International Journal of Pest Management, October–December 2006; 52(4): 303–315

Taylor & Francis
Taylor & Francis Group

Pest management and other agricultural practices among farmers growing cruciferous vegetables in the Central and Western highlands of Kenya and the Western Himalayas of India

FRANCISCO R. BADENES-PEREZ & ANTHONY M. SHELTON

Department of Entomology, Cornell University, New York State Agricultural Experiment Station, Geneva, NY, USA

Abstract
A survey of 125 farmers was conducted in 2005 in the Central and Western highlands of Kenya and the Kullu valley in the Western Himalayas of India to investigate pest management practices and constraints among farmers growing cruciferous vegetables. Lepidopteran insects were the most important pests affecting the crops and pest management relied primarily on application of pyrethroid and/or organophosphate insecticides with high environmental impact quotients (measuring the potential negative effects of insecticides on human and environmental health) averaging 65.6 in the Kenya highlands and 55.7 in the Kullu valley. Just over half (54.4%) of farmers based their decision to apply insecticides on the presence of the pest in the crop, around a third (30.4%) based it on a calendar, and 15.2% based it on both. Farmers cited their own experience (66.4%) and pesticide providers (44.8%) as the main sources of pest management information, while advice from extension (24%) and other farmers (15.2%) was less important. Most farmers interviewed (94%) were not aware of natural enemies. Possibilities to improve pest management practices are discussed in the context of the farmers interviewed.

Keywords: *Highland agroecosystems, cruciferous vegetables, environmental impact quotient, Lepidoptera, natural enemies, insecticide alternatives*

1. Introduction

Cruciferous vegetables are grown worldwide and are a key part of the Indian and Kenyan diet and an important source of vitamins and fibre. India is one of the main producers of cruciferous vegetables worldwide, ranking number one and two in the world in production of cauliflower, *Brassica oleracea* var. *botrytis* L., and cabbage, respectively (FAOSTAT 2005). Production of cruciferous vegetables in India varies across states and the highland agroecosystems of the Kullu valley, Himachal Pradesh, are known for off-season production of cabbage and cauliflower, which can be sold at higher market prices. Kenya is the biggest producer of cabbage in Africa (FAOSTAT 2005). In Kenya, the main cruciferous vegetables are cabbage, *Brassica oleracea* var. *capitata* L., and kale, *Brassica oleracea* var. *acephala* L., which are grown throughout the country, but mostly at altitudes over 800 m (FAOSTAT 2005; Macharia et al. 2005).

Worldwide, major constraints upon production of cruciferous vegetables are insect pests (Capinera 2001). Among insect pests affecting cruciferous vegetables, the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is considered to be the most destructive throughout the world (Talekar 1992). However, the presence and relative importance of *P. xylostella* and other insect pests of cruciferous vegetables vary depending on the location. Management of insect pests often relies exclusively on synthetic insecticides, and indiscriminate use of pesticides is common among farmers in developing countries (FAO 2005). However, cultural practices and other non-chemical pest management methods derived from traditional knowledge have also been shown to be common among some subsistence farmers in developing countries (Thurston 1991; Altieri 1993; Poswal et al. 1993; Morales and Perfecto 2000; Puoubom et al. 2005). Compared with lowland agroecosystems, highland agroecosystems are often characterized by smaller landholdings, lower temperatures that affect the complex of pests on the crops, and more difficult access to agricultural inputs (Riley et al. 1990; Morales and Perfecto 2000; Sanchez 2002).

The main objective of this study was to obtain comprehensive information on pest management and other agricultural practices among farmers growing cruciferous vegetables in highland agroecosystems of India and Kenya. This information can be used to assess the impact of the current pest management practices (e.g. insecticides) and to offer alternative pest management methods. Conducting this research in these study areas can show how differences and similarities in pests and their management occur among locations in the same regions and between

Correspondence: Francisco R. Badenes-Perez, Department of Entomology, Cornell University, New York State Agricultural Experiment Station, 630 W. North Street, Geneva, NY 14456, USA. Tel: 1 315 2782739. Fax: 1 607 2550939. E-mail: frb3@cornell.edu

ISSN 0967-0874 print/ISSN 1366-5863 online © 2006 Taylor & Francis
DOI: 10.1080/09670870600819169

countries that are important producers of cruciferous vegetables in highland agroecosystems. Controlling those insect pests that are most damaging and widespread should be the priority of research and development programmes to improve farmer livelihoods.

2. Materials and methods

The study sites were selected on the basis of being located in highland agroecosystems and being important producers of cruciferous vegetables according to previous studies, recommendations from local scientists and extension agents and statistical data (Kumar et al. 2000; Ministry of Agriculture Republic of Kenya 2004; FAOSTAT 2005; Macharia et al. 2005). Surveys in the Kullu valley (Western Himalayas) of Himachal Pradesh, India, were conducted between April and May 2005 in three areas: Bajaura (1220 m), Katrain (1465 m) and Jana (2286 m). Surveys in Kenya were conducted between September and October 2005 in Embu (1300 m) and Kitale (1900 m) in the Central and Western highlands, respectively. In Embu district, the study included farmers in the Central, Manyatta, and Neinbure divisions. In Trans Nzoia district, where Kitale is located, the study included farmers in the Gitwamba, Nyakinyua, and Kpsaina-arba divisions.

Data were collected using interviews and observational survey techniques. Quantitative data originated from estimates given by the farmers during the interviews. In total, 125 farmers were interviewed (25 in each location, Bajaura, Katrain, Jana, Embu, and Kitale). Most farmers were interviewed while they were in their farms (nearby their homes). In addition to the data provided by farmers responding to a structured questionnaire (see Appendix A), additional data on presence of insect pests were gathered by making *in situ* observations during farm visits.

2.1. Farmers' socioeconomic background and general agricultural practices

Data gathered included age and years of formal education, total amount of land cultivated, percentage of cultivated land devoted to cruciferous vegetables, ownership of the land cultivated, type of irrigation, crop diversity, sources of income, production costs, and crop sale.

2.2. Main pest problems

Farmers were asked about the main insect pests damaging their cruciferous vegetables as well as other causes of crop loss (e.g. diseases). Farmers were also asked to provide an estimate of crop loss derived from insect pests, even with the use of insecticides or other pest management methods. Such perceptions, although not validated, are the basis for the implementation of insect pest management tactics among farmers. Additionally, insect pests were surveyed in the farmer's field by randomly selecting 10 plants and identifying the species of insect pests present at the time the study was conducted.

2.3. Pest management practices

Farmers were asked about their pest management practices, namely pest management methods used, approximate number of sprays per crop, pesticides used, type of pesticide sprayers used, basis for making an insecticide application (presence of insect pests, calendar, or a combination of both), and gender of applicator. In locations where cruciferous vegetables were planted several times per year, the number of sprays per crop was given as an average. Farmers usually sprayed more insecticides in the summer than in the winter, when insect pests were fewer and developed slower because of lower temperatures. Additionally, since the incidence of malaria affects a farmer's ability to produce cruciferous vegetables, the main focus of this study, in Kenya farmers were asked about their awareness of malaria and their use of mosquito nets in their households to prevent this debilitating disease.

2.4. Impact of current practices

The potential negative impacts of pesticides can be quantified using the environmental impact quotient (EIQ) (Kovach et al. 2004). Based on measures of toxicity, exposure and pattern of pesticide use, EIQ values assess the potential negative effects of pesticides on farm workers, consumers and the environment. Given the large quantity of pesticide brands used by the farmers interviewed in this study, the EIQ values of the insecticides mentioned by the farmers interviewed were estimated using the EIQ total values from Kovach et al. (2004). Similarly to other studies (Mazlan and Mumford 2005), EIQ values of the insecticides used were divided into three categories of impact on humans and the environment: low (0 – 20), medium (21 – 40), and high impact ($\geq$41).

The possibilities to use alternatives to the current insect pest management practices to reduce overall EIQ values and to improve pest management in general were considered using a Strengths Weaknesses Opportunities Threats (SWOT) analysis. Three main alternatives to the current use of insecticides for pest management were considered: biological control, trap cropping, and genetically modified Bt-crucifers. The focus of these alternatives was on control of *P. xylostella*, which was overall the pest of greatest concern to the farmers interviewed.

2.5. Pest management information

Farmers were asked (using an open-ended question) about the sources of information they used as a knowledge basis for their pest management practices. Farmers were also asked whether they read the pesticide label and whether they knew about natural enemies in their fields.

2.6. Data analysis

Data were presented as averages (absolute values or percentages, depending on the factor investigated) for each location where the survey was conducted. Prior to taking averages for each location, if individual farmers provided estimates as a range, the median value was considered. A possible correlation between the number of spray applications per crop per season and several factors (age, years of formal education, total land cultivated, land devoted to crucifers, pesticide expenses, and crop loss due to insect damage) was investigated pooling the data within each country and using the PROC GLM procedure of SAS® (SAS Institute Inc. 2004) with location as a block. A possible correlation between production costs and crop sale was also investigated pooling the data within each country and using the PROC GLM procedure of SAS® (SAS Institute Inc. 2004). Differences in number of spray applications per crop between locations within each country were analyzed using the PROC GLM procedure of SAS® (SAS Institute Inc. 2004). Differences among expenses for the main agricultural inputs (pesticides, fertilizer, and seed) were analyzed using a repeated measures analysis with the PROC MIXED procedure of SAS® (SAS Institute Inc. 2004) with farmers being considered a random variable. In order to normalize the residuals before analysis, all data were transformed using a using a natural $\log(x+1)$ function. When significant treatment differences were indicated by a significant *F*-test at $P \leq 0.05$, means were separated by Fisher's protected least significant difference (LSD) (SAS Institute Inc. 2004).

3. Results

3.1. Farmers' socioeconomic background and general agricultural practices

On average, the farmers interviewed were in their mid thirties to early forties and had received less than 10 years of formal education (Table I). The percentage of farmers interviewed that were illiterate ranged from zero in Bajaura and Katrain to over a third in Jana (this village used to be poorly connected to the nearest town with a school). All farmers were small landholders (<1.5 ha). All farmers interviewed owned most of the land that they cultivated, except for two Nepali farmers interviewed in Katrain and Jana who did not own any of the land that they cultivated (they worked for a landlord who allowed them to cultivate part of the land as a form of payment). The mean percentages of land devoted to cruciferous vegetables ranged from 22% in Embu to 56% in Bajaura, indicating the relative importance of these crops in the areas of study (data not shown). All farmers interviewed grew several crops, with over 84% of the farmers visited in each location using multicropping (more than one crop being grown simultaneously in the field) in the fields where their cruciferous vegetables were planted. All farmers interviewed had livestock and only a small percentage had income from jobs related to services or government. Tilapia fish farming was also cited as a source of income by two farmers in Embu. In the areas visited in the Kenya highlands, cruciferous vegetables were planted at the beginning of the rainy season in cases where crops depended exclusively on rain, or almost throughout the year in cases where irrigation was available. As shown by a previous study in the Kullu valley (Kumar and Kashyap 1999), production of cruciferous vegetables occurs only in the summer in the regions of higher altitude (March–September), as in the case of Jana. In the lower Kullu valley (Bajaura), temperatures are higher and allow production of cruciferous vegetables throughout the year (Kumar et al. 2000), with cabbage being planted in the summer and cauliflower in the winter because of its cold requirements (Barwal 2001). Crop sale prices were presented as averages, but market prices were higher for cauliflower than cabbage. There was a positive correlation between production costs and crop sale for both the Kenya highlands ($y = 1.31x + 3.83$, $F_{1,47} = 170.44$, $R^2 = 0.78$, $P < 0.001$) and the Kullu valley ($y = 0.72x + 34.56$, $F_{1,72} = 39.63$, $R^2 = 0.40$, $P < 0.001$), although the relationship, as indicated by the higher R^2 value, was stronger in Kenya. The absolute monetary value of production costs and crop sale was approximately twice as high in the Kullu valley than in the Kenya highlands. However, the ratio of crop sale to production costs was similar (2.2 in the Kenya highlands and 2.3 in the Kullu valley), indicating that farmers sold their production for approximately twice the cost of producing it. In the Kenya highlands the relative cost of fertilizer, pesticides, and seed were 2.2, 1.4, and 1.1 times higher than in the Kullu valley, respectively. On average, in the Kenya highlands production costs allocated to fertilizers (17.5% of all production costs) were significantly higher ($F = 6.28$, df: 2,48, $P = 0.0038$) than production costs spent on seed (11.8% of all production costs), while pesticide expenses (14.1% of all production costs) were not significantly different from fertilizer and seed expenses. In the Kullu valley, production costs allocated to pesticides (12.5% of all production costs) were significantly higher ($F = 29.78$, df: 2,48, $P < 0.0001$) than production costs allocated to fertilizer and seed (7.8 and 8.6% of all production costs, respectively). All farmers interviewed had livestock and used manure as a fertilizer. Except for one farmer in Katrain that purchased open-pollinated

Table I. Socioeconomic background of farmers interviewed in the Kenya highlands and the Kullu valley of India. Data presented as averages for each location (Bajaura, Katrain, Jana, Embu, and Kitale).

	Location				
	India			Kenya	
Socioeconomic background	Bajaura ($n=25$)	Katrain ($n=25$)	Jana ($n=25$)	Embu ($n=25$)	Kitale ($n=25$)
Age ± SE	42.4 ± 1.3	35.6 ± 2.2	34.7 ± 2.1	37.2 ± 3.1	41.8 ± 2.0
Years of education ± SE (percentage illiterate)	7.9 ± 0.7 (0%)	10.6 ± 0.9 (0%)	6.0 ± 1.2 (36%)	7.3 ± 0.7 (8%)	7.7 ± 0.8 (12%)
Total land (in ha) ± SE/crucifers (%)	0.9 ± 0.1/56%	1.0 ± 0.1/30%	1.4 ± 0.3/36%	0.9 ± 0.2/22%	0.9 ± 0.2/28%
Farmers owning/ leasing land (%)	100/0	96/12	96/12	100/0	100/0
Number of crops of crucifers per year	2.6	1.5	1	2.7	2.2
Percentage of farmers whose fields presented multicropping patterns	84%	92%	100%	92%	96%
Farmers with income outside farming[A] (%): livestock/services/ government	100/12/0	100/8/4	100/4/0	100/12/8	100/8/0
Production[B] costs/sale (in $US per ha)	1,962.7/3,914.7	1,262.4/3,066.7	1,664.0/3,872.0	783.6/1,762.2	559.8/1,350.4
Fertilizer[C]/Seed[D]/ Pesticides (% production costs)	5.7/8.0/9.7	12.7/10.7/14.0	5.1/7.1/13.7	17.6/8.0/11.7	17.4/15.6/16.5
Production sale (%): wholesale (W)/retail (R)/broker (B)/retail and broker (RB)	W 100%	W 100%	W 100%	R 20% B 48% RB 32%	R 36% B 60% RB 4%
Access to irrigation scheme (%) (yes, irrigated/no, rain-fed only)	100/0	100/0	100/0	84/16	48/68

[A]Besides livestock, services and government, two farmers in Embu also relied on tilapia fish farming as an additional income source. [B]Included production of cauliflower, cabbage and broccoli in the Kullu valley and cabbage and kale in the Kenya highlands. [C]Referred to inorganic fertilizers. Additionally, all farmers interviewed used manure from their livestock. [D]All farmers except one used hybrid seed from private companies.

seed from a public institution (Indian Agricultural Research Institute), all other farmers interviewed in the Kullu valley and the Kenya highlands purchased hybrid seed from private companies. Farmers interviewed in Kenya sold their produce either to brokers or directly to consumers in retail markets. Farmers interviewed in India always sold their produce in wholesale markets, either at local or regional markets.

3.2. Main pest problems

Insect pests mentioned by the farmers interviewed included diamondback moth, *P. xylostella*, cutworm, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae), cabbage white butterfly, *Pieris brassicae* (L.) (Lepidoptera: Pieridae), aphids, *Brevicoryne brassicae* (L.), *Lipaphis erysimi* (Kaltenbach) and *Myzus persicae* (Sulzer) (Homoptera: Aphididae), fruit borer, *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae), and cabbage maggot, *Delia radicum* (L.) (Diptera: Anthomyiidae) (Table II). These data are in agreement with additional information provided by local entomologists and extension agents as well as other studies surveying insect pests in different parts of Kenya (Kibata 1996b; Odour et al. 1996; Macharia et al. 2005) and the state of Himachal Pradesh in India (Kumar et al. 2000; Barwal 2001). Identification of the insect pests observed in farmers' fields was also in agreement with the species mentioned by farmers with the exception of Jana, where only aphids were seen in the field at the time when this research was conducted because most cruciferous vegetables present were at an early stage. Farmers interviewed cited *P. xylostella* as the most important insect pest in Bajaura, Embu and Kitale, while it was considered the second major insect pest in Katrain. *Agrotis ipsilon* was considered the main insect pest in Jana and the third insect pest in Embu and Kitale. *Pieris brassicae* was cited as the main insect pest in Katrain. Aphids were mentioned often, especially in Embu, Kitale and Katrain; *H. armigera* was mentioned only in the locations visited in India;

Table II. Main pest problems in cruciferous vegetables of farmers interviewed in the Kenya highlands and the Kullu valley of India. Data presented as averages for each location (Bajaura, Katrain, Jana, Embu, and Kitale).

	Location				
	India			Kenya	
Main pest problems	Bajaura ($n=25$)	Katrain ($n=25$)	Jana ($n=25$)	Embu ($n=25$)	Kitale ($n=25$)
Main insect pests[A] (percentage of farmers mentioning it)	DBM (100%) CB (52%) B (8%) A (8%)	CB (64%) DBM (32%) A (28%) CM (12%) CW (8%) B (4%)	CW (60%) B (36%) A (16%) DBM (4%)	DBM (92%) A (60%) CW (44%) CM (8%)	DBM (96%) A (86%) CW (24%)
Main insect pests in field observations during interview	DBM (100%) CB (60%) A (16%)	CB (60%) DBM (36%) A (36%) CM (4%)	A (88%)	DBM (88%) A (72%) CW (4%)	DBM (92%) A (92%)
Crop loss due to insect pests	13.6%	5.2%	5.8%	9.4%	14.2%
Other causes of crop loss (percentage of farmers mentioning it)	Rain (40%)	Rain (32%) Dogs (4%) Monkeys (4%)	Rain (32%) Wind (12%) Excessive sun (8%)	Diseases (20%) Rain (24%) Drought (20%) Cold (12%) Birds (12%)	Diseases (40%) Rain (20%) Drought (16%) Nematodes (4%) Chlorosis (4%)

[A]Main insect pests mentioned by the farmers and/or observed in situ included diamondback moth (DBM), *Plutella xylostella*; cabbage white butterfly (CB), *Pieris brassicae*; aphids (A), *Brevicoryne brassicae*, *Lipaphis erysimi* and *Myzus persicae*; cutworm (CW), *Agrotis ipsilon*; borer (B), *Heliothis armigera*; and cabbage maggot (CM), *Delia radicum*.

and *D. radicum* was mentioned only in Katrain and Embu, indicating its status as a sporadic local pest. Crop losses due to insect pests, despite the application of insecticides, were more than twice as high in Bajaura than in Katrain and Jana, probably because of insecticide resistance in *P. xylostella*, the main insect pest in Bajaura. Farmers in Bajaura grow cruciferous vegetables almost throughout the year and insecticide resistance in *P. xylostella* occurs frequently (Lal and Kumar 2004). On average, the range of estimated crop losses caused by insect pests among farmers in the Kenya highlands was between 9 and 14% and some farmers said that they had problems controlling *P. xylostella* because of insecticide resistance. Resistance to pyrethroid insecticides has also been recorded in Kenya (Kibata 1996a). Another important cause of crop loss was black rot, *Xanthomonas campestris* pv. *campestris* (Pam) Dowson, considered to be the main disease of cruciferous vegetables in Himachal Pradesh (Thakur et al. 2003) and Kenya (Osando 1988). However, farmers often referred to rain (the agent triggering black rot spread) as the cause of the loss, rather than the disease itself. Drought was an important cause of crop loss among farmers growing rain-fed crops. Other diseases, sun, wind, cold, chlorosis due to nutrient deficiency, nematodes, birds, dogs and monkeys were mentioned occasionally as causes of crop loss.

3.3. Pest management practices

All farmers relied on pesticides as their main pest management method (Table III). A few farmers mentioned hand collection of *P. brassicae* larvae in Bajaura and Katrain. Adult females of *Pieris brassicae* lay eggs in batches of 20 – 100 eggs, so they are very visible and easy to pick and kill once larvae emerge because they are concentrated on the same leaf. One farmer mentioned using a barrier crop of *Tagetes minuta* against *P. xylostella*, a technique whose effectiveness has not been scientifically tested. Indian mustard has been shown to be highly attractive to ovipositing *P. xylostella* females (Badenes-Perez et al. 2004) and has been reported to be a successful trap crop in India (Srinivasan and Krishna Moorthy 1991). Two farmers in Katrain had planted Indian mustard, which would be acting as a trap crop for *P. xylostella*, next to a cauliflower crop. These farmers however, were not aware of the use of Indian mustard as a trap crop. The mean number of pesticide applications per crop was 5.8 in the Kenya highlands and 4.8 in the Kullu valley, varying depending on the location within each area of study both in the Kenya highlands ($F=7.49$, df: 1,48, $P=0.0087$) and the Kullu valley ($F=5.77$, df: 2,72, $P=0.0047$), with the highest number of pesticide applications per crop being made in Embu and Jana. In other parts of India, where cruciferous vegetables are grown throughout the year and environmental conditions are drier and warmer than in the Kullu valley, the number of pesticide applications per crop, targeting mainly *P. xylostella*, may be much higher. The main pesticides mentioned were pyrethroids (used by 86.0 and 69.3% of the farmers in the Kenya highlands and the Kullu valley, respectively) and organophosphates (used by 38.0 and 46.7% of the farmers in the Kenya

Table III. Pest management practices of farmers interviewed in the Kenya highlands and the Kullu valley of India. Data presented as averages for each location (Bajaura, Katrain, Jana, Embu, and Kitale).

	Location				
	India			Kenya	
Pest management practices	Bajaura ($n=25$)	Katrain ($n=25$)	Jana ($n=25$)	Embu ($n=25$)	Kitale ($n=25$)
Pest management method	Pesticides 100% Hand collection of insects 8%[A]	Pesticides 100% Hand collection of insects 8%[A] Barrier crop 4%[B] Trap crop 8%[C]	Pesticides 100%	Pesticides 100% Crop rotation 4%	Pesticides 100%
Number of sprays per crop	3.5	3.8	5.0	6.9	4.8
Pesticides used[D]	Organoph. 72% Pyrethroids 64% Chlorinated 20% Mancozeb 20% Streptocycl. 20%	Pyrethroids 64% Organoph. 48% Neem 20% Soap 4% Mancozeb 40% Benzimid. 20% Streptocycl. 28%	Pyrethroids 80% Organoph. 20% Carbamates 4% Soap 4% Mancozeb 40% Trichoder. 20% Streptocycl. 28%	Pyrethroids 88% Organoph. 36% Bt 4% Mancozeb 16% Copper 8% Propineb 8% Curzate 8%	Pyrethroids 84% Organoph. 40% Bt 8% Chlorinated 4% Propineb 8% Curzate 8%
Insecticide application decision basis (presence, P/calendar, C/both, B)	60% P 32% C 8% B	28% P 24% C 48% B	72% P 12% C 16% B	60% P 40% C	52% P 44% C 4% B
Pesticide sprayer (%) (knapsack, K/foot pump, F/power sprayer, P)	64% K 92% F	88% K 48% P 4% F	76% K 76% P	100% K	100% K
Gender of spray applicator (%) (male, ♂/female, ♀/both, B)	100% ♂	100% ♂	100% ♂	84% ♂ 16% B	72% ♂ 20% ♀ 8% B

[A]Referred to hand collection of *Pieris brassicae*. [B]Referred to the use of a barrier crop of *Tagetes minuta* against *Plutella xylostella*. [C]Farmers were using Indian mustard as a trap crop for *Plutella xylostella*, but not deliberately, as they were not aware of the trap cropping effect. [D]Includes insecticides, fungicides, and antibiotics. None of the farmers interviewed in India used herbicides. Only 24 and 16% of the farmers interviewed in Embu and Kitale used herbicides (2,4-D, glyphosate, paraquat), respectively. Insecticides included pyrehtroids (cypermethrin, deltamethrin, fenvalerate, lambda-cyhalothrin, permethrin), organophosphates (chlorpyrifos, diazinon, dichlorvos, dimetoate, malathion, monocrotophos, profenophos, and quinalphos), chlorinated insecticides (endosulfan), carbamates (carbofuran), *Bacillus thuringiensis*, neem, and soap; fungicides included mancozeb, benzimidazole, copper, propineb, curzate and *Trichoderma viridae*; the only antibiotic used was streptocycline.

highlands and the Kullu valley, respectively) (Table III). Several farmers mentioned that they based their decision to purchase insecticides on price (lowest) and effectiveness of the insecticide. Other important pesticides mentioned were the fungicide mancozeb and the antibiotic streptocyclin, used respectively by 33.3 and 25.3% of the farmers in the Kullu valley, and the fungicides mancozeb, propineb, and curzate, used by 8% of the farmers in the Kenya highlands. In most cases, the decision to apply insecticides was based on the presence of insect pests (56.0 and 53.3% of the farmers in the Kenya highlands and the Kullu valley, respectively) or a calendar basis (42.0 and 22.7% of the farmers in the Kenya highlands and the Kullu valley, respectively). The remaining farmers applied insecticides based on a combination of presence of insect pests and a calendar, typically starting calendar applications after noticing insect pests in the crop. Farmers in Kenya used only knapsack sprayers in their pesticide applications, while in the Kullu valley knapsack sprayers were used by 76% of the farmers. Foot pump and power sprayers were also used in cruciferous vegetables, with 92% of the farmers using foot pump sprayers in Bajaura, where mainly vegetables were grown, and 76% of the farmers using power sprayers in Jana, where apple production is widespread. All applications of pesticides were made by men in the case of the Kullu valley, while in the Kenya highlands, pesticide applications were made by men (78%), women (10%), or both men and women (12%). Only 20% of the farmers interviewed in the Kenya highlands used herbicides, which were not used at all by the farmers interviewed in the Kullu valley, who used manual weeding, often done by women in the farmer's household. In the Kenya highlands, 92% of the farmers interviewed were aware of malaria being a problem in the area, but only 48% of them used mosquito nets as a preventive measure against malaria. Malaria does not occur in the Kullu valley.

Age, years of education, and land cultivated with crucifers were not correlated with number of sprays per crop (Table IV). As expected, the number of

Table IV. Correlation between several factors (farmer's age, education, pesticide expenses, location, total land cultivated, land cultivated with crucifers, and crop loss due to insect pests) and number of pesticide applications by farmers in the Kenya highlands and the Kullu valley.

	Age	Education	Pesticide expenses	Location	Land cultivated (total)	Land cultivated (crucifers)	Crop loss due to insect pests
Kenya highlands	$F=0.15$ $P=0.700$	$F=0.16$ $P=0.426$	$F=4.10$ $P=0.047$*	$F=5.48$ $P=0.006$*	$F=0.11$ $P=0.737$	$F=1.16$ $P=0.285$	$F=0.12$ $P=0.730$
Kullu valley	$F=1.70$ $P=0.199$	$F=0.05$ $P=0.817$	$F=5.72$ $P=0.021$*	$F=3.91$ $P=0.054$	$F=4.91$ $P=0.032$*	$F=1.13$ $P=0.294$	$F=3.41$ $P=0.071$*

*Influence of factor statistically significant, $P \leq 0.05$ (Fisher's protected LSD, SAS Institute 2004).

pesticide applications per crop was correlated with pesticide expenses in both India ($y=0.075x+1.051$, $F_{1,71}=4.44$, $R^2=0.18$, $P=0.038$) and Kenya ($y=0.126x+0.648$, $F_{1,47}=7.09$, $R^2=0.23$, $P=0.010$). Number of pesticide applications was positively and inversely correlated with total land cultivated ($y=0.312x+1.505$, $F_{1,47}=4.30$, $R^2=0.21$, $P=0.043$) and crop losses due to insect pests (pest damage) ($y=-0.106x+1.921$, $F_{1,47}=5.11$, $R^2=0.21$, $P=0.028$), respectively, in Kenya, with more pesticide applications made by farmers with more land cultivated and resulting in fewer crop losses due to insect pests. In India, number of pesticide applications was neither correlated with total land cultivated ($y=-0.006x+1.540$, $F_{1,71}=0.11$, $R^2=0.14$, $P=0.744$) nor with crop losses due to insect pests (pest damage) ($y=-0.032x+1.467$, $F_{1,71}=0.29$, $R^2=0.14$, $P=0.592$).

3.4. Impact of current practices

On average, the estimated overall EIQ values of the insecticides used was higher in Bajaura, Embu and Kitale than in Katrain and Jana (Table V). In all locations, 50% or more of the insecticide products used by farmers had high impact EIQ values (Figure 1). Except for Bt, soap, and neem, all insecticides used were broad spectrum products considered hazardous to natural enemies. On average, the number of insecticide products used by each farmer interviewed varied from 7 (Jana) to 12 (Bajaura) in the Kullu valley and from 5 (Embu) to 6 (Kitale) in the Kenya highlands.

The SWOT analysis of the alternatives to the current use of insecticides to reduce overall insecticide applications and EIQ values and to improve pest management is presented on Table VI. The main strengths of biological control, trap cropping, and Bt-crucifers result from the reduction in insecticide applications. The main weakness is the need to train farmers in the use of these practices. The main opportunities could result from the integration of several alternatives and from the increased awareness of pest management and networking between farmers derived from training. The main threats are due to the potential misuse of the alternatives because they would be new to the farmer and would require proper training initially. Economic analyses are needed to compare the viability of the different alternatives in each context.

3.5. Pest management information

The answers provided by the farmers to the open-ended question regarding sources of information for pest management could be grouped into four categories: the farmer's own experience, pesticide salesmen, government extension, and other farmers. Most farmers used their own experience and pesticide salesmen as their main source of information and knowledge for pest management, while extension and other farmers were less important (Table VII). Extension reached less than one-third of the farmers interviewed in the Kullu valley and about one-third of the farmers interviewed in Kenya. Interestingly, in Jana, a relatively isolated village which extension workers visited only once a month, a percentage of farmers similar or higher than that recorded in the other two locations in the Kullu valley (24%) received pest management information from extension. This was due to the fact that farmers in Jana could specifically meet extension workers in their village once a month. Farmers knew when and where to find the extension workers. Awareness and understanding of the concept of natural enemies was low (0–4% in the Kullu valley and 12% in the highlands of Kenya). Most farmers knew about natural enemies in Kenya because of a training programme associated with release of a *P. xylostella* parasitoid by the International Centre for Insect Physiology and Ecology and supported by extension agents of the Ministry of Agriculture. All farmers interviewed in the Kullu valley admitted not reading pesticide labels, while in Kenya approximately 10% of the farmers interviewed said that they did not read pesticide labels.

4. Discussion

This study provides valuable insight into pest management and other agricultural practices of farmers in highland agroecosystems of two different countries. Pest management practices in the locations investigated in India and Kenya varied in some

Table V. Use of insecticides by farmers interviewed in the Kenya highlands and the Kullu valley of India and their respective environmental impact quotient (EIQ) according to Kovach et al. (2004).

			Use by farmers in each location (% farmers)				
			India			Kenya	
Active ingredient	EIQ	Insecticide type	Bajaura (*n* = 25)	Katrain (*n* = 25)	Jana (*n* = 25)	Embu (*n* = 25)	Kitale (*n* = 25)
Lambda cyhalothrin	43.5	Pyrethroid				68%	64%
Cypermethrin	27.3	Pyrethroid	56%	44%	80%		
Deltamethrin	25.7	Pyrethroid	8%	4%			
Fenvalerate	49.6	Pyrethroid	8%				
Permethrin	88.7	Pyrethroid				20%	20%
Monocrotophos	53.3	Organophosphate	24%	8%	12%		
Diazinon	43.4	Organophosphate					24%
Malathion	23.8	Organophosphate	40%	12%	8%	8%	4%
Dimethoate	74.0	Organophosphate	8%	24		25%	8%
Profenophos[A]	59.5	Organophosphate	8%	12%	8%		
Quinalphos[A]	46.7	Organophosphate	12%	12%	8%		
Dichlorvos	40.6	Organophosphate	4%				
Chlorpyrifos	43.5	Organophosphate	4%				
Carbofuran	50.7	Carbamate			4%		
Endosulfan	42.1	Chlorinated	20%				
Azidirachtin	12.8	Botanical		20%			
Bacillus thuringiensis	7.9	Bt microbials				4%	8%
Soap	19.5	Physical poison	4%		4%		
Average weighed EIQ of insecticides applied per location[B]			72.5	53.2	41.4	68.0	63.2

[A]EIQ values for profenophos and quinalphos are preliminary estimates (Petzoldt, unpublished) still not officially published in Kovach et al. (2004). [B]Average EIQ calculated assuming equal use of insecticides mentioned and taking the sum of the multiplications of EIQ values of individual insecticides by the percentage of farmers that had mentioned its use for each location.

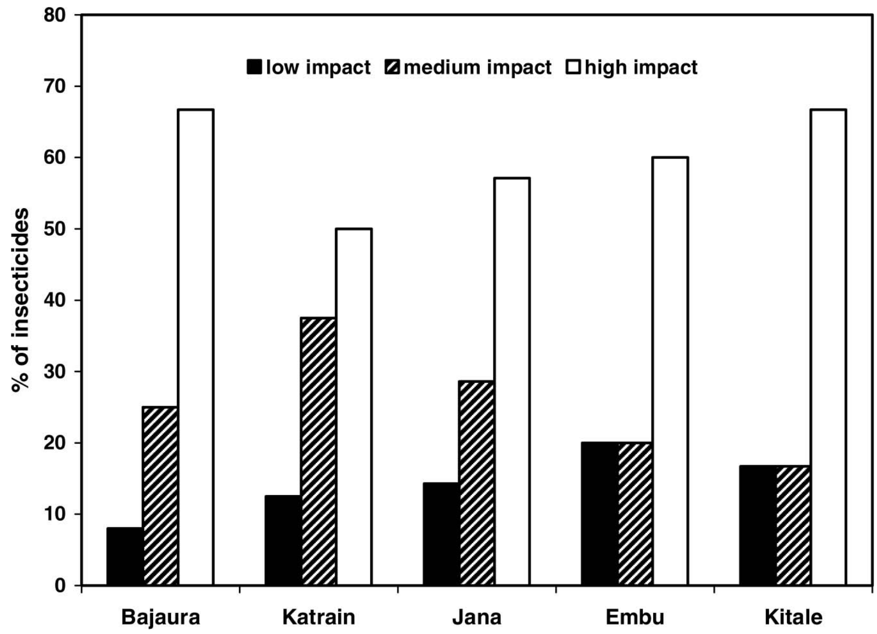

Figure 1. Comparison of environmental impact quotient (EIQ) values for insecticides used by farmers in the Kenya highands (Embu and Kitale) and the Kullu valley (Bajaura, Katrain, and Jana). For all the insecticide products used by farmers, EIQ values were classified as low (0–20), medium (21–40) and high (≥41) impacts on humans and the environment.

aspects (e.g. main insect pest species and types of sprayers used), but were similar in others (e.g. main sources of information and types of insecticides used). Pest management differences occurred even within the same area (e.g. main insect pest species and number of pesticide applications per crop between Jana and Katrain), allowing only a limited number of generalizations to be made (e.g. Lepidoptera as the main order of insect pests affecting the cruciferous vegetables of the farmers interviewed).

Table VI. Strengths, weaknesses, opportunities, and threats (SWOT) analysis of current practices for management of *P. xylostella* (DBM) as compared with biological control, trap cropping, and Bt-crucifers.

Pest management practice	Strengths	Weaknesses	Opportunities	Threats
Current practices based on insecticide control	Information for use directly available at purchase point No training for changing practices needed	Labour for application Human health and environmental costs[A]	Use of insecticides of low toxicity Better use of insecticides in through IPM training	Insecticide resistance Poor insect control Pressure from information sources to buy insecticides
Biological control	Partial protection against DBM Insecticide/EIQ reduction[B]	Information/training needed	Increase knowledge of farmers on pest-natural enemy interactions Networking among farmers derived from training of farmer groups	Control of insect pets besides *P. xylostella* Need to use mainly selective insectices that respect natural enemies As it is a new technique to the farmer, misuse could happen without adequate training
Trap cropping with Indian mustard	Partial protection against DBM Crop diversification Insecticide/EIQ reduction[C]	Information/training needed Lower market price of trap crop Trap crop area[D]	Use of selective insecticides on trap crop would allow biological control Networking among farmers derived from training of farmer groups	Control of insect pets besides *P. xylostella* As it is a new technique to the farmer, misuse could happen without adequate training
Bt-crucifers	Information for use directly available at purchase point Full protection against DBM and lepidopteran pests Insecticide/EIQ reduction[E] Compatible with little use of Bt-insecticides	Increased seed costs Refuge area[F]	Use of selective insecticides would allow biological control Networking among farmers derived from training of farmer groups	Control of non-lepidipteran insect pets As it is a new technique to the farmer, misuse could happen without adequate training

[A]As measured by environmental impact quotients (EIQ) on Table V. [B]EIQ reduction associated with selective insecticides compatible with biological control (e.g. EIQ azadirachtin = 12.8). [C]EIQ reduction depends on insecticides used in main crop and trap crop. At least one or two applications of an insecticide are likely to be needed on the trap crop. [D]Considering trap crop area about 10% (Shelton and Badenes-Perez 2006). [E]EIQ reduction depends on insecticides used in Bt crop and the refuge. At least one or two applications of an insecticide (non-Bt) are likely to be needed on the refuge. [F]Refuge area estimates have not been calculated yet. Bt crucifers for commercial purposes is not expected to be available in the market before 2007.

Table VII. Variables associated with information on pest management: source of information, awareness of pesticide label, and awareness of natural enemies. Data presented as averages for each location (Bajaura, Katrain, Jana, Embu, and Kitale).

	Location				
	India			Kenya	
Variables associated with information on pest management	Bajaura ($n=25$)	Katrain ($n=25$)	Jana ($n=25$)	Embu ($n=25$)	Kitale ($n=25$)
Source of information (%)[A]	84% O 48% S 24% E 8% F	92% O 48% S 4% E 4% F	64% O 40% S 24% E 12% F	48% O 36% S 32% E 24% F	44% O 52% S 36% E 28% F
Read pesticide label (%) (Yes/No)	100% No	100% No	100% No	92% Yes 8% No	88% Yes 12% No
Awareness/knowledge of natural enemies (%) (Yes/No)	4% Yes 96% No	100% No	100% No	12% Yes 88% No	12% Yes 88% No

[A]Considered sources of pest management information were: farmer's own experience (O), pesticide sellers (S), government extension (E) and other farmers (F). Government extension included offices/phone lines where farmers could obtain information, visit of extension workers, and a radio station program on agriculture.

All farmers interviewed relied on pesticides for pest management. The insecticides used were mainly broad spectrum synthetics and the use of Bt sprays and other organic insecticides was very low. The use of Bt sprays is very low in India compared with Western countries because of the relatively high cost of Bt formulations compared to other available insecticides (Kumar 2004).

Farmer response to pest attacks was different depending on whether the farmer was a big or a small landholder in the Kenya highlands, but not in the Kullu valley. The number of insecticide applications was correlated with total land cultivated, crop loss, and pesticide expenses in the Kenya highlands, while in the Kullu valley a correlation occurred only in the case of pesticide expenses. Farmers cultivating more land are more likely to have a higher income and therefore are more likely to afford pesticides than those farmers with less land. It is possible that if farmers in Kenya are poorer than those in India, affordability of agricultural inputs is a stronger factor among small farmers located there. Furthermore, fertilizers are known to be more expensive in Kenya, especially in the highland regions, than in other more developed countries (Sanchez 2002). This trend was also shown here, where the relative cost of fertilizer was higher in the Kenya highlands than in the Kullu valley, also indicating that fewer resources may be available to purchase other agricultural inputs such as pesticides after buying fertilizer if resources are limited. The unexpected lack of correlation between pesticide applications and crop losses due to insect pest damage in the Kullu valley is likely to be due to resistance to the used insecticides, known to be widespread in Bajaura (Lal and Kumar 2004). Not using insecticides adequately because of application of the wrong insecticide product to a target pest or because of poor insecticide application methods could also result in not reducing crop losses due to insect pests despite increasing the frequency of insecticide applications.

The current use of insecticides has potential negative impacts as measured by the high overall EIQ value of the insecticides used. Given the high percentage of farmers that admitted not reading pesticide labels, the real EIQ value of the insecticide treatments made by the farmers interviewed are likely to be higher than those estimated in this study. Biological control, trap cropping, and Bt-cruciferous vegetables can provide alternatives to the current insecticide use trends by reducing the negative impacts of insecticides, reducing expenses on insecticides, and/or lowering crop losses due to insect damage. Several biological control agents of *P. xylostella* have been tested (Sarfraz et al. 2005). In highland agroecosystems, the most successful natural enemy of *P. xylostella* tested has been the larval parasitoid *Diadegma semiclausum* (Hellen) (AVRDC 1988; Talekar et al. 1990). In the case of Kenya, introduction of *D. semiclausum* in areas where cruciferous vegetables are grown is expected to greatly benefit farmers and consumers of crucifers (Macharia et al. 2005). Releases of *D. semiclausum* in other highland habitats, such as those of the Kullu valley, are likely to help managing *P. xylostella*. In addition to *D. semiclausum*, in Himachal Pradesh, the existing local parasitoids *D. fenestralis* (Halmgrew) and *Cotesia plutellae* (Kurdjumov) have also been shown to provide high levels of parasitism of *P. xylostella* larvae (Devi and Raj 1995; Devi et al. 2004). However, the current use of pyrethroids, organophosphates, and other broad spectrum insecticides by farmers in the Kenya highlands and the Kullu valley disrupts any potential biological control of insect pests by parasitoids and other natural enemies (Raj and Kanwar 1990; Barwal 2001; Badenes-Perez et al. 2002). Trap cropping is another pest management practice accessible to farmers in

India and Kenya. *Plutella xylostella* is the insect pest for which most attempts of control through trap cropping have been undertaken (Shelton and Badenes-Perez 2006). In India, a trap crop of Indian mustard, *Brassica juncea* (L.) Czern, combined with biological control with parasitoids and the use of selective insecticides risk-free for natural enemies is the main IPM recommendation to control *P. xylostella* in cruciferous vegetables (Srinivasan and Krishna Moorthy 1991; Singh et al. 2003). The use of Indian mustard however requires the application of insecticides to the trap crop to prevent insect movement to the main crop because of the high larval survival and development of *P. xylostella* on this host (Badenes-Perez et al. 2004). Transgenic crops can also reduce the need to use insecticides. With the current data, in general Bt crops have been an effective and safe method to control lepidopteran pests and can greatly reduce insecticide applications (Shelton et al. 2002). Among various transgenic vegetables (Ram and Dasgupta 2004), cruciferous vegetables with genes of *Bacillus thuringiensis* (Bt) have been developed to control lepidopteran pests using them either as a trap crop (Cao et al. 2005) or a cash crop (Kumar 2004). Biological control, trap cropping and Bt transgenic crucifers can also be used synergistically in combination as part of an IPM approach. For example, using a trap crop of Indian mustard as part of the refuge strategy when Bt crucifers are used as a cash crop could greatly decrease the development of resistance to the Bt crop because of the high ovipositional preference and fast development time of *P. xylostella* on Indian mustard (Badenes-Perez et al. 2004). Using non-Bt insecticides that have low toxicity to natural enemies in the trap crop refuge could also enhance biological control by allowing natural enemies to be more abundant and effective to control *P. xylostella* and other insect pests.

Farmers have been shown to rely on traditional knowledge learned over generations for pest management (Thurston 1991; Scoones and Thompson 1994; Brodt 1999). However, in this study farmers' pest management practices did not seem to be based on traditional knowledge despite the fact that there was a broad range of ages among the farmers interviewed, farmers were relatively small landholders, and sometimes lived in relatively isolated areas. Farmers relied mainly on pesticides for pest management and most of them did not know about natural enemies. In general, farmers tend to notice things that are easily observed, such as conspicuous insect pests, but may not be aware of small parasitic wasps (Bentley 1994). Farmers have also been shown to misdiagnose pest problems as well as use inappropriate pest management techniques (Nyeko et al. 2002). To a certain extent, this was also observed in this study, where farmers often cited aphids as a major pest, while in fact aphids typically do not cause any economical damage in most of the areas (Kumar et al. 2000). Some of the farmers interviewed also had a misconception on the role of insecticides, thinking of them as repellents that had to used "to prevent insect pests from coming to the crop". When asked about reading pesticide labels and following pesticide safety guidelines, several farmers interviewed in Jana that admitted not reading pesticide labels mentioned that they relied on treating accidental pesticide poisoning if it occurred rather than on taking preventive measures, such as protective clothing. The local remedy that they used to treat pesticide poisoning was the ingestion of a water solution high in salt and sugar to induce vomit. Vomiting, however, can only alleviate pesticide poisoning in limited cases when certain pesticides have been swallowed, but not if poisoning occurs through skin contact (The Pennsylvania State University 1997). Thus, this study shows a gap between farmers' current knowledge in pest management and the knowledge that could greatly improve their use of insecticides and pest management in general, such as awareness of pesticide labels and natural enemies. Pesticide salesmen, one of the major sources of pest management information mentioned by the farmers interviewed, are likely to be strongly biased towards their own interests of selling a product, compared to government supported extension educators. Using alternatives to insecticides, such as biological control and trap cropping must be associated with training of farmers to make them aware of these strategies as well as the use of selective insecticides that do not damage natural enemies. Providing training is likely to increase the general understanding of pest management as well as to increase the linkage between official extension/training educators and farmers and between farmers themselves. Training, however, is costly and this should be considered when analyzing the economic viability of different technologies to improve the current pest management practices (Alston et al. 1998; Anderson and Feder in press).

Women have been shown to have a leadership role in insecticide applications in some developing countries (Van de Fliert and Proost 1999). However, in the locations where this study took place, pesticides were mainly applied by men, especially in the Kullu valley, where only men took the role of pesticide applicators.

In the case of the Kenya highlands, given the burden of malaria (Gallup and Sachs 2001), pest management among farmers cannot be taken into account without considering mosquito control. The fact that less than half on the farmers used mosquito nets in their households despite malaria awareness, indicates a lack of resources to prevent the disease, especially considering that some of the farmers that used mosquito-nets in their households did so only in the case of children.

This study shows that farmers in the Kullu valley and the Kenya highlands rely mainly on broad spectrum synthetic insecticides with relatively high

EIQ values to control insect pests in their cruciferous vegetables. Alternatives to the current dependence on insecticides, such as biological control and insect resistant plants, are necessary to reduce human and environmental hazards. However, such approaches will require training farmers in the proper use of these pest management methods new to them. Such programmes would greatly improve the livelihood and environment among farmers in the Kullu valley and the Kenya highlands. Additional economic analyses are needed to study in detail the costs and benefits of these technologies.

Acknowledgements

We are deeply indebted to all the farmers that gave generously their time to share their pest management concerns and practices. Thanks to Dr G. T. Gujar (Indian Agricultural Research Institute) and Drs B. Löhr and D. Mithoffer (International Centre for Insect Physiology and Ecology) as the main contacts that facilitated conducting this research in India and Kenya, respectively. Thanks to Professor Desh Raj, Dr R. N. Barwal, Dr J. K. Sharma, Dr S. D. Sharma, R. Thakur, Dr R. Lal, and Dr V. Gautam in India as well as I. Macharia, G. M. Njuguna, L. Kariuki, M. Aggrey, M. de la Rocha, and P. Tingaa in Kenya for assistance with farmer visits and logistics. Thanks to K. Grace-Martin for assistance with statistical analyses. Special thanks to the following programs at Cornell University for providing partial funding for this research: Cornell Institute for International Food, Agriculture and Development, Griswold Fund of the Department of Entomology, Sigma Xi, African Institute for Development, and South Asia Program.

References

Alston JM, Norton GW, Pardey PG. 1998. Science under scarcity: Principles and practices for agricultural research evaluation and priority setting. Wallingford, UK: CABI.

Altieri MA, editor. 1993. Crop protection strategies for subsistence farmers. Boulder, CO: Westview Press. p 197.

Anderson JR, Feder G. In Press. Agricultural extension. In: Evenson R, Pingali P, editors. Handbook of agricultural economics, agricultural development: farmers, farm production and farm markets. Vol. 3. Washington, DC: Elsevier.

AVRDC. 1988. Progress Report. Asian Vegetable Research and Development Center, Shanhua, Taiwan. p 540.

Badenes-Perez FR, Shelton AM, Nault BA. 2004. Evaluating trap crops for diamondback moth (L.), *Plutella xylostella* (Lepidoptera: Plutellidae). Journal of Economic Entomology 97:1365–1372.

Badenes-Perez FR, Zalom FG, Bentley WJ. 2002. Effects of dormant insecticide treatments on the San Jose scale (Homoptera: Diaspididae) and its parasitoids *Encarsia perniciosi* and *Aphytis* spp. (Hymenoptera: Aphelinidae). International Journal of Pest Management 48:291–296.

Barwal RN. 2001. Managing pests on cole crops scientifically. Indian Horticulture April–June:4–8.

Bentley J. 1994. Stimulating farmers experiments in non-chemical pest control in Central America. In: Thompson J, editor. Beyond farmers first: rural people's knowledge, agricultural research and extension practice. London: Intermediate Technology Publications. pp 147–150.

Brodt S. 1999. Interactions of formal and informal knowledge systems in village-based tree management in central India. Agriculture and Human Values 16:355–363.

Cao J, Shelton AM, Earle ED. 2005. Development of transgenic collards (*Brassica oleracea* L., var. *acephala*) expressing a *cry1Ac* or *cry1C* Bt gene for control of the diamondback moth. Crop Protection 24:804–813.

Capinera JL. 2001. Handbook of vegetable pests. New York: Academic Press.

Devi N, Bhardwaj V, Raj D. 2004. Seasonal abundance of diamondback moth, *Plutella xylostella*, and its natural enemies. Journal of Entomological Research 28:1–4.

Devi N, Raj D. 1995. Biology and parasitization of diamondback moth, *Plutella xylostella* L., infesting cauliflower in mid hill region of Himachal Pradesh (India). Journal of Entomological Research 19:83–86.

FAO. 2005. International code of conduct on the distribution and use of pesticides. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAOSTAT. 2005. [cited 15 January 2006]. Available: http://apps.fao.org. Food and Agriculture Organization of the United Nations.

Gallup JL, Sachs JD. 2001. The economic burden of malaria. American Journal of Tropical Medicine and Hygiene 64:85–96.

Kibata GN. 1996a. Crop protection in high potential areas: diamondback moth, *Plutella xylostella* L., a problem pest of brassicas. In: Kibata GN, editor. Crop protection for resource-poor farmers in Kenya. Proceedings of the 1st Biennial Crop Protection Conference, 27–28 March 1996, Nairobi, Kenya: Kenya Agricultural Research Institute and National Agricultural Research Laboratories. pp 1–10.

Kibata GN. 1996b. The diamondback moth: a problem pest of Brassica crops in Kenya. In: Lim GS, editor. The management of diamondback moth and other crucifer pests: Proceedings of the Third International Workshop, Kuala Lumpur, Malaysia: Asian Vegetable Research and Development Center. pp 47–53.

Kovach J, Petzhold CH, Degni J, Tette J. 2004. A method to measure the environmental impact of pesticides. Geneva, NY: Cornell University.

Kumar H. 2004. Orientation, feeding, and ovipositional behavior of diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae), on transgenic cabbage expressing Cry1Ab toxin of *Bacillus thuringiensis* (Berliner). Environmental Entomology 33:1025–1031.

Kumar J, Kashyap NP. 1999. Estimation of avoidable yield loss due to insect-pests in cabbage (*Brassica oleracea* var. *capitata* L.) in the Kullu valley of Himachal Pradesh. Pest Management and Economic Zoology 7:73–77.

Kumar J, Kashyap NP, Jamwal RS, Sharma SD. 2000. Effect of date of planting on the incidence of insect pests and extent of loss in summer cabbage (*Brassica oleracea* var. *capitata* Linn.) in lower Kullu valley, Himachal Pradesh. Pest Management and Economic Zoology 8:137–144.

Lal R, Kumar J. 2004. Cross-resistance spectrum of strains of diamondback moth, *Plutella xylostella* (L.), resistant to malathion, endosulfan and fenvalerate. Himachal Journal of Agricultural Research 30:89–95.

Macharia I, Löhr B, De Groote H. 2005. Assessing the potential impact of biological control of *Plutella xylostella* (diamondback moth) in cabbage production in Kenya. Crop Protection 24:981–989.

Mazlan N, Mumford J. 2005 Insecticide use in cabbage pest management in the Cameron Highlands, Malaysia. Crop Protection 24:31–39.

Ministry of Agriculture Republic of Kenya. 2004. Horticulture 2004 annual report, Nairobi, Kenya.

Morales H, Perfecto I. 2000. Traditional knowledge and pest management in the Guatemalan highlands. Agriculture and Human Values 17:49–63.

Nyeko P, Edwards-Jones G, Day RK, Raussen T. 2002. Farmers' knowledge and perceptions of pests in agroforestry with particular reference to *Alnus* species in Kabale disctrict, Uganda. Crop Protection 21:929–941.

Odour GI, Lohr B, Seif AA. 1996. Seasonality of major cabbage pests and incidence of their enemies in Central Kenya. In: Lim GS, editor. The management of diamondback moth and other crucifer pests: Proceedings of the Third International Workshop, Kuala Lumpur, Malaysia: Asian Vegetable Research and Development Center.
Osando JM. 1988. Management of black rot of cabbage caused by *Xanthomonas campestris* pv. *campestris* in Kenya. Acta Horticulturae 218:311–314.
Poswal MAT, Akpa AD, Alabi O. 1993. Cultural control of pests and diseases: prelude to integrated pest management practices for resource-poor farmers in Nigerian agriculture. Journal of Sustainable Agriculture 3:5–48.
Puoubom CFN, Awah ET, Tchuanyo M, Tengoa F. 2005. Farmers' perceptions of cassava pests and indigenous control methods in Cameroon. International Journal of Pest Management 51:157–164.
Raj D, Kanwar BB. 1990. Minimizing insecticide use against cauliflower pests in India. Tropical Pest Management 36:10–14.
Ram RB, Dasgupta SK. 2004. Transgenic in vetable crops. Journal of New Seeds 6:411–431.
Riley KW, Mateo N, Hawtin GC, Yadav R, editors. 1990. Mountain agriculture and crop genetic resources. Delhi, India: South Asia Books. p 330.
Sanchez P. 2002. Soil fertility and hunger in Africa. Science 295:2019.
Sarfraz M, Keddie AB, Dosdall LM. 2005. Biological control of the diamondback moth, *Plutella xylostella*: a review. Biocontrol Science and Technology 15:763–789.
SAS Institute Inc. 2004. SAS/STAT® User's Guide. Version 9.1. SAS Institute Inc., Cary, NC.
Scoones I, Thompson J. 1994. Beyond farmer first: rural people's knowledge, agricultural research and extension practice. London, UK: Intermediate Technology Publications.
Shelton AM, Badenes-Perez FR. 2006. Concepts and applications of trap cropping in pest management. Annual Review of Entomology 51:285–308.
Shelton AM, Zhao J-Z, Roush RT. 2002. Economic, ecological, food safety, and social consequences of the deployment of Bt transgenic plants. Annual Review of Entomology 47:845–881.
Singh A, Singh S, Rao SN. 2003. Integrated pest management in India. In: Mota-Sanchez D, editor. Integrated pest management in the global arena. Oxon, UK: CABI Publishing. pp 209–221.
Srinivasan K, Krishna Moorthy PN. 1991. Indian mustard as a trap crop for management of major lepidopterous pests on cabbage. Tropical Pest Management 37:26–32.
Talekar NS. 1992. Management of diamondback moth and other crucifer pests. In: Talekar NS, editor. Proceedings of the second international workshop. Shanhua, Taiwan: Asian Vegetable Research and Development Center.
Talekar NS, Yang JC, Liu MY, Ong PC. 1990. Use of parasitoids to control the diamondback moth, *Plutella xylostella*. In: Kiritani K, editor. The use of natural enemies to control agricultural pests. Taipei, Taiwan: Food and Fertilizer Technology Center for the Asian and Pacific Region. p 254.
Thakur BS, Korla BN, Khosla K. 2003. Inheritance of resistance to black rot disease in late cauliflower. Annals of Agricultural Research New Series 24:244–248.
The Pennsylvania State University. 1997. Small-scale fruite production: a comprehensive guide. University Park, PA: The Pennsylvania State University.
Thurston HD, editor. 1991. Sustainable practices for plant disease management in traditional farming systems. Boulder, CO: Westview Press. p 279.
Van de Fliert E, Proost J, editors. 1999. Women and IPM: crop protection practices and strategies. Amsterdam, The Netherlands: Royal Tropical Institute. p 107.

Appendix A

Farmer Questionnaire

1. General
(a) Date:
(b) Village:
(c) District/Region:

2. Farmers' socioeconomic background
(a) Age:
(b) Years of formal education:
(c) Total land cultivated and percentage grown with cruciferous vegetables, such as cabbage, kale, cauliflower and broccoli:
(d) Amount of land owned versus leased:
(e) Sources of income besides farming:
(f) Number of times cruciferous vegetables were grown per year:
(g) Type of irrigation used:
(h) Multicropping (Yes/No)
(i) Expenses on fertilizers per crop/season:
(j) Expenses on seed per crop/season and type of seed used:
(k) Expenses on pesticides per crop/season:
(l) Approximate total production costs versus produce market sale:
(m) Produce sale:

3. Main pest problems
(a) Insect pests observed in situ:
(b) Main insect pests according to the farmer:
(c) Crop loss caused by insect pest damage despite the use of insecticides (%):
(d) Other causes of crop loss:

4. Pest management practices
(a) Pest management methods used:
(b) Pesticide applications per crop/season:
(c) Pesticides used:
(d) Decision making for insecticide application (presence of insect pest, calendar, both):
(e) Gender involved in pest management (male, female, both):
(f) Malaria incidence (Yes/No) (only asked in Kenya)
(g) Use of mosquito nets in household (Yes/No) (only asked in Kenya)

5. Pest management information
(a) Sources of information used (own experience, pesticide providers, extension, other farmers):
(b) Read pesticide label (Yes/No)
(c) Awareness of the concept of biological control/ natural enemies (good insects that eat insect pests and benefit the farmers) (Yes/No)