environment* 51: 311–331.

Address for correspondence: Helda Morales, Departamento de Agroecología, El Colegio de la Frontera Sur, Carretera Panamericana y Periférico Sur, Apartado Postal 63, C. P. 29290, San Cristóbal de Las Casas, Chiapas, México
Phone: +52-967-81883 ext. 4217; Fax: +52-967-82322; E-mail: hmorales@sclc.ecosur.mx