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Farmer-centered pesticide risk reduction education in Senegal: A novel, participatory approach

Abstract

As pest pressures continue to intensify across Sub-Saharan Africa, many smallholder farmers are increasing their use of pesticides, including highly hazardous options, to meet the market demands for high-quality fresh produce. Many of these farmers, however, have not had access to pesticide risk reduction training or have participated in programs that have not enabled them to protect themselves and their families. Given the risks posed by dried and invisible though still toxic pesticide residues, new forms of information and realistic learning strategies are required. This study combined the innovative Adaptive Learner-Centered Education (ALCE) approach with the Farmer Field School (FFS) model to address the need for a rigorous pesticide risk reduction program. This hybrid method was piloted over two years in a project with smallholder farmers in the Niayes region of Senegal. The findings demonstrate that following a 12-week course, this novel approach enabled 20 farmer-facilitators to educate and train 236 other farmers to reduce their use of highly hazardous pesticides, select pesticides with shorter restricted re-entry intervals, and adopt protective mitigation practices. Through seasonal planning exercises, farmers operationalized new knowledge in ways that fit their crop production needs and protected themselves and their families. Because the ALCE-FFS process is grounded in community-based needs, it can serve as an appropriate educational design framework for practitioners working in a wide range of geographic, sociocultural, and political contexts.

Keywords

community needs, smallholder farmers, human health, behavior change, Adaptive Learner-Centered Education, Farmer Field School

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Farmer-centered Pesticide Risk Reduction Education in Senegal: A Novel, Participatory Approach

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Abstract

As pest pressures continue to intensify across Sub-Saharan Africa, many smallholder farmers are increasing their use of pesticides, including highly hazardous options, to meet the market demands for high-quality fresh produce. Many of these farmers, however, have not had access to pesticide risk reduction training or have participated in programs that have not enabled them to protect themselves and their families. Given the risks posed by dried and invisible though still toxic pesticide residues, new forms of information and realistic learning strategies are required. This study combined the innovative Adaptive Learner-Centered Education (ALCE) approach with the Farmer Field School (FFS) model to address the need for a rigorous pesticide risk reduction program. This hybrid method was piloted over two years in a project with smallholder farmers in the Niayes region of Senegal. The findings demonstrate that following a 12-week course, this novel approach enabled 20 farmer-facilitators to educate and train 236 other farmers to reduce their use of highly hazardous pesticides, select pesticides with shorter restricted re-entry intervals, and adopt protective mitigation practices. Through seasonal planning exercises, farmers operationalized new conceptual knowledge in ways that fit their crop production needs and protected themselves and their families. Because the ALCE-FFS process is grounded in community-based needs, it can serve as an appropriate educational design framework for practitioners working in a wide range of geographic, sociocultural, and political contexts.

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Introduction

In 2010 the Global Environmental Facility International Waters and Persistent Organic Pollutants Reduction Focal Areas Project reported that, despite increased education on pesticide exposure risks and access to personal protective equipment, the overuse and misapplication of pesticides in West Africa was resulting in widespread negative impacts on both the environment and human health (Jepson et al., 2014). Following this report, six United Nations (UN) Food and Agriculture Organization (FAO) Integrated Production and Pest Management (IPPM) coordinators working in Senegal, Mali, Mauritania, and Burkina Faso requested support from researchers in addressing pesticide exposure challenges in this region. In response to this request, an extension education specialist, integrated pest management and risk assessment expert, and UN FAO national-level program leader developed a novel pesticide risk reduction educational program for smallholder farmers in West Africa. The pilot project to test this new approach was based in the Diender area of Senegal located 60km north of Dakar within the Niayes region given that there are many smallholder farmers growing high value crops, trust had been established from past FAO projects, and trained IPPM facilitators were available and willing to participate.

Prior to the start of the project, educational programming on pest management and crop production in West Africa had predominantly been delivered to farmers utilizing the Farmer Field School (FFS) model (Settle et al., 2014; Settle & Hama Garba, 2011). Developed by the FAO in the 1980s, the FFS approach is grounded in the practice of "showing not telling" and educating farmers using demonstrations, hands-on learning experiences, and experimentation (Dhamankar & Wongtschowski, 2014). Pesticide exposures and consequences, however, are difficult to convey within demonstration-based learning contexts as residues often become invisible or odorless upon drying but remain toxic on plant tissues for a period after application. When farmers or others brush up against treated plant tissues some fraction of the remaining pesticide can be absorbed through the skin and by hand-to-mouth transfer (Kim et al., 2017). Furthermore, while some health-related pesticide exposure consequences can be acute and obvious to the victim, repeated exposures over time may also produce a range of serious and potentially deadly health impacts. Given the potential lag in time from chronic exposures to symptoms or disease, the harm from pesticides is not necessarily intuitive. The research team thus hypothesized that the discovery learning model often used in FFS was not compatible with building the conceptual knowledge and skills that are necessary to achieve the outcome of minimizing exposure to highly hazardous pesticides, and an adapted approach was required (Waddington et al., 2014). Between 2014 to 2015 the research team worked with a farmer cooperative and IPPM facilitators in the Niayes region to co-construct and test an active learning process for conceptual knowledge and skill practice that would enable farmers to reduce their pesticide related risks.

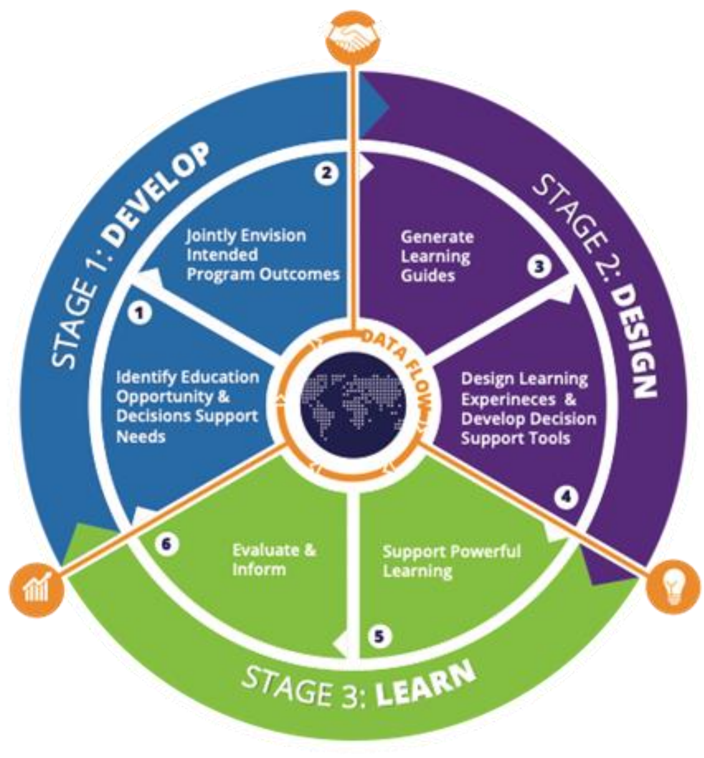
Purpose and Objectives

The purpose of this project was to develop novel pesticide risk management educational programming that could reduce the risk of exposure of smallholder farmers in West Africa to World Health Organization (WHO) Class Ib carbamates and organophosphates, which have been documented to cause cancer, neurodegenerative disease, and reproductive toxicity (Costa, 2018; Gupta et al., 2017; Koureas et al., 2012). The team thus partnered with experienced IPPM facilitators and a local farmers' cooperative to co-develop and co-instruct training on how to deliver pesticide exposure reduction education to other community members following the completion of the program. The research team's objectives were to: 1) assess ongoing gaps in farmer knowledge related to the selection, application, and management of Class Ib carbamates and organophosphates, 2) co-design an educational program and informational resources capable of operationalizing the necessary pesticide-related knowledge and skills to support behavior change that limits pesticide exposure pathways and encourages the use of less toxic Class II and III options, and 3) scale up the educational program using an adapted FFS model with trained trainers.

Conceptual Framework

To address the challenge of delivering non-intuitive and conceptual pesticide-related information to farmers in West Africa, the team refined the constructivist-based Adaptive Learner-Centered Education (ALCE) approach to develop a pilot program that would be tested in Senegal (Halbleib & Jepson, 2016) (Figure 1).

Figure 1
The Adaptive Learner-Centered Education Approach



Developed from previous research and discovery with farmers in the US (Halbleib & Jepson, 2015; Halbleib et al., 2021), the ALCE method utilizes a collaborative design process in conjunction with the science of adult learning to provide relevant decision-making practice that leads to behavior change. The ALCE process begins by merging three areas of knowledge that are needed to create programs that can achieve the intended learning outcomes or desired behavior change: 1) the expressed/known needs of farmers, 2) the perceived needs/risks captured by researchers (i.e., locally specific data), and 3) the necessary science-based information and data (including non-intuitive knowledge) which might be unknown to the farmers but is needed to achieve the intended outcomes. The ALCE approach then assists educators in designing programs that build upon learners' life experiences through relevant skill building with feedback and forms of active learning which have been shown to increase achievement for a wider range of learners (Freeman et al., 2014; Morris, 2020). As active learning experiences are compatible with the FFS model often implemented in Senegal, the research team hypothesized that ALCE in conjunction with the FFS model would be an effective approach in successfully operationalizing and disseminating non-intuitive conceptual knowledge and information on pesticide exposure risk reduction.

Methods

Project Site

The test site for the adapted ALCE-FFS approach was the Niayes region of Senegal where maritime trade winds and productive soils create conditions conducive to growing fruits and vegetables (Fare et al., 2017). Farmers in this region produce more than half of the nation's total fresh vegetables, as well as $38M worth of exported produce that equates to over 9% of global vegetable exports (World Bank, 2018). It is clear based on these figures that Niayes is critical to healthy and sustainable food supplies not just in the region itself, but in Senegal overall. The average size of a family farm in Niayes is 2.7ha (Touré & Seck, 2005), and many farmers grow crops for both their families and for local markets as an important source of income. Prior to initiation of the project, researchers received approval from the village leader and president of the local farmers' cooperative, Federation of AgroPasteurs de Diender (FAPD).

Project Design

This project was developed using the three stages of the ALCE approach: Develop, Design, and Learn. Stage 1 included three needs assessment processes which identified the communities' current pest management practices, educational needs, and interests in relation to pesticide risk reduction. These data informed the Stage 2 design process which included the development of the decision-supporting Pesticide Risk Index (PRI). Stage 3 occurred in three sub-stages which allowed the research team to establish the efficacy of the educational approach and PRI tool, and scale-up the delivery of the educational program to a broader audience. The first sub-stage was a farmer training, in which local farmers tested the decision-support tool in a co-learning experience thereby allowing the team to determine if the combination of the PRI and active learning were effective in engendering pesticide exposure reduction. Once efficacy was established, the team then trained a group of local farmers on the conceptual knowledge necessary for using the PRI and evidence-based strategies for teaching others in their communities how to reduce pesticide risk and exposure. In the final sub-stage of the Learn process, these trainers then delivered the new pesticide exposure and risk reduction curriculum using the ALCE-FFS approach to 236 farmers in 10 villages during the FFS.

Stage 1 Develop: Rapid assessment and jointly envisioned outcomes

To initiate the project, the team conducted a community needs assessment (N = 15), a rapid assessment focus group (N = 15), and semi-structured interviews with pesticide kiosk operators (N = 2). The community needs assessment included farmers, IPPM facilitators, a pesticide kiosk owner, an environmental educator, a Ministry of the Environment pesticide management division director, and country-level IPPM coordinators. Participants recorded and shared their answers to the question, *"What would community members be able to do if an effective pesticide risk reduction education program was available?".* Answers were then placed on sticky notes and attached to large sheets of paper taped to the wall. Once the group had captured everyone's ideas, they worked collaboratively to sort the ideas into clusters. The name created for each cluster then became an intended program outcome statement. This visioning session served to enable the co-generation of a set of five large-scale, community-desired outcomes (Table 1).

Table 1
Outcomes from the Community Needs Assessment

Cluster	Outcome	Outcome Statement
Training	O1	Provide awareness-raising information and education on the risks associated with pesticides
Precautions	O2	Promote good management practices for pesticides
Communication	O3	Strengthen community capacity on the efficient management of pesticides
Regulation	O4	Establish a community process for pesticide regulation
Alternatives	O5	Promote alternatives to chemical pesticides

A rapid assessment method was also developed and conducted. This process included a two-hour focus group with FAPD farmers. Participants were asked questions regarding crops grown, typical pests, and pesticide use and management. Answers were given verbally and recorded by the facilitator. Lastly, the project team conducted interviews with two pesticide kiosk operators. Each vendor was interviewed for approximately 30 minutes using a semi-structured interview format. The research team asked questions regarding commonly sold pesticides, the formulations and label names, and product use and safety information on the containers.

The rapid assessment process confirmed that the most commonly grown vegetables in the area include cabbage (70% of cultivated land), tomatoes, onions, eggplant, peppers, and beans. Often these are grown as cash crops with up to 95% being sold to urban markets such as those in Dakar, Rufisque, and Thies. For these crops the most damaging local pests are caterpillars, aphids, and grasshoppers. Pesticides are frequently used on cabbage, tomatoes, and peppers given their economic value and the need for high quality, unblemished produce for the markets. The most frequently used pesticides were insecticides, including (listed in decreasing order of frequency as reported by the farmers): 1) Biobit (*Bacillus thuringiensis* (Bt) bacteria), 2) Metaphos (methamidophos), 3) K-optimal (lambda cyhalothrin), 4) Tamaron (methamidophos), 5) Decis (deltamethrine), 6) Lannate (methomyl), 7) Dimethoate (dimethoate), and 8) Furadan (carbofuran). This confirmed at least two highly hazardous pesticides (Class Ib), methamidophos and carbofuran, were commonly applied within this community. From the rapid assessment, it also became clear that the farmers were not aware that some pesticides have a 21-day restricted-entry interval (REI) and they often work in these treated fields daily to irrigate, weed, and monitor for pests.

Stage 2 Design: Pesticide Risk Index and Farmer Training Pilot Design

From the input gathered in the Develop stage, it became apparent to the team that, in the Diender area there were gaps in real-world pesticide information, high risk practices were common, and that there were community desired outcomes in relation to pesticide risk exposure reduction that the team could address using their expertise. Some of the pesticide labels in the local kiosks for example, did not contain adequate guidance farmers need to safely use the products and many pesticide labels were in French which some farmers cannot read. To enable more informed pesticide selection and field management decisions, farmers must be able to differentiate between pesticide options and know the level of risk associated with entering a pesticide-treated field. As a result, the team created the PRI, a simple way to convey the protective information.

The PRI is based upon a risk assessment process conducted using the human and environmental risk assessment methods developed by Jepson et al. (2014) and the locally-used pesticide information reported in the rapid assessment. Three forms of risk to human health were assessed including: 1) dermal exposure during application when not wearing protective equipment, 2) REI period based on dermal transfer for adults working and children “playing” in fields, and 3) inhalation risk for a child at the field edge a day after application. Risks to aquatic invertebrates, fish, wildlife, and livestock risk were also depicted (see Jepson et al., 2014 for details).

Table 2
Section of the Pesticide Risk Index

Pesticide	Dermal risk to applicator	Inhalation risk at field edge	Restricted Re-Entry Interval (REI) (days)			Risk to aquatic life	Risk to livestock	Risk to pollinators	Risk to beneficial insects
Abamec	100[a]		>21	>21	>21				
Acarex	4		>21	>21	>21				
Acarius	100		>21	>21	>21				
Acaron	118		20	17	18				
Armada 40EC	53		>21	>21	>21				
Attakan	0.2		1	1	1				
Basudine	133		>21	>21	>21				
Biobit	~0		1	1	1				

[a]The number of times higher the exposure would be over the acceptable limit for a person applying the pesticide without protective equipment.

These data were embedded in the PRI decision-support tool; a novel decision-making resource in the form of a table that used pictograms to visually convey risks associated with the use of locally available pesticides for vegetable production (Table 2). The PRI includes a page of explanations for each category with practical guidance for reducing risk.

Stage 3 Learn: Farmer Training Pilot, Training of Facilitators, and Farmer Field Schools

Farmer Training Pilot

Following the creation of the PRI tool, the research team developed a farmer training pilot (FTP) to ascertain whether its use within a learner-centered educational setting enabled users to develop the necessary knowledge, skills, and behaviors to improve pesticide management and reduce exposure risk on their farms. To ensure that the tool was presented in a way that coincided with community-based needs, the team grounded the development of the two-day FTP curriculum in the community-expressed outcomes (See Table 1). Due to time constraints, the research team chose to focus on O1, O2, O3, and O5. To identify participants for the FTP the research team enlisted the help of the FAPD president in recruiting at least 15 farmers. In an attempt to ensure women's participation, the team specified that they would like at least 40% of participants to be female-identifying. On April 9-10, 2014, 11 men and 4 women farmers from the Diender area responded to the invitation to participate in the FTP.

The core objective of the training was to connect specific pesticide use with field tasks that occur during the REI, thereby linking conceptual knowledge of exposure and toxicity with practice in identifying alternative chemistries and/or options for altering field tasks (e.g., timing of tasks). At the start of the program a farmer survey (N = 11) was completed which collected information on participant demographics, previous pesticide training, crops grown and current pesticides used, and who completes various tasks on the farm. The data showed that six farmers had previously been trained in pesticide use, six had pesticide application training, and nine had training on the health effects of pesticides. During the two-day pilot training, the farmers practiced using the PRI for locally available pesticides by completing realistic crop management and decision-making exercises. To achieve this, the farmers worked in five groups of two or three with an IPPM facilitator to create a seasonal timeline poster for one locally grown vegetable (i.e., tomatoes, potatoes, peppers, onions, and cabbage). The initial step in creating the timelines was to provide the sequence of typical crop management activities throughout the growing season from pre-planting to harvest; this was done using printed photographs or farmers' drawings representing field activities across the season. The farmers then placed printed photographs of the pesticide label names on the timeline corresponding with the time(s) during the growing season when each pesticide would generally be applied. Using the PRI with pictograms as a reference, the farmers drew a red box around the time periods when field activities occur within the REI for the applied pesticides.

Table 3
Pesticide risk course outcome guide for the farmer training pilot course

	Day 1	Day 2
Learning outcomes (Community desired outcomes)	Farmers identify pesticide risks throughout the crop production cycle and select risk management options (O1, O2)	Farmers make pesticide selection decisions based on efficacy and risks Farmers change practices that limit pathways for toxic exposure (O3, O5)
Concepts	Pesticide toxicity and exposure Risk and exposure pathways Health impacts of pesticides Seasonal farming timeline	Restricted-entry interval (REI) Pre-harvest interval Risk mitigation Pesticide efficacy
Skills	Construct a timeline for a representative crop Select pesticides that have a compatible restricted re-entry interval (REI) using the pesticide risk index	Determine options to reduce exposure in treated fields Consider risk mitigation options for higher-risk pesticides
Assessment tasks	Identify opportunities for risk reduction and elimination using the timeline	Reduce risk through altered pesticide choices and/or mitigation practices on the timeline

Once all five timelines were completed, the entire group reconvened to identify risk management practices that could reduce the risk of pesticide exposure while allowing crop management practices to occur when necessary. Referencing the PRI, the groups reflected and then agreed how to modify their timelines through integrating alternative pesticide options with shorter REIs, new mitigation strategies, and/or non-chemical pest control practices. During a group discussion, the farmers shared how helpful it was to know the REI for the pesticides they apply, and it was clear that there was more knowledge of the post-harvest interval (the period after which harvested crops are safe to eat). Through further conversation, the farmers identified additional actions that would reduce exposure to pesticide residues, including the highly protective action of eating lunch outside of treated fields.

After the program the farmers asked to have additional Class Ib compounds added to the PRI including omethoate (Armada 400 EC), chlorpyrifos (Dursban), and dimethoate (Dimeto). This request indicated to the team that: more Class Ib pesticides were in use than what had initially been reported in the Develop stage of the program, that farmers understood the risk of exposure to these chemistries following the completion of the program, and that participants felt the tool was effective in mitigating pesticide exposure risks.

Follow-up surveys three months after the FTP found that the participating farmers were motivated by the REI to select alternative pesticides that allowed field re-entry after 0-1 days. This is an effective change given the average REI for selections made before the training was 10 days. There was encouraging self-reported change in risk reducing behaviors by FTP participants and evidence of diffusion of knowledge about risks to other community members. Farmers shared their concern that lower-risk pesticides were not always available, and that personal protective equipment is neither available, nor affordable. This process provided sufficient evidence of efficacy for the PRI to be used as the foundation for the next stage in scaling up of risk reduction education to a larger population of farmers.

Training of Facilitators

Following the success of the FTP, the team sought to increase the reach of the educational program by designing a curriculum to train facilitators who could deliver the programming to farmer audiences across the region. To craft the instructional design for the training of facilitators (ToF), the community input and data from the rapid assessment were combined with feedback from the FTP process. The intended outcomes for the ToF course were that trainers can select lower risk pesticides and identify options to reduce pesticide risks (including those to women and children) across the growing season.

A 3.5-day course was designed to enable the facilitators-in-training to train a group of farmers in their village. This ToF required a more in-depth curriculum design to provide additional conceptual and technical knowledge on pesticide toxicity and routes of exposure, as well as the additional educational skills necessary to train others in reducing their exposure to pesticides. The more in-depth training covered exposure pathways for each component of the risk index, chronic and acute human health impacts of pesticides with an emphasis on protecting women and children (vulnerability), and scenario-based role-playing exercises focused on communicating information in the PRI to other community members. Prior to the training, a meeting with the IPPM facilitators was held to share the educational design and get their feedback on the process.

On March 7-10, 2015, the ToF course was held with 25 farmers (5 women, 20 men) selected by the FAPD president from ten villages in the Diender area. Four of the five IPPM facilitators from the FTP course were available to assist with this stage. Demographic data for 23 of the participating farmers indicated their ages ranged from 17 to 58 years (mean 35.6 years), all were actively farming with 2 to 43 years of experience (mean 14.8 years), and their experience as a training facilitator ranged from 0 to 10 years (mean 3.1 years). The survey also captured that only 50% had prior training in pesticide use and 58% had education on the health effects of pesticides. Given all of the farmers could read French, the project team provided written documents in French to the facilitators and participants that included daily agendas for the farmers, daily teaching plans for the co-instructing IPPM facilitators, a checklist for assessing the completeness of cropping timelines, pesticide health impacts summary, risk mitigation options list, and guidance for unanticipated pest management outcomes.

Data from the survey conducted on the last day of the course demonstrated the value of this training in enabling the ToF to facilitate a pesticide risk reduction education project for other farmers. On a scale of 1 (low) to 7 (high), they rated the course value at 6.3 and their confidence in facilitating the course with farmers at 5.9 (N = 25). At the closing of the course, the newly trained facilitators discussed how they wanted to proceed with respect to scaling up the educational project to reach more farmers. The group decided to use a 12-week ALCE-FFS format, teaching in pairs in 10 Diender-area villages. The IPPM facilitators offered to provide support for the new facilitators via phone calls and participating in trainings as needed.

Farmer Field Schools

Based on the pesticide risk reduction ALCE-FFS teaching plan, a 12-week instruction guide was designed for the trainers who had completed the ToF. The guide provided weekly plans that outlined the purpose of each session, instructions for the learning activities with photos taken during the ToF to serve as reminders, and a prompt for the weekly group discussion. The pairs of trainers were provided with teaching kits that included the copies of the course resources and supplies to create seasonal timeline posters.

To scale up the project, 10 village-level ALCE-FFS were conducted between August and November 2015. Given that women and children are often actively involved in agricultural systems in this region of Senegal, and the low rates of participation by women in the FTP and ToF, the field school facilitators worked to ensure equal participation of women in the program (110 men, 126 women). The number of farmers participating in each village ranged from 19 to 27.

The ALCE-FFS focused on pesticide risk as a combination of exposure, toxicity, and vulnerability. The majority of the four-hour sessions were spent learning in small groups and developing and adjusting reduced-risk seasonal cropping timelines. Specific skill areas addressed during the field schools included consulting the PRI to determine REI, selecting alternatives with shorter REIs, if necessary, and identifying compatible, practical mitigation options. Other areas of focus included supplementing farmers' knowledge of pesticide health effects, with an emphasis on women of childbearing age and children, identifying responses to possible unintended outcomes from altering pest management practices, and role playing to explore risk communication approaches to extend the reach of this information.

Results

ALCE-FFS

Surveys were conducted three months after the final stage of the pilot project, reaching 137 participants from nine of the 10 villages (Table 4). Though the ALCE-FFS had slightly more participation by women farmers, the follow-up survey response rate was 45% for women and 70% for men. It is unclear why response rates were lower for women.

REI was cited as the top motivation for selecting a different pesticide, resulting in an average decrease in the period of toxic residues by 8.4 days. These changes allowed family members to more safely conduct daily fields tasks such as watering, weeding, and scouting for pests. All but one farmer indicated adoption of practices that reduce pesticide risk. The most commonly implemented practices included: 1) 81% stopped eating lunch in treated fields, 2) 72% kept women, or themselves, out of fields during the REI period, 3) 71% kept children out of fields during the REI period, and 4) 71% wore boots, pants, or gloves in treated fields. While male and female farmers were almost equally as likely to share what they had learned regarding pesticide risks from the field school with their families (99% and 100%, respectively), men were more likely than women to share information with non-farmers in their villages (44% versus 24%). Women were twice as likely to share pesticide risk information with village authorities (42% of women versus 24% of men) and kiosk operators (51% of women versus 27% of men).

Though the PRI did not use the WHO classification system as a means of differentiating between pesticides, 32 (32%) of 100 farmers reported changes in pesticide selection from Class Ib (highly hazardous) to Class II or III (moderately or slightly hazardous, respectively). More than one-third of these farmers (N = 34) kept their risk at the same level by selecting Class II products before and after the ALCE-FFS—a reasonable response given the limited pest control of the available Class III options of Bt (targets caterpillars only in early life stages), sulfur (targets fungal diseases only), and malathion (targets a range of sucking and chewing insects such as aphids, white flies, mites, and caterpillars). Fifteen farmers (15%) recalled a recent application where they changed from a Class II product to a more hazardous Class Ib option and two (2%) went from a Class III to a Class Ib option. When including farmers that selected neem after the program (N = 106), thirty-two farmers (29%) changed from a Class I or II pesticide to Bt (Class III) and/or neem oil (not classified by WHO and derived from *Azadirachta indica* trees).

Table 4
Survey Results from the August-November 2015 ALCE-FFS Pesticide Risk Reduction Education Program in the Diender area of Senegal

Behaviors	Farmer Field School Results[a]
Purchased a lower-risk pesticide	94% (N = 135)
Change in motivation for selecting a lower-risk pesticide	Toxicity during REI: 96% (N = 131)
Change in pesticide REI	-8.4 days ± 11.0 days (N = 97)
Changed practices to reduce pesticide use risks	99% (N = 136)
Risk-reducing behaviors employed	Did not eat lunch in field: 81% (N = 134) Kept children out of field during REI: 71% (N = 134) Women, or self, kept out of field during REI: 72% (N = 134) Wore boots, pants, or gloves: 71% (N = 134)
Communicated pesticide risk information to others	Family: 100% (N = 127) Other farmers in the village: 75% (N = 127) Village leadership: 31% (N = 127)

[a]Survey conducted November 2015-February 2016

Discussion

The needs assessments and both trainings revealed to the project team that crucial knowledge of concepts embedded within REI that can support pesticide risk reduction was lacking in the Diender area. The adapted ALCE-FFS was designed to provide essential knowledge required to make protective decisions that was not gained by these farmers from other pesticide-related education. Using active learning strategies within this novel approach allowed the farmers to build and apply the conceptual knowledge that pesticide risk is a combination of exposure, toxicity, and vulnerability.

Integrating farmer knowledge with scientific knowledge throughout the project was also important in ensuring farmers' capacity for decision-making was connected to their aspirations for change with respect to pesticide management (Damalas & Koutroubas, 2018). Furthermore, involving farmers in the identification of problems, design, and delivery of curricula was crucial to producing desired behavior changes and expanding the reach of the program information following agricultural education initiatives (Bakker et al., 2021; van den Berg et al., 2020).

The evidence of information sharing by the ALCE-FFS participants (Table 4) indicates that this novel approach facilitated the development of community-based knowledge exchanges that extended the reach of the project beyond those who directly participated. These locally-based systems of information exchange contributed to achieving four of the community envisioned outcomes relating to providing training to reduce pesticide risks, promoting safe pesticide management, strengthening community capacity through communication, and sharing information on alternatives to chemical pesticides.

Conclusion

Based on the current availability of highly hazardous pesticides and projections of increased usage of pesticides across West Africa, it is imperative to identify the most effective and efficient pesticide-risk reduction approaches for farmers (Fuhrimann et al., 2022). Adapting teaching and learning methods to combine non-intuitive information transmission with practical and relevant management skills supports farmers in operationalizing information to select less-hazardous pesticides and engage in practices that limit exposure, thus protecting human health. Grounding educational programming in local knowledge, resources, and networks empowers communities and organizations to take ownership of the education process, which is essential for engendering behavioral changes that will balance production and protection goals.

Since the completion of the above program, research on adult education has increasingly validated the efficacy and necessity of learner-centered approaches (Deslauriers et al., 2019; Theobald et al., 2020). The work outlined within this research is thus more relevant than ever. By inspiring new partnerships between scientists, learners, educators, and others to bolster existing knowledge systems, the novel approach described here can assist extension workers and other educators in increasing the desired behavior change in a range of contexts around the globe.

Recommendations

The outcomes of this project demonstrate that the ALCE-FFS approach can effectively address knowledge gaps in education that can result from using discovery learning models, as the approach for pesticide risk reduction. Extension professionals, program planners, and others can adapt findings from this study to increase the impact of pesticide risk reduction and other educational programming. As evidenced from this project and the work of de Bon et al. (2014), it will also be important to engage and train pesticide wholesalers and retailers given their influential interactions with farmers. National plant protection department and extension advisory services personnel should also be included so that institutions, organizations, and communities can work in concert to improve pesticide risk reduction outcomes. In addition, more research is needed to determine if alternative, perhaps less intensive, interventions such as posters, radio messaging, or specialized interventions with kiosk operators could achieve desired impacts similar to those of the ALCE-FFS approach.

References

Bakker, T., Canta, G.B., Dugue, P., & de Tourdonnet. (2021). To what extent is the diversity of Farmer Field School reflected in their assessment? A literature review. *The Journal of Agricultural Education and Extension*. 27(3), 381-401. https://doi.org/10.1080/1389224X.2020.1858890

Costa, L.G. (2018). Organophosphorus compounds at 80: Some old and new issues. *Toxicological Sciences* 162(1), 24-35. https://doi.org/10.1093/toxsci/kfx266

Dhamankar, M. & Wongtschowski, M. (2014). Farmer Field Schools (FFS). Note 2. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/farmer-field-schools.html

Damalas, C.A., & Koutroubas, S.D. (2018). Farmers' behaviour in pesticide use: A key concept for improving environmental safety. *Current Opinion in Environmental Science & Health* 4, 27–30. https://doi.org/10.1016/j.coesh.2018.07.001

de Bon, H., Huat, J., Parrot, L., Sinzogan, A., Martin, T., Malézieux, E., & Vayssières, J.-F. (2014). Pesticide risks from fruit and vegetable pest management by small farmers in sub-Saharan Africa. A review. *Agronomy for Sustainable Development* 34, 723-736. https://doi.org/10.1007/s13593-014-0216-7

Deslauries, L. McCarty, L.S., Miller, K., Callaghan, K, & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Proceedings of the National Academy of Sciences* 116(39), 19251-19257. https://doi.org/10.1073/pnas.1821936116

Fare, Y., Dufumier, M., Loloum, M., Miss, F., Pouye, A., Khastalani, A., & Fall, A. (2017). Analysis and diagnosis of the agrarian system in the Niayes region, northwest Senegal (West Africa). *Agriculture* 7(7), 59. https://doi.org/10.3390/agriculture7070059

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences* 111(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

Fuhrimann, S., Wan, C., Blouzard, E., Veludo, A., Holtman, Z., Chetty-Mhlanga, S., Dalvie, M.A., Atuhaire, A., Kromhout, H., Röösli, M. et al. (2022). Pesticide research on environmental and human exposure and risks in Sub-Saharan Africa: A systematic literature review. *Int. J. Environ. Res. Public Health* 19, 259. https://doi.org/10.3390/ijerph19010259

Gupta, R.C., Miller Mukherjee, I.R., Doss, R.B., Malik, J.K., & Milatovic, D. (2017). Organophosphates and carbamates. In *Reproductive and Developmental Toxicology,* ed. R.C. Gupta, (pp. 609-630). Cambridge, MA: Academic Press.

Halbleib, M.L., Bouska, C., Jones, G., & Walenta, D. (2021). Increasing the reach of integrated pest management through community partnerships: Insights from implementing Adaptive-Learner Centered Education across Oregon. Oregon State University Extension Service. https://catalog.extension.oregonstate.edu/em9328

Halbleib, M.L., & Jepson, P.C. (2015). Adapting an outcome-based education development process to meet near real-time challenges to sustainable agricultural production. *Journal of Agricultural Education and Extension* 21(2), 109-126. https://doi.org/10.1080/1389224X.2014.927377

Halbleib, M.L., & Jepson, P.C. (2016). Adaptive Learner-Centered Education: A toolkit for extension. Oregon State University Extension Service EM9144. https://catalog.extension.oregonstate.edu/em9144

Jepson, P.C., Guzy, M., Blaustein, K., Sow, M., Sarr, M., Mineau, P., & Kegley, S. (2014). Measuring pesticide ecological and health risks in West African agriculture to establish an enabling environment for sustainable intensification. *Philosophical Transactions of the Royal Society B* 369: 20130491. https://doi.org/10.1098/rstb.2013.0491

Kim, K.-H., Kabir, E., & Jahan, S.A. (2017). Exposures to pesticides and the associated human health effects. *Science of the Total Environment* 575, 525-535. http://dx.doi.org/10.1016/j.scitotenv.2016.09.009

Koureas, M., Tsakalof, A., Tsatsakis, A., & Hadjichristodoulou, C. (2012). Systematic review of biomonitoring studies to determine the association between exposure to organophosphorus and pyrethroid insecticides and human health outcomes. *Toxicology Letters* 210, 155-168. https://doi.org/10.1016/j.toxlet.2011.10.007

Morris, T.H. (2020). Experiential learning – a systematic review and revision of Kolb's model. *Interactive learning Environments*. 28(8), 1064-1077. https://doi.org/10.1080/10494820.2019.1570279

Settle, W., & Garba, M.H. (2011). Sustainable crop production intensification in the Senegal and Niger River basins of francophone West Africa. *International Journal of Agricultural Sustainability* 9(1), 171-185. https://doi.org/10.3763/ijas.2010.0559

Settle, W., Soumare, M., Sarr, M., Garba, M.H., & Poisot, A.-S. (2014). Reducing pesticide risks to farming communities: Cotton Farmer Field Schools in Mali. *Philosophical Transactions of the Royal Society B.* 369: 20120277. https://doi.org/10.1098/rstb.2012.0277

Theobald, E.J., Hill, M.J., Tran, E., & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences* 117(12), 6476-6483. https://doi.org/10.1073/pnas.1916903117

Touré, O., & Seck., S.M. (2005). Family and commercial farming in the Niayes area of Senegal. International Institute for Environment and Development. https://pubs.iied.org/pdfs/9548IIED.pdf

van den Berg, H., Phillips, S., Dicke, M. & Fredrix, M., (2020). Impacts of Farmer Field Schools in the human, social, natural and financial domain: A qualitative review. *Food Security*. 12, 1443-1459. https://doi.org/10.1007/s12571-020-01046-7

Waddington, H., Snilstveit, B., Hombrados, J., Vojtkova, M., Phillips, D., Davies, P., & White, H. (2014). Farmer Field Schools for improving farming practices and farmer outcomes: A systematic review. Campbell Systematic Reviews, 10(1), I - 335. https://doi.org/10.4073/CSR.2014.6