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STAKEHOLDER PERSPECTIVES ON BIOLOGICAL CONTROL OF FALL ARMYWORM IN GHANA

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Abstract
As an invasive and destructive pest in Ghana, fall armyworm (FAW) requires effective management that is both cost-effective and environmentally sustainable. In line with providing a basis for designing such a strategy in Ghana, a questionnaire-based survey was conducted with 186 maize farmers and 50 agriculture-oriented researchers. All respondent farmers were aware of the FAW and had experienced the infestation of the pest on their farms. About 39.5%, 31.4%, and 29.1% of respondent farmers respectively indicated that they had applied a control measure against the pest on weekly, bi-weekly and monthly basis. A high proportion of the farmers (67%) indicated awareness of non-chemical control measures. Among the 69% of farmers who were aware of beneficial insects, 75% of them indicated their willingness to use them for FAW management. Majority of respondent researchers (80%) were aware of and had practical experience (55%) of mass rearing of FAW. More than 80% of respondent researchers agreed that the use of biological control agents for managing FAW in Ghana was feasible. These findings provide evidence to support the design and implementation of integrated pest management (IPM) programmes, strengthen farmer education and extension services, and inform agricultural policies that promote the sustainable adoption of biological control technologies for fall armyworm management in Ghana.

Keywords
adoption, biological control agent, fall armyworm, stakeholder

Introduction

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is a versatile insect pest native to tropical and subtropical regions of the Americas (Bajracharya et al., 2019). In Ghana, it poses a significant threat to crop production. Records from the Ghana Statistical Service (GSS) show substantial damage during the 2016 production season, particularly affecting maize fields in the Bono East and Bono Regions (Cock et al., 2017). The Ministry of Food and Agriculture warned of the potential for a 12% decrease in crop yield when fall armyworm (FAW) infestation, especially during the late whorl stage, is left uncontrolled (Ministry of Food and Agriculture (MoFA), 2016).

In Ghana, despite efforts to promote integrated approaches for the management of the FAW, there is a heavy reliance on synthetic insecticides which impose significant economic challenges for resource-poor farmers and has adverse effects on beneficial insects, human health, and the environment (Adams et al., 2024). Prasanna et al. (2018) advocate a comprehensive IPM strategy, incorporating methods such as host plant resistance, biological control, cultural control, and safe pesticide use to safeguard crops while minimizing adverse effects on humans, livestock, and the environment. Sustainable management of the FAW in the country therefore requires the development and dissemination of economically and ecologically friendly management strategies that are easy for resource-poor farmers to implement.

Although biopesticides and botanicals are potential options, their limited availability and cost constraints hinder wide adoption. In this context, biological control approaches utilizing parasitoids and predators emerge as viable alternatives, particularly for resource-constrained smallholder farmers.

To promote the effective management of the FAW using IPM, an understanding of stakeholder and farmer perspectives and challenges in adopting biological control measures is essential. This is particularly so given that demographic variation among farmer populations can influence decision-making and practices related to the use of biological control agents (Abdulai et al., 2018; Asare-Nuamah, 2022; Bariw et al., 2020; Tambo et al., 2020; Wongnaa and Awunyo-Vitor, 2018). The formulation of support initiatives that reflect the farmers' level of appreciation or conception of biological control can assist in mitigating the costs and risks associated with the adoption (Slangen and Polman, 2008). Thus, gaining insights into farmers' knowledge, and their perceptions of the prospects and challenges of adoption of bio-control measures along with stakeholder perspectives on the basic biology and mass rearing of the FAW are vital for developing resilient and adaptive pest management strategies (Awudzi et al., 2021; Obour et al., 2022; Tambo et al., 2020; Umeh et al., 2022). Although previous studies have examined the biology, management, and control of fall armyworm (FAW), little is known about the knowledge, perceptions, and willingness of maize farmers and agricultural researchers to adopt biological control for FAW management in Ghana. This study addresses this gap by comparing the perspectives of these key stakeholder groups, providing evidence to inform policy, extension services, and the implementation of sustainable integrated pest management (IPM) programmes. Therefore, this study sought to investigate the prospects and challenges for farmer adoption of biological control agents of the fall armyworm, paying particular attention to how stakeholders would respond to mass rearing of the pest in Ghana.

Materials and Methods

Study design

The study consisted of two sets of questionnaire-based interviews, one with farmers and another with research scientists working in the area of pest management.

Maize growing areas in Ghana were grouped into three zones, namely southern, middle, and northern zones. Maize farmers were identified with the support of the District Departments of Agriculture in the selected districts. Participants were recruited based on their availability and willingness to participate in the survey. Consequently, a purposive (voluntary/convenience) sampling approach was employed rather than probability-based random sampling. A total of 186 farmers were interviewed. The sample size was determined by the distribution of maize farmers within the selected study areas and the logistical and financial resources available for the study. The questionnaire was developed based on the objectives of the study and informed by previously published literature on farmers' knowledge, perceptions, and management practices relating to fall armyworm. It was reviewed by researchers with expertise in entomology and agricultural extension to ensure the relevance and clarity of the questions. Although a formal pilot test and statistical assessment of reliability were not conducted due to logistical constraints, the questionnaire was administered by trained interviewers using a standardized approach to minimize inconsistencies (Figure 1).

Sample size and data collection from research scientists

Fifty (50) research scientists from various research institutions and centers in Ghana with specialization in insect pest management were identified and sent questionnaires to fill based on their availability and willingness to partake in the study. The questionnaire was designed with a digital platform provided by Google for online surveys. The questions were a mix of open and closed-ended. Respondents filled out the form online, and their responses were automatically collected and stored electronically. After collecting the data, it was cleaned. Cleaning involved identifying and correcting errors (error of omission), inconsistencies, and inaccuracies in the dataset to ensure its quality and reliability. Data cleaning was performed using the Excel package of Microsoft Office 365.

Data analysis

Statistical analyses were conducted using Minitab version 17 and R version 3.6.1, with descriptive statistics used to summarize stakeholder characteristics and responses, while ANOVA, Tukey's HSD, and Chi-square tests were used to compare groups and assess associations at a 5% significance level (α = 0.05). Prior to inferential analyses, data were checked for normality and homogeneity of variances, and appropriate transformations or alternative methods were applied when statistical assumptions were not met.

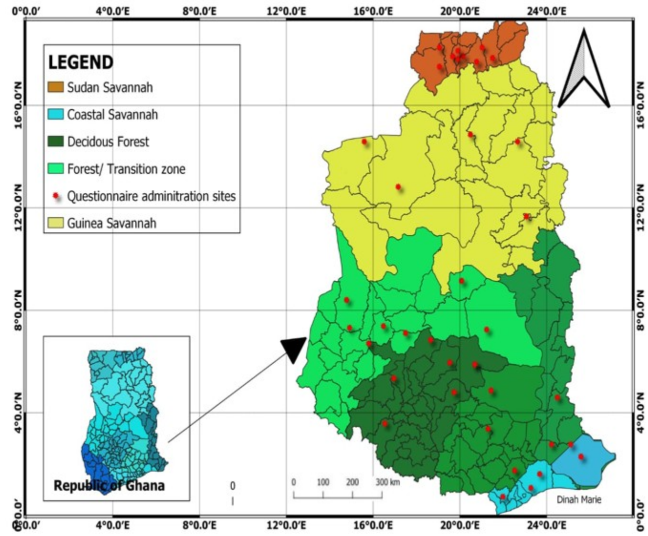

Figure 1. Map of the study area showing the sampling locations

Results and Discussion

Results

Socio–demographic characteristics of the farmer participants

All 186 administered questionnaires were retrieved with responses. The predominant gender of respondent farmers was male, accounting for 74% of respondents. A high proportion (77%) of the interviewed farmers fell within the 31–40 age bracket. About 88% of respondent farmers had received formal education, with 68% having completed pre-tertiary education, i.e., primary, middle, senior high or technical school. Additionally, 42% of respondent farmers possessed a minimum of 11 years of farming experience (Table 1).

The effect of education on the methods by which farmers control FAW on their maize farms

A significant proportion of farmers (59%) with limited (primary school) or no formal education managed the FAW on their maize fields using synthetic insecticides. Meanwhile, some farmers also used a combination of synthetic insecticides and non-synthetic insecticides such as neem extracts, black soap (Alata soap), and pawpaw leaf extracts in combination with practices such as farm sanitation (Table 2).

Effects of gender, age and education on frequency of control

Gender, age of the farmers, and the educational background did not affect the rate at which farmers apply fall armyworm control measures on their maize farms. Most of the farmers

Table 1. Socio-demographic characteristics of respondent farmers

Characteristics	Number (Percentage) of Respondents			
	Southern Sector [N (%)]	Middle Sector [N (%)]	Northern Sector [N (%)]	Overall [N (%)]
Gender				
Female	13 (21.7)	15 (25.0)	20 (30.3)	48 (25.8)
Male	47 (78.3)	45 (75.0)	46 (69.7)	138 (74.2)
Age (Years)				
20 – 30	12 (20.0)	13 (21.7)	10 (15.2)	35 (18.8)
31 – 40	20 (33.3)	25 (41.7)	32 (48.5)	77 (41.4)
41 and above	28 (46.7)	22 (36.7)	24 (36.4)	74 (39.8)
Education				
No education	9 (15.0)	4 (6.7)	11 (16.7)	24 (12.9)
Non formal educ.	3 (5.0)	16 (26.7)	5 (7.6)	24 (12.9)
Primary school	12 (20.0)	14 (23.3)	13 (19.7)	39 (21.0)
Middle school	14 (23.3)	10 (16.7)	9 (13.6)	33 (17.7)
Secondary school	14 (23.3)	9 (15.0)	16 (24.2)	39 (21.0)
Technical	4 (6.7)	4 (6.7)	7 (10.6)	15 (8.1)
Tertiary	4 (6.7)	3 (5.0)	5 (7.6)	12 (6.5)
Experience (Years)				
1 – 5	6 (10.0)	19 (31.7)	22 (33.3)	47 (25.3)
6 – 10	23 (38.3)	13 (21.7)	25 (37.9)	61 (32.8)
11 years and above	31 (51.7)	28 (46.7)	19 (28.8)	78 (41.9)

Note: N = number of responses.

Table 2. The effect of education on farmer's methods of fall armyworm control

Educational background	Method of fall armyworm control							
	Southern Sector		Middle Sector		Northern Sector		Overall	
	CI [N (%)]	Int. [N (%)]	CI [N (%)]	Int. [N (%)]	CI [N (%)]	Int. [N (%)]	CI [N (%)]	Int. [N (%)]
No formal education	9 (23.7)	0 (0.0)	2 (5.6)	2 (8.3)	9 (28.1)	2 (28.1)	20 (18.9)	4 (5.0)
Non formal Educ.	3 (7.9)	0 (0.0)	12 (33.3)	4 (16.7)	4 (12.5)	1 (12.5)	19 (17.9)	5 (6.3)
Primary School	8 (21.1)	4 (18.2)	9 (25.0)	5 (20.8)	6 (18.8)	7 (18.8)	23 (21.7)	16 (20.0)
Middle School	10 (26.3)	4 (18.2)	7 (19.4)	3 (12.5)	5 (15.6)	4 (15.6)	22 (20.8)	11 (13.8)
Secondary School	6 (15.8)	8 (36.4)	4 (11.1)	5 (20.8)	5 (15.6)	11 (15.6)	15 (14.2)	24 (30.0)
Technical School	1 (2.6)	3 (13.6)	1 (2.8)	3 (12.5)	2 (6.3)	5 (6.3)	4 (3.8)	11 (13.7)
Tertiary Education	1 (2.6)	3 (13.6)	1 (2.8)	2 (8.3)	1 (3.1)	4 (3.1)	3 (2.7)	9 (11.2)
Overall	**38 (100)**	**22 (100)**	**36 (100)**	**24 (100)**	**32 (100)**	**34 (100)**	**106 (100)**	**80 (100)**

Note: CI = Chemical Insecticides; Int. = Integrated (combination of synthetic and non-synthetic methods). Numbers in the table represent individuals and those in the brackets represent percentages of the individuals. Southern Sector: $p = 0.02034$ (S); Middle Sector: $p = 0.42$ (NS); Northern Sector: $p = 0.0683$ (NS); Overall: $p = 5.99 \times 10^{-5}$ (S). S = Significant; NS = Non-significant.

applied FAW control measures on a bi-weekly or monthly basis, with majority of them doing weekly controls (Tables 3 to 6).

The impact of education on farmer's awareness of biological control

Majority of the farmers with formal education said they were aware of biological control agents. However, a few of the farmers who had no formal or non-formal education were not aware of the existence of biological control agents (Table 7).

The effect of education on farmer's willingness to use biological agents

Most of the respondent farmers who acknowledged being aware of the existence of biological control agents also expressed willingness to use them if they had the opportunity. However, farmers with no formal education and those with non-formal education said they were not willing to use biological control agents (Table 8).

Farmers' perception about FAW, its effects and management strategies

A vast majority of farmers (99%) reported the presence of insect pests in their maize fields. Among them, only 4% did not observe physical damage to their plants, while the remaining 96% noticed damage to their maize crop. Although some farmers admitted uncertainty about the specific identity of the insects in their fields, a significant majority (85%) confidently identified them as the FAW. Despite the challenges, most respondent farmers sought advice from Extension Officers within their operational areas. While 55% of farmers were familiar with methods other than synthetic insecticides,

Table 3. Effect of gender, age and education on frequency of fall armyworm control – Southern Sector

Category	Frequency of fall armyworm control – Southern Sector				p-value
	Daily [N (%)]	Bi-Weekly [N (%)]	Weekly [N (%)]	Monthly [N (%)]	
Gender					
Female	2 (100.0)	0 (0.0)	5 (29.4)	6 (17.1)	0.0193 (S)
Male	0 (0.0)	6 (100.0)	12 (70.6)	29 (82.9)	
Age (Year)					
20 – 30	0 (0.0)	3 (27.3)	2 (11.8)	7 (20.0)	
31 – 40	0 (0.0)	1 (9.1)	8 (47.1)	11 (31.4)	0.2832 (NS)
41 and above	2 (100.0)	2 (63.6)	7 (41.2)	17 (48.6)	
Educational					
No education	0 (0.0)	2 (33.3)	2 (11.8)	5 (14.3)	
Non formal Edu.	0 (0.0)	0 (0.0)	1 (5.9)	2 (5.7)	
Primary Sch.	1 (50.0)	0 (0.0)	3 (17.6)	8 (22.9)	
Middle Sch.	0 (0.0)	1 (16.7)	3 (17.6)	10 (28.6)	0.3263 (NS)
Secondary Sch.	0 (0.0)	3 (50.0)	3 (17.6)	8 (22.9)	
Technical	1 (50.0)	0 (0.0)	2 (11.8)	1 (2.9)	
Tertiary	0 (0.0)	0 (0.0)	3 (17.6)	1 (2.9)	

Note: S = Significant; NS = Non-significant. N = number of respondents.

Table 4. Effect of gender, age and education on frequency of fall armyworm control – Middle Sector

Category	Frequency of fall armyworm control – Middle Sector				p-value
	Daily [N (%)]	Bi-Weekly [N (%)]	Weekly [N (%)]	Monthly [N (%)]	
Gender					
Female	0 (0.0)	4 (50.0)	8 (29.6)	3 (13.6)	0.1396 (NS)
Male	3 (100.0)	4 (50.0)	19 (70.6)	19 (86.4)	
Age (Year)					
20 – 30	0 (0.0)	1 (12.5)	6 (22.2)	6 (27.3)	
31 – 40	0 (0.0)	3 (37.5)	9 (33.3)	13 (59.1)	0.0638 (NS)
41 and above	3 (100.0)	4 (50.0)	12 (44.5)	3 (13.6)	
Educational					
No education	0 (0.0)	1 (12.5)	1 (3.7)	2 (9.1)	
Non formal Edu.	1 (33.3)	1 (12.5)	6 (22.2)	8 (36.4)	
Primary Sch.	0 (0.0)	3 (37.5)	5 (18.5)	6 (27.3)	
Middle Sch.	0 (0.0)	2 (25.0)	4 (14.8)	4 (18.2)	0.5497 (NS)
Secondary Sch.	1 (33.3)	1 (12.5)	5 (18.5)	2 (9.1)	
Technical	1 (33.3)	0 (0.0)	3 (11.1)	0 (0.0)	
Tertiary	0 (0.0)	0 (0.0)	3 (11.1)	0 (0.0)	

Note: S = Significant; NS = Non-significant. N = number of respondents.

53% had knowledge about beneficial insects. However, a substantial proportion of respondent farmers (62%) were not aware of insects that could be utilized for FAW control. About 45% of the respondent farmers expressed a willingness to discontinue the use of synthetic insecticides if provided with biological control agents, emphasizing their need for training and support in employing such alternatives (Table 9).

Research scientists

Fifty researchers with various academic backgrounds, including individuals with bachelor's (34%), master's (54%) and PhD (12%) degrees were interviewed (Figure 2). The majority (94%) of the respondent researchers confirmed being aware of the FAW (Figure 3). The primary sources of their knowledge about FAW were diverse, with mass media being the most mentioned (40%), followed by research activities being undertaken (26%), training and conferences attended and reports from farmers.

Out of the fifty (50) researchers interviewed, 88% were of the view that biological control agents like sterile insects technique, parasitoids, and predators will be successful in managing the FAW. While 12% said it was not possible (Fig-

Table 5. Effect of gender, age and education on frequency of fall armyworm control – Northern Sector

Category	Frequency of fall armyworm control – Northern Sector				p-value
	Daily [N (%)]	Bi-Weekly [N (%)]	Weekly [N (%)]	Monthly [N (%)]	
Gender					
Female	0 (0.0)	4 (50.0)	8 (29.6)	3 (13.6)	0.2628 (NS)
Male	3 (100.0)	4 (50.0)	19 (70.6)	19 (86.4)	
Age (Year)					
20 – 30	0 (0.0)	1 (33.3)	1 (3.4)	8 (24.2)	
31 – 40	1 (100.0)	1 (33.3)	17 (58.6)	13 (39.4)	0.2783 (NS)
41 and above	0 (0.0)	1 (33.3)	11 (37.9)	12 (36.4)	
Educational					
No education	0 (0.0)	0 (0.0)	5 (17.2)	6 (18.2)	
Non formal Edu.	0 (0.0)	0 (0.0)	1 (3.4)	4 (12.1)	
Primary Sch.	1 (100.0)	2 (66.7)	4 (13.8)	6 (18.2)	
Middle Sch.	0 (0.0)	0 (0.0)	4 (13.8)	5 (15.2)	0.5461 (NS)
Secondary Sch.	0 (0.0)	1 (33.3)	6 (20.7)	9 (27.3)	
Technical	0 (0.0)	0 (0.0)	6 (20.7)	1 (3.0)	
Tertiary	0 (0.0)	0 (0.0)	3 (10.3)	2 (6.1)	

Note: S = Significant; NS = Non-significant. N = number of respondents.

Table 6. Effect of gender, age and education on frequency of fall armyworm control – Overall

Category	Frequency of fall armyworm control – Overall				p-value
	Daily [N (%)]	Bi-Weekly [N (%)]	Weekly [N (%)]	Monthly [N (%)]	
Gender					
Female	0 (0.0)	4 (50.0)	8 (29.6)	3 (13.6)	0.1948 (NS)
Male	3 (100.0)	4 (50.0)	19 (70.6)	19 (86.4)	
Age (Year)					
20 – 30	0 (0.0)	5 (29.4)	9 (12.3)	21 (23.3)	
31 – 40	1 (16.7)	5 (29.4)	34 (46.6)	37 (41.1)	0.1243 (NS)
41 and above	5 (83.3)	7 (41.2)	30 (41.1)	32 (35.6)	
Educational					
No education	0 (0.0)	3 (17.6)	8 (11.0)	13 (14.4)	
Non formal Edu.	1 (16.7)	1 (5.9)	8 (11.0)	14 (15.6)	
Primary Sch.	2 (33.3)	5 (29.4)	12 (16.4)	20 (22.2)	
Middle Sch.	0 (0.0)	3 (17.6)	11 (15.1)	19 (21.1)	0.0553 (NS)
Secondary Sch.	1 (33.3)	5 (29.4)	14 (19.2)	19 (21.1)	
Technical	2 (0.0)	0 (0.0)	11 (15.1)	2 (2.2)	
Tertiary	0 (0.0)	0 (0.0)	9 (12.3)	3 (3.3)	

Note: S = Significant; NS = Non-significant. N = number of respondents.

Table 7. The effect of education on farmer's awareness of biological control agents

Educational background	Southern Sector		Middle Sector		Northern Sector		Overall	
	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]
No formal education	1 (3.8)	8 (23.5)	0 (0.0)	4 (11.4)	0 (0.0)	11 (25.0)	1 (1.4)	23 (20.4)
Non formal Educ.	0 (0.0)	3 (8.8)	2 (8.0)	14 (40.0)	1 (4.5)	4 (9.1)	3 (4.1)	21 (18.6)
Primary School	3 (11.5)	9 (26.5)	5 (20.0)	9 (25.7)	1 (4.5)	12 (27.3)	9 (12.3)	30 (26.5)
Middle School	6 (23.1)	8 (23.5)	6 (24.0)	4 (11.5)	3 (13.6)	6 (13.6)	15 (20.5)	18 (15.9)
Secondary School	9 (34.6)	5 (14.7)	6 (24.0)	3 (8.6)	8 (36.4)	8 (18.2)	23 (31.5)	16 (14.2)
Technical School	3 (11.5)	1 (2.9)	3 (12.0)	1 (2.9)	5 (22.7)	2 (4.5)	11 (15.1)	4 (3.5)
Tertiary Education	4 (15.4)	0 (0.0)	3 (12.0)	0 (0.0)	4 (18.2)	1 (2.3)	11 (15.1)	1 (0.9)

Note: Southern Sector: p = 0.00889 (S); Middle Sector: p = 0.0053 (S); Northern Sector: p = 0.00167 (S); Overall: $p = 1.95 \times 10^{-9}$ (S). S = Significant. N = number of respondents.

ure 4).

Eighty percent of the respondent researchers had knowledge about insect rearing, while the remaining 20% had no knowledge about the topic (Figure 5).

Table 8. The effect of education on farmer's willingness to use biological control agents

Educational background	Southern Sector		Middle Sector		Northern Sector		Overall	
	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]
No formal education	1 (3.8)	8 (23.5)	0 (0.0)	4 (12.9)	0 (0.0)	11 (25.0)	1 (1.3)	23 (20.9)
Non formal Educ.	0 (0.0)	3 (8.8)	2 (6.9)	14 (45.2)	1 (4.5)	4 (9.1)	3 (3.9)	21 (19.1)
Primary School	3 (11.5)	9 (26.5)	9 (31.0)	5 (16.1)	1 (4.5)	12 (27.3)	13 (17.1)	26 (23.6)
Middle School	6 (23.1)	8 (23.5)	6 (20.7)	4 (12.9)	2 (9.1)	7 (15.9)	14 (18.4)	19 (17.3)
Secondary School	9 (34.6)	5 (14.7)	6 (20.7)	3 (9.7)	8 (36.4)	8 (18.2)	23 (30.3)	16 (14.5)
Technical School	3 (11.5)	1 (2.9)	3 (10.3)	1 (3.2)	5 (22.7)	2 (4.5)	11 (14.5)	4 (3.6)
Tertiary Education	4 (15.4)	0 (0.0)	3 (10.3)	0 (0.0)	4 (18.2)	1 (2.3)	11 (14.5)	1 (0.9)

Note: Southern Sector: $p = 0.00889$ (S); Middle Sector: $p = 0.0035$ (S); Northern Sector: $p = 0.00112$ (S); Overall: $p = 1.89 \times 10^{-8}$ (S). S = Significant. N = number of respondents.

Table 9. Farmer responses about fall armyworm, its effects and management strategies

Question	Southern Sector		Middle Sector		Northern Sector		Overall	
	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]	Yes [N (%)]	No [N (%)]
Did you observe any insect pests in your farm?	60 (100.0)	0 (0.0)	60 (100.0)	0 (0.0)	64 (97.0)	2 (3.0)	184 (98.9)	2 (1.1)
Was there any damage to the plants on your farm?	59 (98.3)	1 (1.7)	56 (93.3)	4 (6.7)	62 (93.9)	4 (6.1)	177 (95.2)	9 (4.8)
Could you identify the insects?	59 (98.3)	1 (1.7)	48 (80.0)	12 (20.0)	50 (78.1)	14 (21.9)	157 (85.3)	27 (14.7)
Have you heard about fall armyworm?	59 (98.3)	1 (1.7)	60 (100.0)	0 (0.0)	64 (97.0)	2 (3.0)	183 (98.4)	3 (1.6)
If yes, have you encountered some on your farm?	58 (96.7)	2 (3.3)	59 (98.3)	1 (1.7)	65 (98.5)	1 (1.5)	182 (97.8)	4 (2.2)
Did it affect your maize cultivation in any ways?	59 (98.3)	1 (1.7)	52 (86.7)	8 (13.3)	64 (97.0)	2 (3.0)	175 (94.1)	11 (5.9)
Have you had to change the way you cultivate maize because of the FAW?	51 (85.0)	9 (15.0)	38 (63.3)	22 (36.7)	41 (62.1)	25 (37.9)	130 (69.9)	56 (30.1)
Did you consult anyone for advice on how to manage the pest?	48 (80.0)	12 (20.0)	45 (75.0)	15 (25.0)	56 (84.8)	10 (15.2)	149 (80.1)	37 (19.9)
Apart from the use of chemical insecticides, do you know any other control method?	33 (55.0)	27 (45.0)	20 (33.3)	40 (66.7)	49 (74.2)	17 (25.8)	102 (54.8)	84 (45.2)
Do you know of any beneficial insects in crop production?	36 (60.0)	24 (40.0)	24 (40.0)	36 (60.0)	38 (57.6)	28 (42.4)	98 (52.7)	88 (47.3)
Are you aware of any insects that can help in the management of FAW on maize?	26 (43.3)	34 (56.7)	23 (38.3)	37 (61.7)	22 (33.3)	44 (66.7)	70 (37.6)	116 (62.4)
If some of these insects are brought to your farm, will you be willing to stop spraying chemical insecticides?	26 (43.3)	34 (56.7)	36 (60.0)	24 (40.0)	21 (31.8)	45 (68.2)	83 (44.6)	103 (55.4)
Do you think you will require any training or support to use insects to manage FAW on your farm?	54 (90.0)	6 (10.0)	45 (75.0)	15 (25.0)	41 (62.1)	25 (37.9)	140 (75.3)	46 (24.7)

Note: FAW = Fall armyworm. N = number of respondents.

Out of the 80% of the researchers that had knowledge about mass rearing of insects, only 45% revealed that they had practical experience in the subject. The remaining 55% said they had no practical experience in insect rearing (Figure 6).

The total number of researchers interviewed were fifty (50). Almost all the researchers interviewed 94% were aware of the existence of fall armyworm. The rest 6% knew nothing about it Figure 7A. The academic background of these researchers were first Degree 34%, Masters Degree 54% and PhD holders were 12% Figure 7B

Majority of the researchers interviewed 40% heard about FAW from the media, other researchers 26% also said their source of information about the FAW was through their research the 20% said it was through training and conference and the rest of them 14% said farmers often reported to them Figure 8A. 76% of the researchers said they know at least one effective

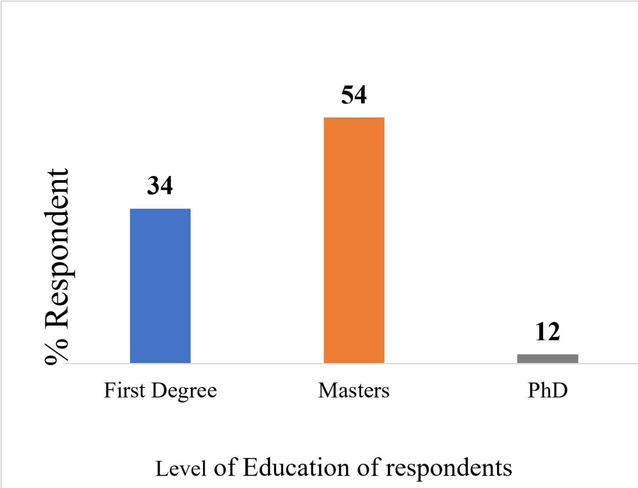

Figure 2. Educational status of the Researchers

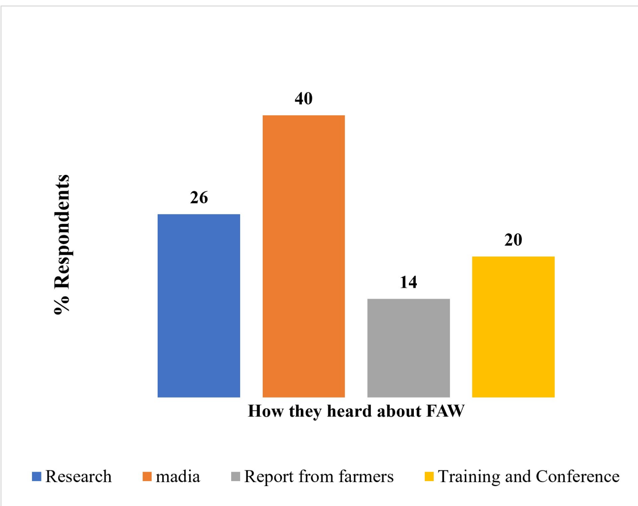

Figure 3. Sources of FAW knowledge by researchers

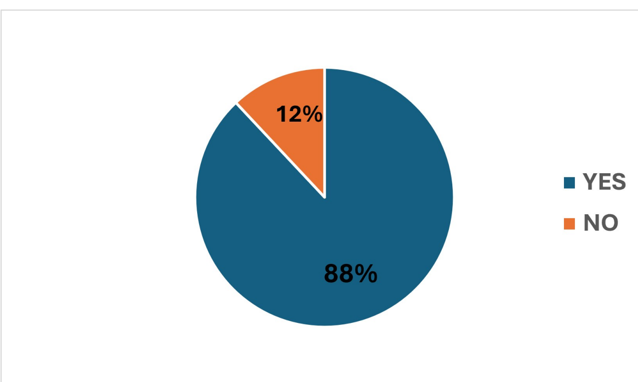

Figure 4. Researchers' views on the feasibility of biological control for FAW management

way of managing the FAW the rest 24% said they do not know anything about FAW management Figure 8B.
Out of the fifty (50) researchers interviewed, 88% were of the view that SIT will be successful in managing the FAW. Whiles 12% says it is not possible Figure 9A. 80% of the researchers have knowledge about mass rearing of insect the remaining

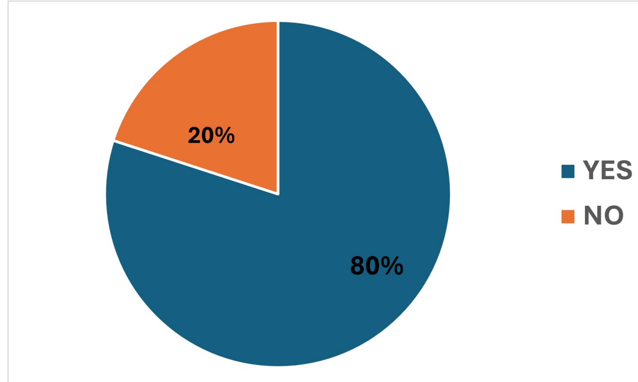

Figure 5. Researchers' knowledge about insect rearing

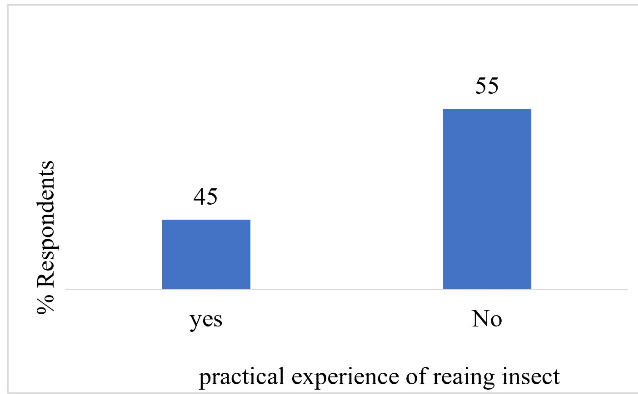

Figure 6. Practical experience in insect rearing among researchers

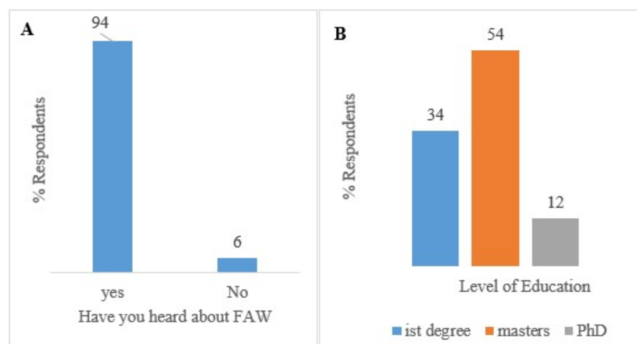

Figure 7. A: Researchers who have or have not heard about FAW. B: Educational level of the Researchers

20% said they have no knowledge about mass rearing of insects Figure 9B 55% of the researchers said that they have practical experience in mass rearing of insect the remaining 45% said they have no practical experience in mass rearing of insect Figure 10

Discussion

In this study, a greater proportion of interviewed maize farmers were male. This observation is consistent with previous studies conducted by Bosompem and Mensah (2012), Anang et al. (2013) and Boateng et al. (2014). The high prevalence of male farmers can be attributed to the traditional role of men as providers within the cultural context of Ghana. Addi-

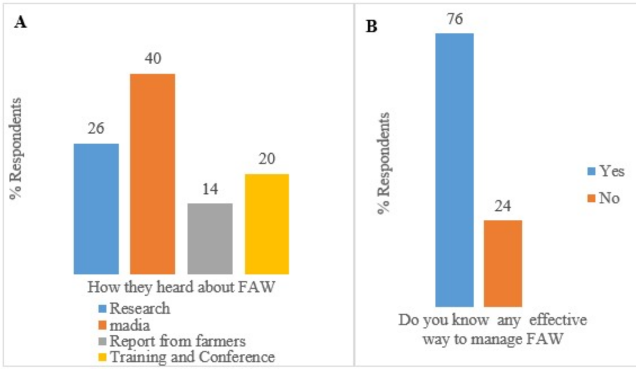

Figure 8. A: Researchers source of information about FAW. B: whether or not if researchers know any management of FAW

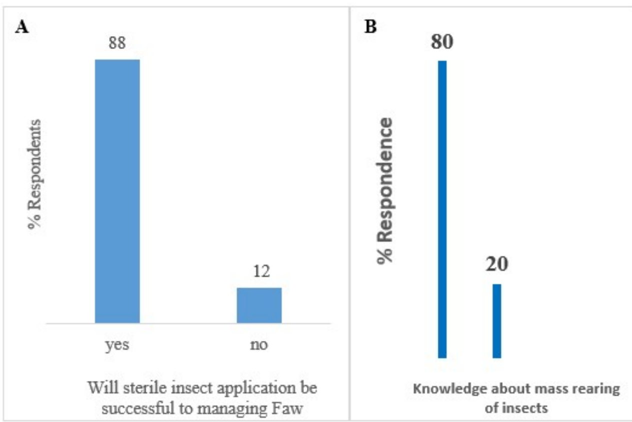

Figure 9. A: Researchers view about management of FAW using SIT. B: Ascertain researchers' knowledge about mass rearing of FAW

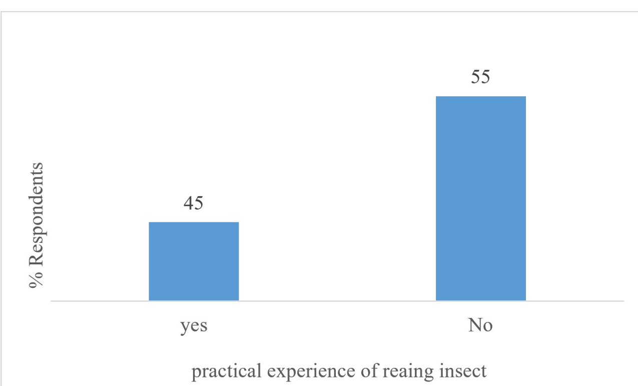

Figure 10. Whether Researchers have practical experience in mass rearing of insects

tionally, the labour-intensive nature of maize farming, which may be less appealing to most females, could contribute to this pattern. The age distribution indicated a higher percentage of youth, a positive sign for sustaining maize production. Similar findings were reported by Sarfo et al. (2023) in the Ejura-Sekyedumase municipality. About 88% of farmers had formal education, consistent with the studies conducted by Wongnaa et al. (2019), Koffi et al. (2020), and Sarfo et al. (2023). Formal education might provide improved access to information on pesticides and a better understanding of biocontrol agents. In the Southern sector, education influenced farmers' methods for FAW control, with educated farmers integrating multiple methods, while those without formal education relied solely on synthetic insecticides. This contrasts with the findings reported from the Adansi North District of the Ashanti region of Ghana where farmers lacking formal education showed a lower tendency to use pesticides (Asare-Nuamah, 2022).

Gender, age, and education did not significantly affect the frequency at which respondent farmers applied control measures against the FAW. Various control practices were implemented daily, weekly, bi-weekly, or monthly based on the methods used by farmers. Surprisingly, no farmers reported using biological control agents. Additionally, the majority of respondent farmers were unaware of the existence of biological control agents. This observation is in contrast with the findings reported by Sharifzadeh et al. (2017) in Kenya. The relatively low awareness and adoption of biological control technologies observed among maize farmers in Ghana contrasts with findings from countries such as Kenya, where biological control programmes have received sustained investment and institutional support. In Kenya, collaborations among research institutions, government agencies, international organizations, and extension services have facilitated the development, commercialization, and dissemination of biological control technologies, resulting in greater farmer awareness and adoption. In addition, frequent farmer training, field demonstrations, and stronger extension services have increased farmers' confidence in the effectiveness of biological control agents. In Ghana, however, biological control technologies for fall armyworm are still emerging, and farmer exposure remains relatively limited due to lower awareness, limited commercial availability of biological control products, fewer demonstration programmes, and constrained extension support. These differences in institutional capacity, extension systems, commercialization pathways, and farmer engagement are likely to explain the contrasting findings between Ghana and Kenya reported in the literature. This suggests that strengthening extension services, expanding farmer education programmes, and improving access to biological control products will be essential for increasing adoption among Ghanaian maize farmers. This lack of awareness of biological control agents could mean that farmers adopt and extensively use pest management strategies that negatively affect biocontrol agents. This is evident in the higher proportion of farmers relying solely on synthetic insecticides and the low willingness to adopt biological control. This calls for efforts to create awareness on biological control agents, several of which have been reported across Ghana (Abbas et al., 2022; Agboyi et al., 2020, 2023; Koffi et al., 2020). Education positively correlated with awareness, suggesting that higher educational levels increase familiarity and willingness to use biological control agents. This supports the assertion by Constantine et al. (2020) which states that, increased levels of education correlate with greater familiarity with and readiness to utilize biological control agents. Most respondents successfully identified the fall armyworm as the insect pest infesting their maize fields, a critical skill for early detection and targeted control. This ability empowers farmers to make informed decisions and contributes to sustainable insect pest management practices.

Awareness of the fall armyworm among researchers was high, emphasizing the importance of research in deepening understanding of pest behavior, biology, and ecology for developing effective and environmentally sustainable pest control strategies, including biological control methods, cultural practices, and resistant crop varieties.

Respondent researchers primarily received information about the fall armyworm through the media, underscoring the primary role of the media in disseminating information. Given this, the effective use of the media can contribute to the widespread adoption of sustainable FAW management strategies. Close collaboration between the media and scientists who hold the conviction that biological control agents are the best bet for the management of the FAW can be leveraged to educate and involve farmers as well as agricultural extension officers in disseminating and promoting sustainable and profitable FAW management practices.

Insect rearing plays a crucial role in various fields, including scientific research, pest management, environmental conservation, education, and commercial activities, contributing to sustainable agriculture and fostering a greater understanding of biodiversity and ecosystem dynamics. Despite this, most researchers interviewed in this study lacked practical experience in this area. This deficiency may be a drawback to the elucidation of the biology, ecology, and management of the fall armyworm.

Conclusion

While there was no maize farmer in the country employing biological control agents for the control of FAW at the time of the study, a significant number of them expressed awareness of such agents and declared their willingness to adopt them when the opportunity arises. Similarly, nearly all the researchers interviewed acknowledged their awareness of biological control agents. They were also optimistic about the high likelihood of success associated with the utilization of bio-control agents. Results of this study indicate that education is a key determinant of the methods farmers use to manage insect pests on their maize farms. The key implication of this study is the need to bridge the gap between the availability of effective biological control agents and farmers' access to and confidence in using them. Strengthening extension services to provide practical training and link farmers with researchers and reliable sources of quality biological control agents, alongside investment in local mass production and quality assurance, could accelerate adoption and reduce reliance on synthetic insecticides.

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