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ABSTRACT: Small-scale farmers in developing countries use hazardous pesticides taking few or no safety measures. Farmer field schools (FFSs) teaching integrated pest management (IPM) have been shown to reduce pesticide use among trained farmers. This cross-sectional study compares pesticide-related knowledge, attitude, practice (KAP), potential exposure, and self-reported poisoning symptoms among 35 FFS farmers, 44 neighboring farmers, and 35 control farmers after an IPM intervention in Uganda (2011-2012). The FFS farmers were encouraged to teach their neighboring farmers. Data were based on standardized interviews and were analyzed using a linear trend test and logistic regression. The results showed that FFS and neighboring farmers used significantly fewer pesticide applications ($P = .021$) and used more safety measures. No differences were found on the hazardousness of pesticides used or self-reported symptoms. The study supports IPM as a method to reduce pesticide use and potential exposure and to improve pesticide-related KAP among small-scale farmers in developing countries.

KEYWORDS: Integrated pest management, farmer field schools, pesticides, small-scale farmers

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Introduction

Synthetic pesticides are widely used to control pests in agriculture. Small-scale farmers in developing countries use pesticides classified by the World Health Organization (WHO) as extremely, highly, or moderately hazardous. In 1985, the Food and Agriculture Organization of the United Nations published "The International Code of Conduct on the distribution and use of pesticides" with the purpose of improving pesticide management around the world. In the revised version from 2002, they state that highly hazardous or substandard pesticide formulations are still widely sold, and end users lack training on how to handle the pesticides.[1]

Human exposure to hazardous pesticides leads to several different acute and chronic health effects and may affect the health of both farmers and consumers.[2–4] Acute symptoms are widely experienced among farmers with a high prevalence in African countries.[5] The use of personal protective equipment (PPE) and precautions may, according to several studies, reduce self-reported acute symptoms and the inhibition of acetylcholinesterase (AChE) or cholinesterase, which is caused by organophosphate pesticides.[6–8] However, not all studies found that PPE protects sufficiently against pesticides.[9] Studies from African countries found that small-scale farmers use insufficient PPE and lack safe practices when handling hazardous pesticides.[10–13] Poor pesticide practices may be caused by the lack of knowledge concerning side effects and lack of instructions on pesticide usage.[4] Improving pesticide practices and reducing the use could also be beneficial for the environment.[4]

Reducing the use of hazardous pesticides is an important part of reducing the occupational health hazards from pesticides.[14] A color code marking the pesticide hazard after WHO classification is shown on the container and works as a useful tool to identify toxic pesticides. However, small-scale farmers are often not aware of the color codes.[7,8,15] Knowledge of alternatives to pesticides is another crucial factor toward reduced pesticide use, and less than one-third of farmers in a study among farmworkers from the Gaza Strip knew about pesticide alternatives.[16] Such alternative nonchemical pest management methods include, among others, biological control and mechanical control (nets and traps), which have shown positive results in various studies from African countries.[4,17]

Since the 1980s, integrated pest management (IPM) programs or farmer field schools (FFSs) teaching IPM have been implemented in developing countries.[14,18] Integrated pest management is a pest management method that involves different pest management strategies to protect the agroecosystem, environment and human health without affecting the farmer's yield.[19] The strategy includes crop rotation, pest identification, and use of alternative nonchemical pest management methods.[20] Impact studies from FFS/IPM projects generally show positive results regarding improvement on yields, value of crops, and less use of pesticides but often fail to show improvement in the health and dissemination of knowledge.[14,18] In sub-Saharan African countries, FFSs have focused on Integrated Production and Pest Management due to relatively low production and pesticide use. The production of cotton, vegetables, and tobacco is responsible for most of the pesticides used in sub-Saharan African countries.[18]

Fifty-eight percent of the land size in Uganda is used for agriculture production, and approximately two-third of the population depend on subsistence farming as their main source of livelihood.[21,22] Within the last 2 decades, the monetary value of imported pesticides into Uganda has increased 10-fold.[23] In 2010, 1.7% of the import value was from hazardous pesticides.[24]

In 2011, an intervention was launched among small-scale farmers in 2 districts in Uganda. The intervention was part of the project "Pesticide use, Health and Environment (PHE) – Uganda 2010-13." The main objective of the project was to reduce the negative health effects and environmental pollution from pesticides through IPM training of small-scale farmers, governmental extension workers, agro dealers, and health workers. The aim of the project was to train FFS farmers, who should then train the farmers in the area (neighboring farmers). The intervention was preceded by a cross-sectional study among 318 Ugandan small-scale farmers.[25] The results from this preintervention study showed that, before the intervention, only one-third of the farmers had received training on how to use and handle pesticides. Few used sufficient PPE, and 40% did not understand the color codes on pesticide containers. The results indicated that IPM training was needed to reduce potential exposure to hazardous pesticides.[25]

Thus, the objective of this study was to study the effect of the abovementioned IPM intervention regarding the use of pesticides and knowledge, attitude, and practice (KAP) concerning toxicity and preventive measures.

Methods

Design and setting

This study was designed as a cross-sectional study based on data from standardized interviews with 114 small-scale farmers after an IPM intervention. The study was conducted in 2 districts in Uganda: Wakiso, an urban district near the capital Kampala that mainly produces vegetables, and Pallisa, a rural area 170 km from Kampala, where the main produce is cotton.

The intervention started in July 2011 and continued until November 2012. Forty FFS farmers were trained in IPM and communication over 14 to 16 lessons, including knowledge of pesticides, pesticide handling, natural pesticides, and health and environment. The FFS farmers were encouraged to train their neighboring farmers, and they were supervised teaching 1 session.

Material

Before the intervention, local community leaders and extension workers selected 20 existing farmers' groups distributed in the intervention subdistricts. Each farmers' group selected 2 farmers to participate in the FFS. The selection of FFS farmers was not random but rather was based on equal sex distribution and leadership skills to improve the effect and sustainability of the training. In the very first phase of the intervention, some of the 40 FFS farmers dropped out and were substituted by other farmers who then participated in the FFS.

The study population was composed of 3 groups: the FFS farmers, neighboring farmers, and control farmers. The FFS farmers consisted of 35 of 40 trained farmers. The neighboring farmers consisted of 44 small-scale farmers who were living in the intervention areas and therefore expected to be offered training from the FFS farmers. The control group consisted of 35 small-scale farmers living in one of the control subdistricts where no training occurred. The neighboring farmers and control farmers were supposed to be randomly selected from participants in the preintervention study.[25] During data collection, it was not possible to find or locate all of the randomly selected farmers because they were not at home or had migrated. Instead, farmers in the same neighborhood were selected by convenience.

Data collection

The data collection in November 2012 was managed by the project staff assisted by a student research team. The farmers were interviewed at home in their local language or in English, with the help from a local interpreter, if necessary.

The questionnaire used for the standardized interviews was adapted from other studies that have assessed pesticide-related KAP and symptoms.[7,25]

Effect measures of training

The effect of the IPM training was evaluated using several self-reported parameters. The parameters were divided into 5 categories: potential exposure, practice, knowledge, attitude, and symptoms. The questions concerning potential exposure included the following: hazard level of the pesticides used, application frequencies (dichotomized into <3 or ⩾3 times last month), use of PPE during spraying (± for each type of PPE), precautions taken after spraying (± for different precautions), use of the mouth to unblock the sprayer nozzle (±), and field reentry periods after spraying (⩽1, 2-5, or >5 days). The pesticides used for crops were searched on the Internet to find the active ingredients before classification after WHO guidelines.[26] In all, 5 of 186 mentioned pesticides were not identified. Not all farmers performed the spraying themselves. Farmers who did not spray were excluded from the analyses of questions that directly concerned spraying (use of PPE, precautions taken after spraying). Measures of practice included spraying crops before taking them to the market (±), cleaning of the knapsack sprayer after spraying (±), and disposal of pesticide containers in the field (±). Knowledge included understanding of pesticide color code classifications (±), knowledge of alternatives to pesticides (±), and knowledge of negative health and environmental effects measured with different questions (±). The farmer's attitudes toward pesticides were assessed through 1 question, where the farmer was asked whether he or she thought he or she could reduce the pesticide use. Symptoms caused by pesticides were assessed from self-reported symptoms. Thirteen well-known acute symptoms caused by pesticide exposure were read out loud, and the farmers affirmed whether they had experienced the symptom working with pesticides within the last 6 months. The frequencies of each symptom in the FFS farmers, neighboring farmers, and control farmers were compared as well as a dichotomized measure (0-2 vs >2 symptoms).

Questions on demographic and agricultural characteristics were used to assess the comparability between the groups and to control for possible confounders. Agricultural characteristics included whether the farmers were members of a farmers' group (±). A farmers' group is a group of farmers regularly meeting to exchange knowledge on farming. In their farmers' group, the farmers received national extension service collectively that may otherwise be difficult to receive.

Statistical analyses

Mantel-Haenszel χ^2 analysis was used to test for trends across the 3 groups. The test was considered significant if $P < .05$—ie, the groups were different and linearly correlated with the dependent variable in the following order: control farmers, neighboring farmers, and FFS farmers. The differences between the neighboring and control farmers were analyzed with χ^2 tests on effect measures with significant differences in the trend analyses. Logistic regression analyses were used to control for possible confounders on variables with significant trends across the 3 groups. However, several effect measures were excluded because of either 100% or 0% values—eg, no farmers in the FFS group used the mouth to unblock the nozzle. For the logistic regression analysis, field reentry periods after spraying were dichotomized into ⩽5 or >5 days. The analyses were controlled for the potential confounders—ie, sex and age and additionally for the educational level and district. The district was included because of different weather conditions and crops could influence farming techniques, such as application frequencies. It was expected that being a member of a farmers' group could influence the potential exposure and KAP of the farmers. Because FFS farmers were selected from the farmers' groups, it could be an overcontrol to include the variable farmers' group in the logistic regression analysis. However, to estimate the influence on the results, logistic regression analyses with control for farmers' group were also conducted. The data were analyzed using the statistical software SAS.[27]

Ethical considerations

Before the interview, all farmers signed informed consent, confirming that they were willing to participate in the interview. The study complies with the Helsinki Declaration.

Results

Demographic and agricultural characteristics

Demographic and agricultural characteristics are listed in Table 1. The distribution in the 2 districts was not entirely equal with more FFS farmers and neighboring farmers than control farmers living in Pallisa than in Wakiso (57% and 50% vs 37%). The FFS farmers and neighboring farmers had a higher female to male ratio (1.33 and 1.09 vs 0.41) and higher educational level (77% and 61% vs 28%), and more farmers were members of a farmers' group than control farmers (100% and 91% vs 46%).

Potential exposure, practice, knowledge, and attitude

Results from the trend analyses of potential exposure, practice, knowledge, and attitude are listed in Table 2. The FFS and neighboring farmers had fewer pesticide applications in the preceding month than the control farmers ($P = .021$). The pesticides most frequently used belonged to WHO class II (moderately hazardous) and were not significantly different between the groups. The FFS farmers and neighboring farmers adopted significantly more protective measures—eg, using more PPE ($P \leqslant .005$) longer field reentry periods after spraying ($P = .007$) and not using the mouth to unblock the sprayer nozzle ($P = .011$).

The FFS and neighboring farmers showed a trend toward more appropriate practices using pesticides. Fewer of these farmers left the empty pesticide containers in the field ($P < .001$) or sprayed the crops immediately before taking them to the market ($P = .023$), and more of them washed their knapsack sprayer after use ($P < .001$).

The FFS and trained farmers also showed a trend toward broader pesticide-associated knowledge on questions concerning alternative nonchemical pesticides ($P < .001$), the color codes that indicate the toxicity of the pesticides ($P < .001$), and different environmental side effects. There was a positive linear trend in attitude, where more FFS and trained farmers thought that they could reduce the use of pesticides without affecting the yield ($P = .008$).

There were several significant differences between the neighboring farmers and control farmers on potential pesticide exposure and pesticide-related KAP, indicating a possible effect of FFS farmers training their neighboring farmers (Table 2).

The potential pesticide exposure and pesticide-related KAP among small-scale farmers after IPM training, controlled for

Table 1. Demographics and agricultural characteristics of the participants in the 3 groups.

	FFS FARMERS		NEIGHBORING FARMERS		CONTROL FARMERS	
	N = 35	%	N = 44	%	N = 35[a]	%
Demographics						
District						
Wakiso	15	43	22	50	13	63
Pallisa	20	57	22	50	22	37
Sex						
Male	15	43	21	48	24	71
Female	20	57	23	52	10	29
Age, y, mean (SD)	44 (13)		44 (13)		40 (14)	
Education						
⩾Secondary school	27	77	27	61	10	28
Agriculture						
Member of a farmers' group	35	100	39	91	16	46
Use pesticides	35	100	43	98	34	97
Years using pesticides, mean (SD)	15 (11)		17 (12)		13 (11)	
Size of the field >3 acres	11	32	11	26	5	16
Interviewed farmer does the spraying	26	74	29	66	27	79
Help from hired labor	23	66	18	42	11	31

Abbreviation: FFS, farmer field school.
[a]89% of the participants in the groups responded to the questions.

relevant confounders, are listed in Table 3. Consistent with the findings of the evaluation of potential exposure and KAP, being an FFS farmer was the overall strongest predictor for a reduced potential pesticide exposure (eg, the use of gloves [adjusted (adj.) odds ratio (OR): 19.1, confidence interval (CI): 3.5-104.5]), more pesticide-related knowledge (eg, knowing that pesticides kill good insects like bees [adj. OR: 6.4, CI: 1.4-28.0]), and a more positive attitude toward pesticide reduction (adj. OR: 9.0, CI: 2.1-39.4). Being a neighboring farmer was a predictor of the same parameters but to a lesser extent. Several potential confounders were evaluated, and the results are listed in Table 3. Farmers with a higher educational level were less likely to use domestic clothes when applying pesticides (OR: 0.2, CI: 0.1-0.5) and were more likely to use gloves during spraying (OR: 4.0, CI: 1.6-10.4). However, after adjustments, educational level was not a significant predictor. Living in Pallisa than in Wakiso increased the OR for a field reentry period by more than 5 days after spraying (OR: 7.5, CI: 2.9-19.4). Sex and age did not have any independent effect, and the inclusion of these variables did not change the estimates. Being a member of a farmers' group was, from the results of the binary analysis, a potential confounder, but it was not a predictor for any effect measures when included in the analyses (data not shown). When the variable "farmers' group" was included, less significant results were seen for the FFS farmers—eg, the OR for knowing that pesticides kill good insects like bees was no longer significant (adj. OR: 4.6, CI: 0.9-22.3).

Self-reported symptoms

There were no significant differences between the groups in self-reported symptoms within the last 6 months except for vomiting, which only 4 farmers had experienced, and they were all either FFS or neighboring farmers. In all, 20 (57%) FFS farmers compared with 29 (66%) neighboring farmers and 16 (46%) control farmers had experienced at least 3 symptoms in the last 6 months, a finding that was not significantly different between the groups.

Discussion

Key results

This study showed that after an IPM intervention, FFS farmers and neighboring farmers applied pesticides less frequently and used more protective measures to reduce potential pesticide exposure than the control farmers. They also used more appropriate pesticide handling practices and had more

Table 2. Differences in potential exposure, practice, knowledge, and attitude among small-scale farmers after training in integrated pest management.

	FFS FARMERS		NEIGHBORING FARMERS		CONTROL FARMERS		*P*-VALUE	
	N = 35[a]	%	N = 44[a]	%	N = 35[a]	%	MANTEL-HAENSZEL χ^2 TEST[b]	χ^2 TEST NEIGHBORING VS CONTROL[c]
Potential exposure								
WHO class of pesticide used by the farmer								
Class 1a	0	0	0	0	0	0		—
Class 1b	1	3	1	3	0	0	0.372	—
Class II	30	94	31	84	30	94	1.0	—
Class III	3	9	2	5	2	6	0.624	—
Class U	6	19	12	32	9	28	0.399	—
Applications last month								
<3 times	22	65	21	50	12	36	**0.021**	0.241
Use of PPE among farmers who spray								
Domestic clothing whether long or short/ordinary clothes	3	12	9	31	16	59	**0.0003**	**0.034**
Gloves	22	85	11	38	5	19	**<0.0001**	0.108
Overalls	17	66	5	17	0	0	**<0.0001**	**0.024**
Boots	26	100	23	79	19	68	**0.005**	0.440
Mask	25	96	10	34	2	7	**<0.0001**	**0.014**
Hat	15	58	6	21	0	0	**<0.0001**	**0.012**
Precautions taken after spraying								
Wash whole body immediately	22	85	25	86	19	73	0.2872	—
Change clothes after spraying	22	85	26	90	20	77	0.4527	—

(Continued)

Table 2. (Continued)

	FFS FARMERS		NEIGHBORING FARMERS		CONTROL FARMERS		*P*-VALUE	
	N=35[a]	%	N=44[a]	%	N=35[a]	%	MANTEL-HAENSZEL χ^2 TEST[b]	χ^2 TEST NEIGHBORING VS CONTROL[c]
Field reentry period after spraying, d								
⩽1	5	15	6	15	17	50		
2 to 5	16	47	20	49	9	26		
>5	13	38	15	37	8	24	**0.007**	**0.004**
Use mouth to unblock nozzle on sprayer when it is blocked	0	0	4	10	6	18	**0.011**	0.292
Practice								
Spray crops before taking them to the market	6	18	4	10	14	41	**0.023**	**0.002**
Clean knapsack sprayer after use	34	100	40	91	22	67	**<0.001**	**0.033**
Leave empty pesticide containers in the field	0	0	3	7	11	32	**<0.0001**	**0.004**
Knowledge								
Knowledge of alternatives to pesticides for controlling pest	35	100	32	74	13	38	**<0.0001**	**0.001**
Understand the color codes used on pesticide labels	32	91	25	61	9	27	**<0.0001**	**0.004**
Pesticides can have a bad/negative effect on your health	35	100	44	100	33	94	0.070	—
Pesticides have a negative effect on the environment	35	100	40	91	28	80	**0.006**	0.322
Negative effects caused to the environment								
Affect other nontarget organisms/animals	25	74	30	75	12	43	**0.016**	**0.007**
Contamination of drinking water	18	53	17	43	8	29	0.055	—
Killing good insects like bees	18	53	8	20	5	18	**0.002**	0.825
Effects on soil performance	17	50	24	60	12	43	0.633	—
Attitude								
Numbers of farmers who think that they can reduce the amount of pesticides used in agriculture without affecting expected yield	20	57	23	55	7	22	**0.008**	**0.012**

Abbreviations: FFS, farmer field school; WHO, World Health Organization; —, not calculated.
Bold values are significant with $p < 0.05$.
[a]⩾84% of the farmers in the group responded.
[b]Test for trend on differences between FFS farmers, neighboring farmers, and control farmers.
[c]χ^2 test for the difference between neighboring and control farmers. Calculated if the trend across the group was significant.

Table 3. Pesticide-related potential exposure, practice, knowledge, and attitude among small-scale farmers after training controlled for relevant potential confounders.

VARIABLE	POTENTIAL EXPOSURE								PRACTICE		KNOWLEDGE						ATTITUDE	
	APPLICATIONS LAST MONTH <3		USE OF DOMESTIC CLOTHES		USE OF GLOVES		FIELD REENTRY PERIOD AFTER SPRAYING >5 D		SPRAY CROPS BEFORE TAKING THEM TO THE MARKET		KNOWLEDGE OF COLOR CODES		PESTICIDES AFFECT OTHER NONTARGET ORGANISMS		PESTICIDES KILL GOOD INSECTS LIKE BEES		POSITIVE ATTITUDE TOWARD REDUCING PESTICIDE USE	
	OR[A] (95% CI)	ADJ. OR (95% CI)[a]	OR (95% CI)	ADJ. OR (95% CI)	OR (95% CI)	ADJ. OR (95% CI)	OR (95% CI)	ADJ. OR (95% CI)	OR (95% CI)	ADJ. OR (95% CI)	OR (95% CI)	ADJ. OR (95% CI)	OR (95% CI)	ADJ. OR (95% CI)	OR (95% CI)	ADJ. OR (95% CI)	OR (95% CI)	ADJ. OR (95% CI)
FFS farmers	**3.0 (1.1–7.9)**	2.3 (0.7–8.4)	**0.1 (0.02–0.4)**	**0.1 (0.0–0.8)**	**25.3 (6.0–106.6)**	**19.1 (3.5–104.5)**	2.1 (0.7–6.0)	1.1 (0.2–4.8)	0.3 (0.1–1.0)	0.4 (0.07–1.7)	**25.6 (6.3–103.2)**	**18.4 (3.5–97.0)**	**3.4 (1.2–9.8)**	**5.9 (1.4–24.3)**	**4.3 (1.4–13.3)**	**6.4 (1.4–28.0)**	**5.0 (1.7–14.4)**	**9.0 (2.1–39.4)**
Neighboring farmers	1.6 (0.6–4.0)	1.4 (0.5–4.3)	**0.3 (0.1–0.9)**	0.4 (0.1–1.6)	2.8 (0.8–9.6)	2.5 (0.6–11.0)	1.9 (0.7–5.4)	1.2 (0.3–4.6)	**0.2 (0.0–0.6)**	**0.1 (0.03–0.7)**	**3.8 (1.4–9.9)**	2.7 (0.8–8.9)	**3.7 (1.3–10.3)**	**5.6 (1.6–20.0)**	1.0 (0.3–3.1)	1.4 (0.3–5.6)	**4.5 (1.6 –12.6)**	**7.9 (2.1–29.5)**
Control farmers (ref.)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sex: being a woman	1.9 (0.9–4.1)	1.7 (0.7–4.0)	0.9 (0.3–2.3)	1.3 (0.4–4.4)	1.6 (0.7–4.0)	1.3 (0.4–4.6)	0.9 (0.4–2.0)	1.3 (0.5–3.8)	0.7 (0.3–1.7)	0.8 (0.2–2.5)	1.4 (0.7–3.1)	0.8 (0.3–2.4)	1.1 (0.5–2.5)	0.6 (0.2–1.6)	0.7 (0.3–1.5)	0.5 (0.2–1.3)	0.7 (0.4–1.6)	0.4 (0.2–1.1)
Older age (>50, 49–30, <30 y)	1.0 (0.6–1.8)	0.9 (0.5–1.8)	0.8 (0.4–1.6)	1.0 (0.4–2.3)	1.0 (0.5–1.9)	0.8 (0.3–1.8)	1.8 (1.0–3.3)	**3.0 (1.3–6.9)**	0.6 (0.3–1.2)	0.6 (0.3–1.4)	1.9 (1.0–3.5)	1.5 (0.7–3.1)	1.0 (0.5–1.7)	0.7 (0.4–1.5)	1.1 (0.6–2.0)	0.9 (0.4–1.8)	1.0 (0.6–1.7)	0.8 (0.4–1.5)
Educational level: ⩾secondary	1.2 (0.6–2.6)	1.0 (0.4–2.5)	**0.2 (0.1–0.5)**	0.3 (0.1–1.1)	**4.0 (1.6–10.4)**	2.0 (0.6–6.9)	1.2 (0.5–2.7)	1.3 (0.4–4.2)	0.7 (0.3–1.8)	1.5 (0.4–5.9)	2.1 (0.9–4.5)	1.0 (0.3–3.0)	1.5 (0.7–3.5)	0.7 (0.4–1.5)	1.6 (0.7–3.7)	0.9 (0.3–2.6)	1.3 (0.6–2.8)	0.6 (0.2–1.7)
District: living in Pallisa	0.8 (0.4–1.8)	0.7 (0.3–1.7)	0.7 (0.3–1.8)	1.0 (0.3–3.0)	1.4 (0.6–3.5)	1.1 (0.3–3.7)	**7.5 (2.9–19.4)**	**12.4 (3.7–41.1)**	0.9 (0.3–2.1)	1.0 (0.4–3.2)	1.5 (0.7–3.4)	1.2 (0.4–3.1)	0.6 (0.3–1.5)	0.9 (0.3–2.6)	1.0 (0.4–2.3)	0.8 (0.3–2.1)	**2.2 (1.0–4.7)**	1.6 (0.7–4.0)

Abbreviations: Adj., adjusted; CI, confidence interval; OR, odds ratio; ref., reference.
Bold Values are 95% CI not containing 0.
[a]Adjusted for sex, age, educational level, and district.

knowledge on alternatives to synthetic pesticides, the color codes indicating pesticide toxicity, and environmental side effects caused by pesticides than the control farmers. A greater percentage of farmers in the intervention group (57%) and their neighbors (55%) indicated that they believed they can reduce their pesticide use without affecting the expected yield when compared with the control group (22%). The possible effect of training on potential exposure, practices, knowledge, and attitude controlled for potential relevant confounders showed the same tendency as the trend analysis, but with less pronounced results.

Limitations

This study was a cross-sectional study with several limitations. Some of the FFS farmers initially selected dropped out of the intervention and were substituted with other farmers. This substitution may have contributed to the good results—eg, if the substituted farmers were more motivated and dedicated. The use of pesticides, level of knowledge, and attitude and practice among farmers before the intervention were very similar to the results of the control farmers in this study, indicating that the control farmers served as a reference for the average farmer before the intervention.[25] The neighboring farmers were supposed to represent the average farmer living in the intervention subdistrict after IPM training from FFS farmers. They were, however, different from the control farmers according to some demographic and agricultural characteristics—eg, more neighboring farmers lived in Pallisa, were women, had a higher education and were members of a farmers' group, which were all possible confounders in the study. The selection of the neighboring farmers and control farmers was supposed to be a random selection from participants in the preintervention study.[25] Because it was not possible to reidentify all selected farmers during data collection, other farmers from the intervention subdistrict were selected by convenience. This may have caused selection bias, contributing to the differences between the groups. Controlling for the relevant confounders (age, sex, district, educational level, and member of a farmers' group) did not change the results significantly, but it cannot be excluded that selection bias and differences in demographic and agricultural characteristics may have influenced the results.

This study included relatively few participants. Thus, the estimates in the logistic regression analyses had very broad confidence intervals. Because of the differences in the characteristics of the groups, it was relevant to control for potential confounders. The direction of the ORs supported the trend analyses.

This study assessed the measures of practice and exposure through a standardized questionnaire because objective measures would be difficult and time-consuming to obtain. Participants may have overstated their answers to impress the interviewer.[28] The validity may be limited, and the results may be biased by the self-reporting of practice vs actual practice.

For some participating farmers, family members or hired labor conducted the pesticide spraying. It was not considered problematic for the results because small-scale farming often involves the whole family, and the trained farmer would be expected to share the knowledge with the person spraying and may as well be in charge of decisions concerning type of pesticide, frequency of spraying, and use of alternatives to pesticides. However, it reduced the number of participants for questions concerning spraying, reducing the power of the study.

This study was a cross-sectional study like most studies in this area. Genuine follow-up studies are lacking and warranted, but it must be realized that such studies are difficult to conduct due to challenging settings in remote areas with the inclusion of participants, with whom contact possibilities are limited.

Interpretation

The lower frequency of pesticide applications between FFS and neighboring farmers found in this study indicates potentially reduced pesticide exposure. Several studies found a reduction in insecticide applications or the amount of pesticides used after IPM/FFS training of small-scale farmers in developing countries.[9,29–34] Being an FFS farmer was the only significant predictor for application frequencies, but this was not significant after adjustments. This weak result could be due to the short interval (applications the last month) and low power because of the study size.

The expected use of less hazardous pesticides among IPM farmers was not found in the study. Two studies found a change toward the use of less hazardous pesticides among IPM farmers comparing pre- and postintervention data.[31,33] A possible explanation may be that extremely or highly hazardous pesticides were used initially in the 2 other studies. The pesticides used in this study were moderately hazardous. Another possible explanation may be pesticide availability and economic constraints, which was suggested as a reason in a study from Benin.[35] Governmental legislation on hazardous pesticides and regulation of the pesticide market may be necessary to reduce the use of hazardous pesticides because that has shown to reduce the cases of pesticide poisoning in other countries.[36]

Farmer field school farmers and neighboring farmers had a tendency toward the use of more PPE, reducing potential pesticide exposure compared with farmers in the control group. Other studies found an increased use of headgear/hat, long pants, and long-sleeved shirts among IPM farmers.[30,37] In this study, FFS farmers obtained a sample of PPE to use for demonstrations teaching neighboring farmers. That may explain the use of more costly PPE among FFS farmers, but it does not explain the difference between neighboring farmers and control farmers unless they borrowed PPE from the FFS farmer. In 2 other studies among irrigation workers in Ghana and vegetable producers in Benin, the primary reason not to use PPE was economic constraint.[35,38] To deliver the PPE is not a sustainable solution, but the results could indicate that farmers use

PPE if provided, and some neighboring farmers may have bought the PPE after training with demonstrations. Alternatives to fabricated PPE should be taught to farmers with fewer economical resources to secure some protection during the spraying and mixing of pesticides.

In this study, FFS and neighboring farmers tended not to use the mouth to unblock the spray nozzle when it was blocked. This is an important indicator for potential reduced exposure because this practice increased the risk of self-reported acute symptoms among farmers in the study area before the intervention, and similar results were found in a study among small-scale farmers in Bolivia.[7,25]

In this study, there were no significant differences in the symptoms experienced among farmers in the 3 groups or in the number of farmers who had experienced symptoms within the last 6 months. This is contrary to the results from a longitudinal study in India, where they measured self-reported symptoms on FFS farmers over a whole season.[31] The same study also found reduced use of extremely hazardous pesticides and a correlation between the severity of symptoms and pesticide toxicity. In the preintervention study in Uganda, symptoms could not be related to the application frequencies for the different classes of pesticides, and the absence of positive associations regarding symptoms in this study may be due to the minimal use of extremely and highly hazardous pesticides.[25] Self-reported symptoms are, however, an imprecise measure of acute pesticide poisoning, which is shown in a study among Nepalese farmers working with organophosphate pesticides.[39] In addition, farmers may not know the possible symptoms from pesticide exposure. Thus, they may not relate symptoms to the use of pesticides, which could lead to potential underreporting. However, the awareness of symptoms may cause overreporting among trained farmers. Objective measures are needed to clarify whether an association exists. Two studies found less organophosphate exposure among IPM farmers measured through AChE blood levels, supporting a positive health effect of IPM.[9,30]

Farmer field schools are a cost-effective method to reduce pesticide use and improve safe pesticide practice if FFS farmers share their knowledge with neighboring farmers. Several significant differences were found between the neighboring farmers and control farmers, indicating a possible diffusion of IPM knowledge from FFS farmers to their neighboring farmers. Other studies have evaluated the diffusion of knowledge between IPM farmers and neighboring farmers, where farmers in the intervention group were apparently not encouraged to train their neighboring farmers. In Philippines, such informal knowledge sharing was assessed 5 years after an FFS intervention.[40] No knowledge sharing was found within FFS villages, but the FFS farmers retained their knowledge. Similar results were found in other studies assessing the diffusion of informal knowledge after FFS intervention.[29,41] A study from Nicaragua found an effect on farmers trained by FFS-trained farmers in the number of insecticide applications; in Bolivia, improvements in several IPM measures were found among neighboring farmers to FFS farmers after an intervention similar to that in this study.[9,33] These findings indicate that more formal training from FFS farmers might be a way to achieve knowledge diffusion and that the FFS farmers being encouraged to train their neighboring farmers might be an important factor. However, study limitations decrease the validity of the present results.

Conclusions

This study found that the IPM-trained FFS farmers and their neighboring farmers, who they trained, tended to have fewer pesticide applications and used more PPE and safe handling practices presumably, leading to reduced pesticide exposure. They had more knowledge on alternatives to pesticides, color code classifications, and negative side effects. These findings are in line with those of several other studies. The training did not seem to change the hazardousness of the pesticides used. To address this aspect, governmental legislations and regulations could be a way to reduce the use of moderately hazardous pesticides. The results indicated possible knowledge diffusion between FFS farmers and their neighboring farmers. Compared with other studies, the focus on formal training from FFS farmers might have been of importance for diffusion, thus making FFSs more cost-effective. This study had several limitations considering the study power, design, and risk of selection bias. Despite the low internal validity, this study showed some results supporting that IPM through FFSs can be used as a tool to reduce occupational health hazards and environmental pollution from pesticides in developing countries.

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Author Contributions

EJ, ASC, JFT, and AA conceived and designed the experiments; agreed with the manuscript results and conclusions; jointly developed the structure and arguments for the paper; and made critical revisions and approved final version. ASC and JFT analyzed the data. ASC wrote the first draft of the manuscript. ASC, JFT, and EJ contributed to the writing of the manuscript. All authors reviewed and approved the final manuscript.

Disclosures and Ethics

As a requirement of publication, the author(s) have provided to the publisher signed confirmation of compliance with legal and ethical obligations, including but not limited to the following: authorship and contributorship, conflicts of interest, privacy and confidentiality, and (where applicable) protection of human and animal research subjects. The authors have read and confirmed their agreement with the ICMJE authorship and conflict of interest criteria. The authors have also confirmed that this article is unique and not under consideration or published in any other publication and that they have permission from the rights holders to reproduce any copyrighted material.

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