FARMERS KNOWLEDGE ON FALL ARMYWORM (SPODOPTERA FRUGIPERDA) PESTICIDE APPLICATION AND ITS RELATIONSHIP WITH QUANTITY OF MAIZE THAT IS LOST TO FALL ARMYWORM

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Abstract: *Fall armyworm (Spodoptera frugiperda) has spread rapidly and posed numerous threats to the food security and livelihood of millions of smallholder farmers in Ghana. This study quantifies the damages of fall armyworm infestation in maize production and identifies the various methods used in controlling fall armyworm infestation. Almost all farmers (94%) experienced fall armyworm infestation on their farms. They cited key common visual damages as yellowish leaves, stunted growth, poor yield quality, holes in leaves, and egg masses on leaves. Farmer's loss an average of GH¢2616.07 to fall armyworm infestation. Pesticide application is the frequent control measure mostly used by farmers. Farmers do not mostly use biological methods for the control of the fall armyworm. The use of pesticide as a control method is however not effective as about GH¢ 3 000 per 1 acre is lost with the use of insecticides. It is recommended that the use of other control measures like the contemporary measures involving the use of birds and chickens as predators of eggs and worms of fall armyworm should be encouraged.*

Keywords: *pest control, fall armyworm, maize pest, pesticide application*
(JEL code: Q16)

INTRODUCTION

Maize is a staple food (Shiferaw, 2011) in Ghana. Most Ghanaian foods like banku, akpele, kenkey, and porridge are made from maize. There is however a threat to maize production caused by the Fall armyworm (FAW). Maize loss in Africa is estimated at $150 000 as of 2017 (Toepfer et al., 2019). Maize is among the crops fall armyworm infects most (Igyuve et al., 2018; Kammo et al., 2019). The proportion of maize loss to fall armyworm (Spodoptera frugiperda) is between 21-53%. The percentage loss allocated to fall armyworm infestation in Ghana however is unknown (Igyuve et al., 2018). Also, the quantitative and monetary loss to the farmer is not known.

Farmers are not able to identify that their farms are infected with the fall armyworm until the period when the worm has taken over the entire farm. A female worm can lay 2000 eggs in one period. The practices that cause an infestation of fall armyworm is not known as they travel mostly by wind dispersal (Wightman, 2018). Fall armyworm is a viral pest and very hard to control with normal practice. With the fall armyworm (FAW) invasion worldwide, looking at their destructive work on maize fields, has left farmers with fewer options to combat this crop pest. Pesticides application remains prominent among control options against FAW. However, due to lack or less education on the part of smallholder farmers, who are major cultivators of maize, the understanding of the nitty-gritties of pesticide use, i.e. reading of labels (Sharma et al., 2015) and decoding the precautions information on adverse impacts of pesticides (Lekei et al., 2014) prevail leading to wrong decisions.

Farmers' inner drive and individual differences influence how the application is done (Pan et al., 2020), applying excessively both recommended and banned ones, although fully aware of pesticide risks that they pose. The majority of small-

holders, trusting their farmers' network (Pan et al., 2020), pass on erroneous experience and information among themselves (Rios-Gonzalez et al., 2013), and also rely on village suppliers to procure pesticides, access information on dosage (C. Zhang et al., 2015), though suppliers' advice on the safe and proper application of pesticides are deficient (Fan et al., 2015).

Upadhyay et al., (2020) remark that during FAW pest invasion, smallholder farmers normally do not take time to check the effect pest have had on the crops (i.e. the economic threshold level, ETL) before deciding measures and they tend to adopt environmentally unfriendly practices. In trying to avert the problem, most farmers seek advice from other local farmers, extension officers or agrochemical dealers. Most farmers lack knowledge about FAW pest and maize plant morphology (Bariw et al., 2020), production requirements (Nie et al., 2018) and the relationship between pesticides and agricultural products (L. Zhang, Li, et al., 2018). Therefore, in farmers' quest to see quick results, heavy doses of sometimes restricted-use chemicals are frequently applied (Jepson et al., 2020), without ascertaining the morphology of the pest, specific pesticide that is used for control, and the right time to spray (Bariw et al., 2020). A common trend is that some farmers think that any handy chemical could be used on just any pest without a thorough check of its efficacy, pertinence and how it will enhance yield.

Even though there is increased use of pesticides on maize fields against FAW, losses experienced have been huge (Quansah, 2020), largely due to the misapplication of pesticides. This is due to poor execution of pesticide application by farmers in less developed countries (Schreinemachers et al., 2017). Averagely an estimated 90% of farmers acquire agricultural skills, in this case, pesticide application, through their exploits or as learned from parents (Pan et al., 2020), leading to poor efficacy. The following question were answered through this study

Which control method is effective?
What are the steps taken by farmers in the application of pesticides?
What is farmer's knowledge on the application of chemical pesticides in relation to fall armyworm infestation?
What is the relation between how spraying is done and the quantity of maize that is lost by farmers to fall armyworm?

This research is essential because most farmers about 60% do not have a suitable solution to combat the deadly infestation (Bonsu, 2017). The research would help to know the most frequent way farmers take to combat FAW. This research is going to provide farmers and the general public with the right knowledge concerning FAW and how proper pesticides use positively affect the control of FAW pest. The study would examine how farmers use the right steps in applying pesticides when their farms are infested with FAW to ensure that maize that reaches the final consumer is of the best safety. The farmers would know the best way and timings to apply chemical pesticides during infestation to enhance yield and profitability. The work would bring out the best way spraying should be done on farms to cut maize lost to FAW to improve the country's GDP. The research would be relevant to academia due to limited studies on causes of fall armyworm infestation on maize production.

MATERIALS AND METHODS

The survey was conducted in Ejura-Sekyeredumasi Municipality, in the Ashanti Region and the Sunyani and Nkoranza district in the Bono region. The Ejura-Sekyeredumasi Municipality, Sunyani and Nkoranza district were randomly chosen among the many maize producing municipalities or areas due to its favourable environment and because most farmers are in maize production.

A total of 110 respondents were selected. About fifty (50) respondents was carefully selected from maize farmers in the Sunyani district and Nkoranza district all in the Bono region respectively. A simple random sampling technique was utilized in picking 60 farmers from the four communities in the the Ejura-Sekyeredumasi municipality.

Anyinaso, Sekyeredumase and Drobu were randomly selected from the maize producing areas in the Ejura-Sekyeredumasi municipality. New Dormaa, Old Abbisim, Nkrankrom, Kofikrom and Kyiribogya were randomly selected from the communities in the Sunyani and Nkoranza district. A list of farmers were garnered from the extension department of the municipality's Ministry of Food and Agriculture (MoFA) office in sampling maize farm households. The number of farmers picked from each community depended upon the number of maize farm households in each given area

The selection criteria were that each participant had to be at least 18 years and cultivate maize in addition to other crops. Local dialect (Akan) was used in the data collection because illiterate participants were included.

The research relied on primary data for the work. Respondents were interviewed during data collection and gave answers to a list of questions about the study. The interview was done with a structured questionnaire. A questionnaire was administrated as the data collection tool. Data was collected on the socioeconomic characteristics of farmers, the quantity of maize lost to fall armyworm infestation on the maize field, the agronomic practices observed in the field, and the method of controlling fall armyworm infestation. Descriptive statistics were utilized in assessing spray actions of farmers and was analyzed using the Microsoft Excel . The choice of pesticides, knowledge on the morphology of maize plant and fall armyworm (FAW) pest, knowledge on pesticide use, how spraying is done, the number of times spray was applied was computed in percentages.

Respondents were asked if their field was infected with fall armyworm. Farmers were asked the total amount in kg of maize lost to fall armyworm infestation. This amount was converted in Ghana cedis to know the monetary value of maize lost to fall armyworm infestation on the farm. Question on the experience of fall armyworm and agronomic practices were measured as a dummy variable. Where 1= Yes to a practice and 0= No to a practice. Also, the different methods of controlling fall armyworms were mentioned of which farmers chose the most frequent method they used in controlling fall armyworm on their various farms.

Frequency, mean, and correlation were the method of data analysis. Correlation analysis using STATA was performed on the various variables to see their relationship.

Questions focused on the steps farmers took before pesticide application against fall armyworm (FAW) was done. Respondents were asked about prophylactic measures they took against FAW infestation, how they monitored and scouted for pest presence, the reason why they chose to spray, the type of pesticide used as per the literature reviewed.

We sought to ascertain the knowledge of farmers in pesticide application regarding fall armyworm (FAW) infestation as reviewed in the literature. The 5-point Likert scale was used in ascertaining farmers knowledge. The scores (totally agree = 1 point, agree = 2 points, neutral = 3 points, disagree = 4 points and totally disagree = 5 points) were applied. The respondent scores were presented as mean ± standard deviation (SD) with $p < 0.05$ level of significance.

Farmers were asked when and how they apply pesticides with regards to calibration and spraying on maize plants against fall armyworm. The field outcomes of the application were inquired of to find out how effective each farmers' case was, and then compared with maize loss. The results were correlated to determine the direction and degree of relationship between the educational level and their application methods, and then their application methods and maize loss.

RESULT AND DISCUSSIONS

Demographic characteristics of respondents

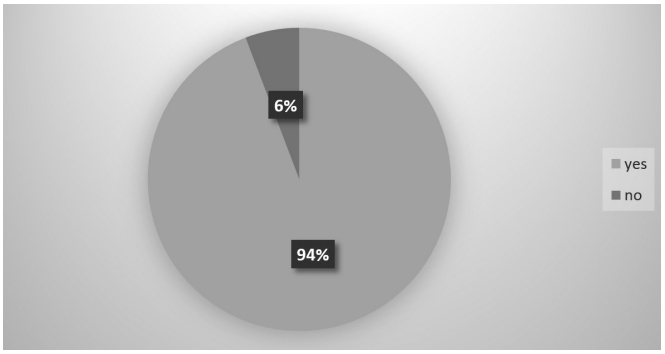
Analysis of demographic characteristics of the respondents indicate that more than two-thirds (67%) of respondents are males (Table I). This might be because males have more access to funds and resources for farming as compared to their female counterparts (Tijani and Umoh, 2020). More than half (59%) of the respondents are youth between the ages 31 and 50 years (Table I). This shows that there is more vigor as the youth are encouraged to go into agriculture. More than four-fifth (88%) of the respondents are married (Table I). This might explain the support maize farmers get in the cultivation of the crop from their spouses. About one quarter (22%) of farmers have no formal education (Table I).

Table I: Demographic Characteristics of Respondents

Variables	Measurement	Frequency	Percentage (%)
Sex	Male	74	67%
	Female	36	33%
		110	100%
		18	16%
Age	15-30	65	59%
	31-50	19	17%
	51-65	8	8%
	66-80	110	100%
Marital Status	Single	13	12%
	Married	97	88%
		110	100%
Household	1-5	56	50%
	6-10	44	38%
	11-15	7	10%
	Above 15	3	2%
		110	100%
Level of Education	Primary	26	26%
	J.H.S	28	40%
	S.H.S	9	4%
	Tertiary	21	8%
	No Formal Education	26	22%
		110	100%

About 96% of farm households experience fall armyworm (Spodoptera frugiperda) infestation (Figure I). They cited key common visual damages as yellowish leaves, stunted growth, poor yield quality, holes in leaves, and egg masses on leaves.

Figure I: Infestation by fall armyworm



Fall armyworm infestation is high during the dry season resulting in huge income loss to farmers. Farmer's loss an average of ¢2616.07 (Ghana Cedis) for 1 acre of land to fall armyworm infestation. It appears that fall armyworm infests farms whether they weed their farms frequently or not (Table II).

Table II: Relationship between KG of maize lost to fall armyworm and the various agronomic practices

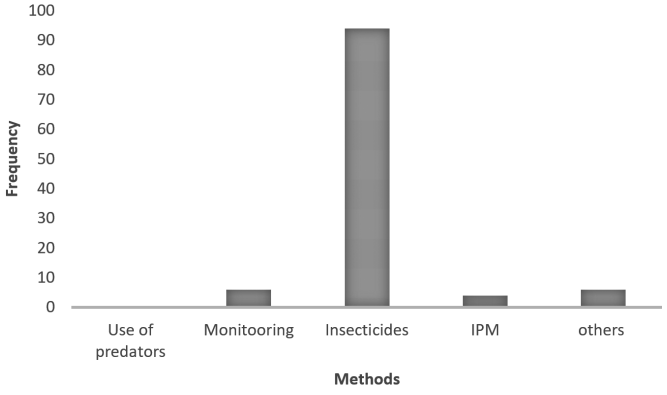
	Kg lost	Weeding	Intercropping	Harvest
Kg lost	1.0000			
Weeding	0.1108	1.0000		
Sig	0.4389			
Intercropping	0.1235	-0.1243	1.0000	
Sig	0.3877	0.3849		
Harvest	0.0450	-0.1878	0.3328*	1.0000
Sig	0.7539	0.1868	0.0170	

All other agronomic practices have not relationship with kg of maize lost to fall armyworm infestation on a farm. Acevedo-Siaca and Goldsmith (2019) mentioned that crop rotation with maize and soybean can lead to the transmission of fall armyworm from one plant to the other. It is perceived that intercropping maize with other crops reduces the infestation of fall armyworm. The results however show that intercropping does not affect the infestation of fall armyworm.

Methods used for combating the infestation of fall armyworm

The most frequent method used by farmers to combat the infestation of fall armyworm is pesticides (Figure II). This finding agrees with that of All et al. (1986) that insecticide is the most frequent method used for combating the infestation of fall armyworm.

Figure II: Frequency of the various methods used by farmers to combat fall armyworm infestation



This finding however shows that farmers do not conform with contemporary measures as stated by Wightman (2018) or the use of natural enemies (Tendeng et al., 2019). The use of natural enemies involves the use of other parasites (nematode Hexamermis sp. and two Hymenopterans Chelonus sp. and Campoletis sp.) which are enemies to fall armyworm. The insecticide is preferred to the use of contemporary measures since birds cannot see some hiding sites of fall armyworm on the farm (Tendeng et al., 2019).

Contemporary measures involve the use of birds and chickens as predators of eggs and worms of fall armyworm. This method discourages the use of pesticides and pesticides on farms. It appears that farmer's use of pesticides is quite moderate as compared to not taking any measures as proposed by Kammo et al. (2019).

Pesticides are a combination of biopesticides and chemical pesticides. It appears that the use of biopesticides or chemical pesticides has little effect on the damage of fall armyworm. This is in agreement with Kammo et al. (2019) and Tendeng et al. (2019) that the relation between the use of pesticides and fall armyworm infestation was insignificant. The use of pesticides to control fall armyworm is however better than when no measures are applied to the field. All et al. (1986) however noted that pesticides with methomyl and chlorpyri can reduce fall armyworm infestation. Fenvalerate and permethrin chemicals were not effective in controlling fall armyworm (All et al., 1986).

From Figure III, the use of chemicals led to the highest loss of maize (3 000 Ghana cedis for 1acre). The use of diverse methods like monitoring and the use of integrated pest management led to the reduction of maize loss in Ghana cedis.

A correlation test showed a weak correlation (p=0.2227) between the use of pesticides and the quantity of maize lost to fall armyworm infestation (Appendix). This finding agrees with Wightman (2018) assumption that pesticides are not a good way of controlling the fall armyworm. This finding agrees with that of Goergen et al. (2016) that pesticides are mostly used by farmers to control fall armyworm infestation but it is often ineffective. The frequent misuse of pesticides has led to resistance to insects.

Steps taken by farmers in the application of pesticides against fall armyworm.

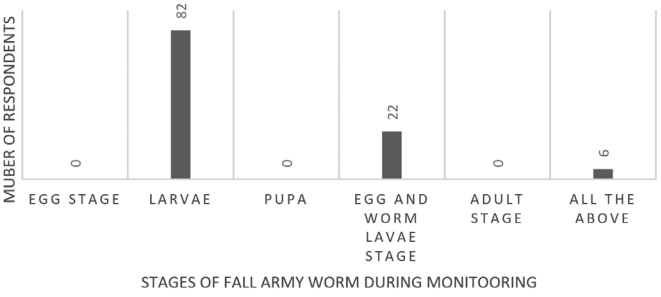
More than three-fourth (84%) of the respondents revealed that they visit and monitor their farms against fall army worm infestation on a weekly basis (Table III). A week is so long for effective monitoring of fall army worm since they spread very fast. There was not one pheromone traps in the Municipality, with some farmers totally oblivious of it.

Table III: Frequency of monitoring of farm against fall army worm infestation

How frequently farmers monitor maize crops	Percentage
Every day	16%
Every week	84%
Totals	100%

Farmers know there is fall army worm infestation when there are holes in leaves. Most farmers (82 out of 110) notice fall army worm infestation when the armyworm is at the larvae stage (Figure III). This might be because farmers do not monitor crops on daily basis (Table III).

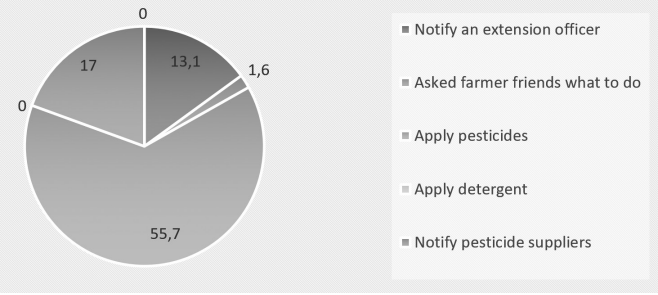
Figure III: Stage at which fall army worm is seen by farmers



Very surprisingly, some farmers reported they have never sighted eggs masses of the fall armyworm. Leave damages was mostly reported by farmers, proceeded by ear damages.

Even though farmers weed regularly to prevent infestation of fall army worm on their farm, the opposite is seen. Farmers thus averagely apply pesticides when there is fall army worm infestation on their farms (Figure IV). This confirms why all farmers use pesticides (Figure I).

Figure IV: Step taken when farm is infested with fall army worm



Farmers apply pesticides 1-3 days after seeing signs of fall army worm infestation. One would think that farmers would notify experience farmers, pesticide suppliers and extension officers before he applies pesticides. It might be that since farmers averagely have about 20 years of experience (Table I) on maize production, they know the pesticides to be used for fall army worm infestation on their farms. Farmers mentioned that pesticides received from extension officers was not effective.

Farmers' knowledge on the application of chemical pesticides in relation to fall armyworm infestation.

Using the 5-point Likert scale farmers knowledge and attitudes were determined. The scores (totally agree = 1 point, agree = 2 points, neutral = 3 points, disagree = 4 points and totally disagree = 5 points) were applied and presented as mean. The survey revealed that a large number of the respondents in the survey were not abreast with information on pesticide application on fall armyworm (Table IV).

Table IV: Farmer's knowledge and attitudes on negatives questions

Questions	Totally agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Totally disagree (5)	Mean
You can mix different chemicals for spraying at the same time	30%	15%	1.7%	18.3%	35%	3.13
Detergent is more effective than pesticides	0%	5%	8.3%	50%	36.7%	4.18
Pesticides given by extension officers is not effective	21.7%	18.3%	16.7%	23.3%	20%	3.02
All leaf damages are caused by fall armyworm?	63.3%	11.7%	3.3%	18.3%	3.3%	1.87
Spraying can be done just anytime	36.7%	48.3%	8.3%	0	6.7%	4
Spraying can be done when maize is above chest level	15%	13.3%	1.7%	26.7%	43.3.%	3.7
My nozzle is faulty	11.7%	8.3%	16.7%	30%	33.3%	3.65

The average of the mean numbers is 3.36 (Table IV). Farmers response on questions posed from the negative angle shows that they were neither in between doing the wrong things or the right ones, which is dangerous. Farmers that participated in the survey agreed that all leaf damages are caused by fall armyworm, which is not always the case (Table V). Though some used detergent, they emphasized that detergent is not more effective than pesticides. Comments from respondents also show that different chemicals are mix in the same tank, and DDT a banned chemical was used. Respondents' reasons for mixing different chemicals were that they give better efficacy than using only a single chemical.

Table V: Farmer's knowledge and attitudes on positives questions

Questions	Totally agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Totally disagree (5)	Mean
Best treatment should be administered 30 days after seedlings emerge	46.7%	40%	6.7%	5%	1.7%	1.75
Insecticide treatment prevent leaf damages	46.7%	46.7%	10%	0	0	1.67
Spraying can be done multiple times	36.7%	48.3%	8.3%	0	6.7%	1.91
Frequent spraying increase yield	18.3%	38.3%	25%	18.3%	0	2.43
Labels on pesticides provides the correct dosage to use for fall army worm infestation	31.7%	23.3%	6.7%	21.7%	16.7%	2.68
Fall army worm has a white head	16.7%	13.3%	43.3%	20.0%	6.7%	2.87
I wear PPE when applying pesticides	30.0%	11.7%	8.3%	20%	30.0%	3.08
Nozzle type and size used is recommended on labels of pesticides	16.7%	31.7%	41.7%	8.3%	1.7%	2.46
I have a drift shield fixed to my knapsack sprayer	11.7%	10.0%	25.0%	26.7%	26.7	3.06
My hose is very close to the plant when I am spray	35.0%	25.0%	10.0%	26.7%	3.3%	2.38
I don't spray when the atmosphere is windy	26.7%	25.0%	3.3%	20.0%	25.0%	2.91

Averagely, farmers response to questions posed from the positive angle indicated that, farmers were doing the right things. Farmers agreed fairly that insecticide treatment prevent leaf damages. With regards to PPE, farmers agreed that putting on PPE is a good practice but most did not use it because they complained of the tropical weather. Some also do not have the PPE at all (Table V). When more than 100kg of maize is lost to fall amry worm, spraying of field is frequent (Table VI).

Table VI: Relationship between how spraying is done and the quantity of maize that is lost by farmers to fall armyworm.

		kg of maize was lost per acre 1=25-50 kg 2=50-100 kg 3=More than 100 kg		Total
		2	3	
Number of times the field were sprayed 1=1 2=2 3=3 4=More than	1	0	4	4
	2	1	32	33
	3	3	30	33
	4	0	40	40
Total		4	106	110

As more kg of maize is loss more spraying is done. This implies that farmers spend money on insecticides when fall army worm has already infested the farm. Farmers thus prefer to spend money on eliminating fall army worm infestation than spend money on preventive measures to aviod the infestation of fall army worm on maize fields.

CONCLUSION

We analyzed and assessed the damages and effects of control on Fall armyworm (Spodoptera frugiperda) infestation in maize production using recent survey data from maize growing households. Results show that pesticides are adopted by farmers for the control of fall armyworm. There is however loss of income with the use of pesticides.

It is recommended that the use of pesticides in controlling fall armyworm infestation should be reduced. The chemical composition of biopesticides should be researched to know their chemical composition. Further studies should look at other methods of controlling fall armyworm infestation in maize farms.

- Farmers monitor their farms weekly so are not able to detect fall armyworm infestation on time
- Farmers averagely have knowledge and a positive attitude on the application of pesticides on fall armyworm infested farms
- Farmers spray their farms more than twice as kg of maise loss increases

RECOMMENDATION

- Farmers should monitor their farms every day to detect fall army worm infestation early
- Farmers should frequently call the services of experts like the extension officers to help detect fall armyworm infestation early

STATEMENTS AND DECLARATIONS

The authors did not receive support from any organization for the submitted work. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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