



# Farmers' Preferences and Willingness to Pay for Attributes of Integrated Pest Management Methods Against *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Benin

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## Abstract

In response to the invasion of *Spodoptera frugiperda* (J.E. Smith) in Africa, farmers rely mainly on synthetic pesticides which are harmful to human health and environment. This study investigated farmers' preferences and willingness to pay (WTP) for attributes of integrated pest management (IPM) methods against *S. frugiperda*. A survey was conducted among 400 randomly selected maize farmers in eight districts of Benin using a questionnaire. Results showed that the majority of farmers (66.5%) who were interested in the IPM approach preferred a combined use of intercropping and ecological control products in managing *S. frugiperda*. Farmers who were more likely to pay for IPM strategies against *S. frugiperda* had less access to extension services, very small farms, and relatively low income. They represented 38.82% of the sample and were willing to pay additional protection costs of 4.53 US\$/ha for the combination of several management methods, 86.09 US\$/ha for the reduction of human health risks, 22.20 US\$/ha for the preservation of environment, and 4.90 US\$/ha for a reduction in yield losses. The policy implications of these findings for the extension of IPM technologies were discussed.

**Key words:** fall armyworm, willingness to pay, integrated pest management, welfare, Benin

In Africa, agriculture is one of the main sources of economic growth and the main source of employment for rural households. More than half of Africa's population depends on agriculture for their livelihoods (NEPAD 2013). However, this sector of activity struggles to develop because it faces several problems including the effective and sustainable management of exotic insect pests which is one of the major challenges in the agricultural development process (Mendesil et al. 2016, Allahyari et al. 2017).

*Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is one of the most devastating exotic insect pests Africa has seen in the last five years. Native to the Americas and first detected in most African countries in 2016, *S. frugiperda* causes significant economic losses to several crops (Nboyine et al. 2020). It has a preference for maize, the main foodstuff in Sub-Saharan Africa. It also feeds on sorghum, rice, sugarcane, groundnut, soybean, cotton, millet, and tomato (Prasanna et al. 2018). *S. frugiperda* represents a serious threat to food security and contributes to income losses for smallholder farmers (Kumela et al. 2019, Tambo et al. 2020a). In Benin, a national survey revealed that on average 49% of maize yields were lost due to *S. frugiperda* attacks in 2018 (Hougbo et al. 2020).

The management of *S. frugiperda* has proven to be quite difficult in Africa due to its resistance to synthetic pesticides which are

the main management methods used by farmers (Yu 1992, Al-Sarar et al. 2006, Kumela et al. 2019, Chimweta et al. 2020). The dispersal of *S. frugiperda* larvae lower down in the maize canopy prevents sprayed synthetic pesticides from killing the larvae, making chemical control laborious, and ineffective (Cook et al. 2004). Furthermore, evidence that synthetic pesticides pose risks to human health and preservation of beneficial organisms has been widely documented (Cuyno et al. 2001). Therefore, the Integrated Pest Management (IPM) is considered a viable alternative for effective and sustainable management of *S. frugiperda* (Harrison et al. 2019, Nboyine et al. 2020, Njuguna et al. 2021).

Integrated Pest Management (IPM) is an environmentally friendly approach. It involves the harmonious combination of biological, cultural, and chemical control to improve productivity and minimize the use of synthetic pesticides (Allahyari et al. 2017, Rahman et al. 2018). The goal of IPM is to control pest populations in a way that avoids economic losses by using techniques that minimize risks to the environment including humans (Prasanna et al. 2018). In general, this approach has had wide impact on agriculture. It has been successful in reducing the use of many broad-spectrum pesticides, conserving natural bio-agents, and has proven to be more efficient than chemical control (Timprasert et al. 2014). However,

an important question is whether farmers in African countries are willing to pay for IPM technologies.

In order to contribute to the development of an integrated and sustainable management program for *S. frugiperda*, management methods have been tested and refined by researchers in Benin. These include the use of *Palmida* (a local household soap), neem oil, the semi-synthetic pesticide Emacot 19 EC (Aniwanou et al. 2021), intercropping maize with soybean, cowpea, or groundnut, and the use of natural enemies such as entomopathogenic nematodes. This study was conducted to examine farmers' preferences for management methods developed by researchers, their combined use in the management of *S. frugiperda*, and the extent to which farmers are willing to pay for the attributes of IPM.

## Survey and Data

### Survey Design and Implementation

The surveys were carried out in eight districts known to be major maize producing districts in Benin. These districts are: Ouèssè, Kétou, Aplahoué, Adjohoun, Kandi, Gogounou, N'Dali, and Péhunco. They are also among the districts that reported severe *S. frugiperda* attacks in 2018 (Houngbo et al. 2020). In total, 16 villages (two villages per district) were selected with the assistance of maize advisors from the 'Agences Territoriales de Développement Agricole' (ATDA). The main criterion for selecting villages was the level of maize production. Twenty-five farmers who had experienced at least one attack by *S. frugiperda* were randomly selected per village. Data collection was carried out from December 2019 to January 2020 using the choice experiment method. The first step of this method is the selection of attributes and different levels for each attribute. According to Bateman et al. (2002), four to six attributes with two to five levels per attribute are sufficient to characterize a good or service. Based on this, six attributes were selected to describe IPM strategies: the number of management methods combined, reduction of human health risks, preservation of environment, reduction of yield losses, and cost of protection against *S. frugiperda*. The environment attribute here includes livestock, birds, aquatic species, beneficial insects, and soil. To identify attribute levels, the study relied on a focus group conducted in the N'Dali district (northern Benin). The focus group was composed of nine participants, seven maize farmers, and two researchers. The focus group was conducted using an interview guide. The levels of attributes retained from the focus group are presented in Table 1.

The second step of the choice experiment method was to develop choice cards. Combining the six selected attributes and their respective levels yielded 120 IPM profiles ( $2^3 \times 3 \times 5$ ). From these 120 profiles, 28 realistic, and applicable IPM profiles were selected, taking into account the management methods developed by the researchers. Choice cards were constructed by randomly pairing the profiles and using a status quo option as a reference. The status quo option refers to farmers' current management practices against *S. frugiperda*, primarily the use of synthetic pesticides. In total, 14 cards with three options (two IPM options and status quo) were constructed. One of the choice cards is shown in Table 2.

Farmers were interviewed face-to-face in their local language on the basis of a questionnaire including choice cards. The questionnaire consisted of three sections of questions: 1) characteristics of the respondents and their farms, 2) respondents' expectations and preferences regarding management methods developed against *S. frugiperda* by the researchers and the combined use of these methods, 3) respondents' preferences regarding the IPM options on the choice cards. First, respondents were asked about their level of education, years of

**Table 1.** Selected IPM attributes and attribute levels

IPM attributes	Attribute levels
Number of combined management methods	(1) Two management methods (2) Three management methods
Reduction of yield losses	(1) <50% (2) ≥50% and <100% (3) 100%
Reduction of the risks of pest management on human health	(1) No (2) Yes
Reduction of the risks of pest management on environment	(1) No (2) Yes
Protection costs against <i>S. frugiperda</i> (US\$/ha)	23 46 69 92 114

**Table 2.** Example of choice card

Attributes	Option A	Option B	Status Quo
Combination of management methods	2	2	
Reduction of yield losses	100%	≥50% and <100%	
Reduction of health risks	Yes	No	
Reduction of environmental risks	Yes	No	
Protection cost (US\$/ha)	69	23	
I prefer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

farming experience, household size, access to extension services, farm size, area cropped for maize production, and income. Respondents were also asked about their knowledge, perceptions, and practices for controlling *S. frugiperda*. Color images showing the condition of a field attacked by *S. frugiperda*, the developmental stages of *S. frugiperda*, and the severity of attacks were used to prevent farmers from confusing *S. frugiperda* attacks with those of other maize pests. In a second step, the management methods developed by the researchers against *S. frugiperda* and their effectiveness were presented to the farmers. Color images showing how to apply these management methods were also used. The management methods presented to the farmers included the use of *Palmida* (a local household soap), neem oil, the semi-synthetic pesticide Emacot 19 EC (emamectin benzoate), and intercropping maize with soybean, cowpea, and peanut. Farmers were asked to choose which of these methods they preferred and which combination of methods they would be willing to adopt. In a third step, the philosophy behind the IPM approach was explained to the farmers and the designed choice cards were presented to them. Farmers were then asked to select their preferred IPM option on each card. Given the sample size, the number of choice cards, and the number of options per card, the data collection method yielded 16,800 choice responses.

### Data Analysis

The information generated from the first two sections of the questionnaire was analyzed using descriptive statistics. The percentages

of farmers who prefer each of the management methods developed by the researchers were calculated based on the total number of respondents. The percentages of farmers who prefer the combined use of the developed management methods were calculated based on the total number of respondents interested in integrated management. Pearson's chi-square test ( $\chi^2$ ) was used to examine differences in farmers' preferences for the management methods developed by the researchers.

Analysis of farmers' preferences for attributes of IPM methods was carried out using a Latent Class Logit (LCL) model. The LCL model analyzes preferences by grouping respondents into a number of homogeneous classes (Greene and Hensher 2003). LCL models with different numbers of classes were estimated and compared using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The best model is the one with the lowest AIC and BIC values (Vivithkeyoonvong and Jourdain 2017, Kornher et al. 2019). Based on this, the four-class LCL model was identified as the best model and was therefore selected for this study. The explanatory variables included in the LCL model were farmer characteristics and IPM attributes. Analysis of the model results was performed at the 5%, 1%, and 0.1% significance levels. Farmers' willingness to pay (WTP) for each attribute was calculated using the estimated parameters of the LCL model (Kornher et al. 2019). In this study, WTP is defined as the additional cost of protection that a farmer is willing to pay to benefit from the attributes of IPM methods. All data analyses were performed using STATA software, version 15.0.

## Results

### Characteristics of the Farmers Surveyed

The majority of farmers surveyed (62%) had no education. They had an average of 20 years of experience in agriculture and their households had an average of 11 persons. About 42% of the farmers had access to extension services. The average farm size was 8.24 ha. The smallest farms were 1 ha and the largest 23 ha. On average, farmers devoted 3.62 ha to maize crop, or 43% of the area available. The average total income of farmers was US\$ 2298.88 per year.

The farmers interviewed were familiar with *S. frugiperda* larvae and recognized its damage in maize fields. However, very few farmers (3%) were able to identify other developmental stages of the pest, including eggs, pupae, and adults. All farmers interviewed recorded *S. frugiperda* attacks in their maize fields. The severity of the damage was high according to the farmers' perceptions. They observed an average of 78% of maize plants in their fields with severely attacked whorls, numerous elongated lesions, and the presence of larval droppings. About 92% of farmers used synthetic pesticides to control *S. frugiperda*. However, 7% of farmers used botanical pesticides made from neem leaves (*Azadirachta indica*), vernonia leaves (*Vernonia amygdalina*), chili pepper (*Capsicum annum*), and ash. In addition, about 6% of farmers did early planting, handpicking larvae, and application of ash on maize whorls to reduce the level of pest infestation.

### Farmers' Preferences for Management Methods Developed by Researchers

Most farmers (98%) were interested in at least one of the developed management methods presented to them during the interviews. These methods were the use of Emacot 19 EC, neem oil, *Palmida* soap, and intercropping maize with groundnut, soybean, or cowpea.

Farmers preferred the use of *Palmida* soap (69%) more than the other methods (Fig. 1). After *Palmida* soap followed intercropping and neem oil. The lowest proportion of farmers (38.5%) preferred Emacot 19 EC because it was the least accessible management option in the study area. Pearson's chi-square test indicated significant differences between the proportions of respondents who preferred *Palmida* soap and those who preferred Emacot 19 EC ( $\chi^2 = 48.24$ ,  $df = 1$ ,  $P = 0.000$ ), neem oil ( $\chi^2 = 8.27$ ,  $df = 1$ ,  $P = 0.004$ ), or intercropping maize with groundnut ( $\chi^2 = 8.27$ ,  $df = 1$ ,  $P = 0.004$ ). However, there were no significant differences between the proportions of respondents who preferred *Palmida* soap and those who preferred intercropping maize with cowpea ( $\chi^2 = 3.53$ ,  $df = 1$ ,  $P = 0.060$ ) or intercropping maize with soybean ( $\chi^2 = 2.29$ ,  $df = 1$ ,  $P = 0.130$ ).

The majority of farmers (76.1%) were interested in an integrated management approach combining the management methods developed by the researchers. About 66.5% of the farmers were willing to apply a combined use of intercropping and ecological control products (*Palmida* soap or neem oil) to control *S. frugiperda*. In addition, 22.1% of the farmers preferred the combined use of intercropping and the semi-synthetic pesticide Emacot 19 EC. About 19% of the farmers were willing to apply a combined use of Emacot 19 EC and ecological control products (*Palmida* soap or neem oil).

### Farmers' Preferences for IPM Attributes

The estimated LCL model distinguished four classes of farmers in the sample. Variables such as formal education, years of farming experience, farmer's household size, access to extension services, total cropped area, and total farmer income were significantly relevant to characterize the classes of farmers (Table 3). Farmers in class 1 were more likely to have large farms than farmers in other classes. Class 2 was more likely to be educated, have more experience in farming, a large household size, less access to extension services, and small farms. Class 3 farmers were more likely to have large household size, very small farms, and relatively low total income. Class 4 farmers were more likely to have less access to extension services, very small farms, and relatively very low total income. Farmers in classes 1, 2, 3, and 4 represented 37.26%, 2.38%, 21.54%, and 38.82% of the sample, respectively.

The model showed that all IPM attributes were significantly relevant to the choices made by farmers on the cards (Table 4). The protection cost parameter was significant and negative for classes 1, 2, and 4. This means that these classes preferred management methods that minimize their protection cost. The parameter of health risk reduction was significant and positive for all four classes. This indicates that farmers, regardless of class, preferred management methods that preserve their health. The parameter of environmental risk reduction was significant and positive for classes 1, 2, and 4. These classes preferred management methods that preserve

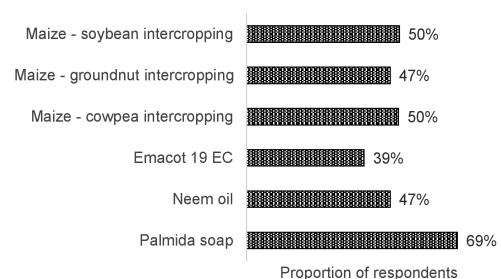


Fig. 1. Farmers' preferences for some control methods developed by researchers.

**Table 3.** Parameter estimation results of the socio-economic variables included in the four-class LCL model

Variables	LCL model		
	Class 2	Class 3	Class 4
Formal education (0 = Not educated; 1 = Educated)	0.7746*** (0.1694)	-0.0065 (0.3790)	0.1590 (0.4811)
Number of years of experience in agriculture	0.0265*** (0.0064)	0.0142 (0.0129)	0.0081 (0.0182)
Size of farmer's household	0.0682*** (0.0177)	0.0687* (0.0315)	0.0854 (0.0447)
Access to extension services (0 = No; 1 = Yes)	-0.4278* (0.1879)	-1.0659 (0.7425)	-0.9123* (0.4147)
Area cropped (ha)	-0.0622*** (0.0365)	-0.1993* (0.0874)	-0.1560** (0.0575)
Total farmer income (US\$/year)	-8.70e-09 (6.51e-08)	-1.14e-06* (4.94e-07)	-9.18e-07** (2.63e-07)

Numbers without brackets are estimated parameters; numbers in brackets are standard errors of the estimated parameters; numbers with one or more asterisks are significant parameters and show the relevant variables to characterize each class; \* indicates parameters significant at the 5% level; \*\* indicates parameters significant at the 1% level; \*\*\* indicates parameters significant at the 0.1% level. Class 1 was considered as the reference. This means that a positive parameter indicates a higher probability that the respondent with a given characteristic is a member of class 2, 3, or 4 compared to class 1. Conversely, a negative parameter indicates a higher probability that the respondent is a member of class 1 compared to class 2, 3, or 4.

**Table 4.** Parameter estimation results for IPM attributes included in the four-class LCL model presented

Variables	LCL model			
	Class 1	Class 2	Class 3	Class 4
Protection cost	-0.0013*** (0.0001)	-0.0058*** (0.0004)	-0.0096 (0.0070)	-0.0111*** (0.0019)
Combination of management methods	4.14e-04 (0.0054)	-0.0615** (0.0184)	-0.2029 (0.2917)	0.0503 (0.4554)
Reduction of health risks	0.1984*** (0.0108)	0.1982*** (0.0160)	0.9858*** (0.1182)	0.9556* (0.4615)
Reduction of environmental risks	0.1414*** (0.0063)	0.1355*** (0.0111)	0.2510 (0.2886)	0.2464** (0.0834)
Reduction of yield losses	0.0275*** (0.0027)	0.0523*** (0.0051)	0.2418 (0.1529)	0.0544** (0.0173)
Status quo <sup>a</sup>	-0.6658*** (0.0270)	-0.4938*** (0.0548)	-2.4061 (0.0000)	-2.3039 (0.0000)
Number of farmers (%)	37.26	2.38	21.54	38.82

<sup>a</sup>Status quo or current management practices (1 if the respondent chooses the status quo and 0 otherwise); numbers without brackets are estimated parameters; numbers in brackets are standard errors of the estimated parameters; numbers with one or more asterisks are significant parameters and show the attributes relevant to the farmers in each class.

\* indicates parameters significant at the 5% level; \*\* indicates parameters significant at the 1% level; \*\*\* indicates parameters significant at the 0.1% level. A positive parameter indicates that the respondent has a positive preference for the considered attribute. Conversely, a negative parameter indicates a negative preference of the respondent for the attribute.

their production environment. The parameter associated with yield loss reduction was also significant and positive for classes 1, 2, and 4. This means that the effectiveness of IPM methods in terms of yield loss reduction determined the choice of farmers in these classes. The parameter associated with the combined use of management methods was significant and negative for class 2. This shows the negative preference of farmers in class 2 for the combined use of several management methods against *S. frugiperda*.

### Farmers' WTP for IPM Attributes

Farmers were willing to pay for the attributes of the IPM options (Table 5). Class 1 farmers were willing to pay additional protection costs of 0.32 US\$/ha for the combined use of several management methods, 152.64 US\$/ha for reducing human health risks, 108.79 US\$/ha for preserving the environment, and 21.15 US\$/ha for reducing yield losses caused by *S. frugiperda*. Thus, class 1 farmers were willing to pay a very small amount for the combined use of several pest management methods. However, their WTP was more important for the preservation of their health and environment. Class 2 farmers had positive WTPs for reducing human health risks (34.17 US\$/ha), preserving the environment (23.36 US\$/ha), and reducing yield losses (9.01 US\$/ha). However, they have a negative WTP for the combined use of several management methods (-10.60 US\$/ha). Farmers in class 3 also had a negative WTP for the combined use of several management methods (-21.14 US\$/ha) and positive WTPs for the other attributes. Class 4 farmers had positive WTPs for all

non-monetary attributes. They were willing to pay additional protection costs of 4.53 US\$/ha for the combined use of several management methods, 86.09 US\$/ha for the reduction of human health risks, 22.20 US\$/ha for the preservation of the environment, and 4.90 US\$/ha for a reduction in yield losses.

Thus, all classes of farmers were willing to pay additional protection costs to apply management methods that reduce health risks, preserve the environment, and reduce yield losses. However, only farmers in classes 1 and 4 were willing to pay to apply management options that integrated several management methods. Class 4 farmers' WTP for the combined use of management methods was higher. These farmers were therefore more likely to apply IPM options than those in class 1. Regardless of class, environmental conservation and health risk reduction were the most important attributes that led farmers to choose IPM options on the cards.

### Discussion

Several management methods were tested and refined by the researchers against *S. frugiperda* (neem oil, *Palmida* soap, Emacot 19 EC, and intercropping maize with groundnut, soybean, or cowpea). The majority of farmers (69%) preferred to apply *Palmida* soap despite the fact that it was less effective than the semi-synthetic pesticide Emacot 19 EC in terms of reducing yield losses (Aniwanou et al. 2021). Indeed, *Palmida* soap is a local soap commonly used for domestic purposes by households in Benin. It is more available

**Table 5.** Farmers' WTP for each IPM attribute by class (US\$/ha)

Attributes	Class 1	Class 2	Class 3	Class 4
Combination of management methods	0.32	-10.60	-21.14	4.53
Reduction of health risks	152.64	34.17	102.69	86.09
Reduction of environmental risks	108.79	23.36	26.15	22.20
Reduction of yield losses	21.15	9.01	25.19	4.90

The numbers reported in this table were calculated from the estimated parameters of the IPM attributes (Table 4). For example, WTPs for the attribute 'Combination of management methods' were calculated by dividing the estimated parameters of this attribute by those of the attribute 'Protection cost' multiplied by -1 (Kornher et al. 2019).

and accessible in the study area than Emacot 19 EC. Tambo et al. (2020b) showed that transaction costs associated with access to crop protection inputs determine farmers' choice of management methods. Management methods that reduce these costs are likely to be more successful for farmers.

In the four-class LCL model, farmers in classes 2 and 3 were reluctant to combine several management methods. The main reason was the increased labor that this attribute might require. Thus, farmers in classes 2 and 3 were not willing to apply IPM methods. However, they were willing to pay for alternative management methods that protect their health and environment. Classes 1 and 4 had positive WTPs for all nonmonetary attributes, including the combined use of several management methods. Therefore, farmers in these classes were willing to pay to apply IPM methods against *S. frugiperda*. The WTP of class 1 farmers for combining several management methods (0.32 US\$/ha) was very low compared to WTPs for the other attributes. In addition, farmers in class 4 had a higher WTP for the combined use of several management methods than those in class 1 (4.53 US\$/ha). This shows that farmers who are more likely to apply IPM methods against *S. frugiperda* are those in class 4. These farmers were willing to pay a maximum of 117.72 US\$/ha to adopt an IPM technology against *S. frugiperda*.

The positive WTP of farmers in classes 1 and 4 for the combined use of several management methods may be explained by the potential for improved input productivity through IPM. In other words, to increase the likelihood of choosing an IPM option for *S. frugiperda*, the combination of management methods must not only be more effective than the status quo in reducing yield losses, but also improve input productivity. It is clear that a farmer will only adopt a technology if its productivity and anticipated profitability are higher compared to nonadoption (Marenya and Barrett 2007). The surveys revealed that the majority of farmers (66.5%) who were interested in an integrated management approach were willing to apply a combined use of intercropping and ecological control products (*Palmida* soap or neem oil) to control *S. frugiperda*.

Preservation of environment and human health are the most important attributes that led class 4 farmers to prefer IPM over their current pest management practices. Several studies have confirmed the interest of farmers in preserving their production environment in Africa as well as in other continents of the world. For example, in the Philippines, Cuyno et al. (2001) showed that farmers were willing to pay 14–17 US\$/season to reduce the risks to human health and environment associated with the exclusive use of synthetic pesticides. In Italy, Traversi and Nijkamp (2008) reported that households were willing to pay 1049 US\$/year to protect endangered bird species, 1,758 US\$/year to avoid soil and groundwater contamination in agricultural zones, and 1,543 US\$/year to eliminate all risks of poisoning from synthetic pesticides. In Togo, Yovo (2010) found that farmers were willing to pay a premium of 18–22% of the price

of the most expensive synthetic pesticides to apply environmentally friendly management methods, including biopesticides.

Farmers who were more likely to pay to apply IPM methods against *S. frugiperda* had small farm size. Timprasert et al. (2014) came to this same result. They found a negative relationship between farm size and adoption of IPM practices. According to farmers, IPM is more appropriate for small farms because of the field monitoring constraints imposed by the approach. Monitoring pest populations is less burdensome on small farms. This study also showed that farmers who were more likely to apply IPM had a relatively low income. It is up to agricultural research institutions and scientists to intensify research efforts on effective, low-cost, and low-risk IPM practices to ensure sustainable management of *S. frugiperda*.

Farmers who were more likely to apply IPM had less access to extension services. In Benin, extension services in general struggle to perform their functions due to insufficient staff to monitor farmers (Davito et al. 2017). The extension worker–farmer ratio was estimated at 1:500 in 2015 (Mur et al. 2015). Furthermore, the messages disseminated by extension services for pest management in Benin are more focused on the use of synthetic pesticides. Khan and Damalas (2015) revealed that farmers who received information on handling synthetic pesticides were less willing to pay for IPM. For extension services to contribute to the success of an IPM program, there is a need to improve the extension workers/farmers ratio through increasing the staff of extension workers, train extension workers on IPM approach, and adapt extension message content to promote IPM technologies.

## Conclusions

This study reported on farmers' preferences and their WTP for attributes of IPM methods against *S. frugiperda*. It shows that farmers in Benin are mostly illiterate. They are familiar with *S. frugiperda* larvae but have very little knowledge of the other developmental stages of the species. Attacks by the pest have been severe in 2019 and the majority of farmers have used synthetic pesticides that still do not satisfy them. Farmers have been interested in the control methods developed by researchers and the combined use of these methods against the pest. The majority of farmers expressed a preference for the combined use of intercropping and ecological control products. Some farmers were reluctant to combine control methods because of the increased labor that it might involve. Preservation of the environment and human health are the most important attributes that drive farmers to choose IPM methods. Farmers who are more willing to pay for IPM methods have less access to extension services, small farm size, and relatively low income. The findings suggest that research efforts on effective, low-cost, and low-risk IPM practices should be intensified. Specifically, IPMs that combine intercropping with the use of ecological control products are likely to be more successful for farmers. The government should also help

to: 1) improve the extension worker–farmer ratio by increasing the staff of extension workers, 2) train extension workers on IPM approach, and 3) adapt the extension message content to promote the IPM technologies developed. Institutional barriers to the adoption of IPM strategies remain unknown and should be studied through further investigation to ensure the social viability of IPM technologies for farmers.

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## References Cited

- Allahyari, S. M., A. C. Damalas, and M. Ebadattalab. 2017. Farmers’ technical knowledge about integrated pest management (IPM) in olive production. *Agriculture*. 7: 1–9.
- Al–Sarar, A., F. R. Hall, and R. A. Downer. 2006. Impact of spray application methodology on the development of resistance to cypermethrin and spinosad by fall armyworm *Spodoptera frugiperda* (J.E. Smith). *Pest Manag. Sci.* 62: 1023–1031.
- Aniwanou, C. T. S., A. A. C. Sinzogan, J. M. Deguenon, R. Sikirou, D. A. Stewart, and A. Ahanchede. 2021. Bio-efficacy of diatomaceous earth, household soaps, and neem oil against *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae in Benin. *Insects*. 12: 1–18.
- Bateman, I. J., T. R. Carson, B. Day, M. W. Hanemann, N. Hanley, T. Hett, J. M. Lee, G. Loomes, S. Mourato, E. Özdemiroglu, W. D. Pearce, and E. Elgar. 2002. *Economic valuation with Stated Preference Techniques: a manual*. Edward Elgar Publishing, Cheltenham, England.
- Chimweta, M., I. W. Nyakudya, L. Jimu, and A. B. Mashingaidze. 2020. Fall armyworm [*Spodoptera frugiperda* (J.E. Smith)] damage in maize: management options for flood-recession cropping smallholder farmers. *Int. J. Pest Manag.* 66: 142–154.
- Cook, D. R., B. R. Leonard, and J. Gore. 2004. Field and laboratory performance of novel insecticides against armyworms (Lepidoptera: Noctuidae). *Fla. Entomol.* 87: 433–439.
- Cuyno, C. M. L., W. G. Norton, and A. Rola. 2001. Economic analysis of environmental benefits of integrated pest management: a Philippine case study. *Agric. Econ.* 25: 227–233.
- Davito, T., F. Okry, A. Kouevi, and S. Vodouhe. 2017. Efficacité comparée de trois méthodes de diffusion d’informations rizicoles par des vidéos au Sud du Bénin. *Cahiers Agricultures*. 26: 1–7.
- Greene, W. H., and D. A. Hensher. 2003. A latent class model for discrete choice analysis: contrasts with mixed logit. *Transp. Res. B: Methodol.* 37: 681–698.
- Harrison, D. R., C. Thierfelder, F. Baudron, P. Chinwada, C. Midega, U. Schaffner, and J. van den Berg. 2019. Agro–ecological options for fall armyworm (*Spodoptera frugiperda* J.E. Smith) management: providing low–cost, smallholder friendly solutions to an invasive pest. *J. Environ. Manage.* 243: 318–330.
- Houngbo, S., A. Zannou, A. Aoudji, C. H. Sossou, A. Sinzogan, R. Sikirou, E. Zossou, S. H. Totin Vodounon, A. Adomou, and A. Ahanchede. 2020. Farmers’ knowledge and management practices of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in Benin, West Africa. *Agriculture*. 10: 1–15.
- Khan, M., and C. A. Damalas. 2015. Farmers’ willingness to pay for less health risks by pesticide use: a case study from the cotton belt of Punjab, Pakistan. *Sci. Total Environ.* 530–531: 297–303.
- Kornher, L., M. Schellhorn, and S. Vetter. 2019. Disgusting or innovative–consumer willingness to pay for insect based burger patties in Germany. *Sustainability*. 11: 1–20.
- Kumela, T., J. Simiyu, B. Sisay, P. Likhayo, E. Mendesil, L. Gohole, and T. Tefera. 2019. Farmers’ knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *Int. J. Pest Manag.* 65: 1–9.
- Marenya, P. P., and C. B. Barrett. 2007. Household–level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food Policy*. 32: 515–536.
- Mendesil, E., Z. Shumeta, P. Anderson, and B. Rämert. 2016. Smallholder farmers’ knowledge, perceptions and management of pea weevil in north and north–western Ethiopia. *Crop Prot.* 81: 30–37.
- Mur, R., F. Williams, S. Danielsen, G. Audet–Bélanger, and J. Mulema. 2015. Listening to the silent patient: Uganda’s journey towards institutionalizing inclusive plant health services. Working paper No. 7, CABI, Uganda.
- Nboyine, J. A., F. Kusi, M. Abudulai, B. K. Badii, M. Zakaria, G. B. Adu, A. Haruna, A. Seidu, V. Osei, S. Alhassan, and A. Yahaya. 2020. A new pest, *Spodoptera frugiperda* (J.E. Smith), in tropical Africa: its seasonal dynamics and damage in maize fields in northern Ghana. *Crop Prot.* 127: 1–7.
- (NEPAD) New Partnership for Africa’s Development. 2013. *Agriculture in Africa: transformation and outlook*. NEPAD, Lusaka, Zambia.
- Njuguna, E., P. Nethononda, K. Maredia, R. Mbabazi, P. Kachapulula, A. Rowe, and D. Ndolo. 2021. Experiences and perspectives on *Spodoptera frugiperda* (Lepidoptera: Noctuidae) management in Sub-Saharan Africa. *J. Integr. Pest Manag.* 12: 1–9.
- Prasanna, B. M., J. E. Huesing, R. Eddy, and V. P. Peschke. 2018. *Fall Armyworm in Africa: a guide for Integrated Pest Management*. 1st ed. CIMMYT, CDMX, Mexico.
- Rahman, M. S., W. G. Norton, and H. M. Rashid. 2018. Economic impacts of integrated pest management on vegetables production in Bangladesh. *Crop Prot.* 113: 6–14.
- Tambo, A. J., K. R. Day, J. Lamontagne–Godwin, S. Silvestri, K. P. Beseh, B. Oppong–Mensah, A. N. Phiri, and M. Matimelo. 2020a. Tackling fall armyworm (*Spodoptera frugiperda*) outbreak in Africa: an analysis of farmers’ control actions. *Int. J. Pest Manag.* 66: 298–310.
- Tambo, A. J., K. M. Kansiime, I. Mugambi, I. Rwomushana, M. Kenis, K. R. Day, and J. Lamontagne–Godwin. 2020b. Understanding small–holders’ responses to fall armyworm (*Spodoptera frugiperda*) invasion: evidence from five African countries. *Sci. Total Environ.* 740: 1–11.
- Timprasert, S., A. Datta, and S. L. Ranamukhaarachchi. 2014. Factors determining adoption of integrated pest management by vegetable growers in Nakhon Ratchasima Province, Thailand. *Crop Prot.* 62: 32–39.
- Travisi, M. C., and P. Nijkamp. 2008. Valuing environmental and health risk in agriculture: a choice experiment approach to pesticides in Italy. *Ecol. Econ.* 67: 598–607.
- Vivithkeyonvong, S., and D. Jourdain. 2017. Willingness to pay for ecosystem services provided by irrigated agriculture in Northeast Thailand. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* 13: 14–26.
- Yovo, K. 2010. Consentement à payer les biopesticides: une enquête auprès des maraîchers du littoral au sud-Togo. *Tropicicultura*. 28: 101–106.
- Yu, S. J. 1992. Detection and biochemical characterization of insecticide resistance in fall armyworm (Lepidoptera: Noctuidae). *J. Econ. Entomol.* 85: 675–682.