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Prevalence, effects and management of fall army worm in the Nkoranza South Municipality, Bono East region of Ghana

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Abstract: Fall Army Worm (FAW) emerged in Ghana in 2017 as a major threat to maize production in the country. Considering that maize is the staple crop of the country, any major shock in its prodcution can have negative consequences on the food security of the entire country. Therefore, this study analysed the prevalence of FAW, control strategies and its effect on output in a highly infested area, the Nkoranza South Municipality of Bono East region. A total of 200 farmers who cultivated maize in the 2018 production season were selected using multistage sampling procedure. The data was analysed using descriptive statistics and Kendall's coefficient of concordance. From the result, FAW prevalence is as high as 79.5%. A total of 96.3% of farmers who experienced FAW had at least half of their farms infested. There is a significant output gap among infested farms and non-infested farms of about 17%. The strategies adopted to control FAW were chemicals (pesticides), neem extract, detergents, hand picking and burning of affected farm areas. The study concluded that among the control strategies, burning affected farm areas leads to higher output. However, to achieve a higher output, a combination of neem extracts with the burning of affected farm areas is recommended.

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Dr William Adzawla holds a PhD in Economics from University of Cheikh Anta Diop, Senegal and a Master of Philosophy (MPhil) degree in Agricultural Economics from University for Development Studies, Ghana. He doubles as an Agricultural and Climate Change Economist. Dr. Adzawla have in-depth knowledge in policy analysis and socioeconomic research. Currently, he is the Economist at IFDC-FERARI, Ghana. He has published over 25 journal articles especially in the areas of climate change and adaptation, gender, poverty, livelihoods and crop production. His research goal is to identify how inequality in all forms can be addressed and ensure all-inclusive development. Dr Adzawla have high expertise in data analysis.

PUBLIC INTEREST STATEMENT

Improving crop production is important in ensuring food security of every Ghanaian. However, a number of challenges including pests and diseases has limited this goal. One major pest with high devastating effect is fall armyworm. This pest has become a major threat to maize production in Ghana during the 2017 cropping season. It is one pest that can lead to zero output. As such, research on fall armyworm is crucial. In this current research, the authors unravel the prevalence, impacts and management strategies of fall armyworm in one of the high risk areas to the pest. The understanding from this study is that fall armyworm is highly prevalent in the area and pose as a major threat to maize production. The management strategies adopted by the farmers, including burning of affected farmland areas and use of neem extracts, had shown positive outcomes. We therefore advocate for the use of combined fall armyworm mitigation strategies.

Research into the cost benefit of each control strategy and their combination is also recommended for future scholars.

Subjects: Development Studies; Sustainable Development; Rural Development

Keywords: control strategies; fall army worm; output; prevalence

1. Introduction

The role of agriculture in Ghana's development dates back to pre-independence. Its roles include employment creation, inputs for industries, contribution to household incomes and Gross Domestic Product (GDP), foreign earning from export that is essential for the country's trade balance, and most fundamentally, ensuring the food security of the country. The first food crop relevant for Ghana's food security is maize. Nearly, almost every farming household in Ghana produces maize.

Agriculture, for that matter maize production in Ghana is largely by smallholder farmers. These small-scale producers account for a substantial volume (over 70%) of maize production in the country especially in the Brong Ahafo, Ashanti, Eastern, Northern, Upper East, and Upper West regions of the country (Amanor, 2009; Ministry of Food and Agriculture [MoFA], 2017). However, there are productivity/yield gaps in maize and other crops cultivated in the country. For instance, in 2016, the average maize yield obtained was 1.99 Mt/ha as against a potential yield of 5.5 Mt/ha, giving as high as about 64% shortfall in yield (MoFA, 2017). . Meanwhile, general maize productivity in the country has remained comparatively constant both in terms of area harvested and volume; despite the use of new technologies. For instance, the average production between 2011 and 2013 was 1,799.47 Mt while output recorded in 2014–2016 was 1,727.48 Mt (MoFA, 2017). The importance of maize is not only limited to Ghana as it is described as the "queen of cereals" globally (Shah et al., 2016, p. 2), especially due to its yield and nutritional composition. For Huma et al. (2019), maize is the "oldest and powerful" crop known for its fodder, food and medicinal benefits across the globe.

In addition to human consumption in both developed and developing countries, maize is used for animal feed and industrial raw material (Macauley & Ramadjita, 2015). Maize serves as feed for livestock either in seed or fodder forms in most developed countries and about 80% of maize is consumed as food in developing countries. The per capita consumption of maize in Ghana is 45 kg/year, as such the most consumed food crop in the country. In terms of nutrition, evidence provided in Shah et al. (2016) shows that per a 100 g of edible portion of maize, there is 71.88 g of carbohydrate, 8.84 g of protein, 4.57 g of fat, 2.33 g of ash, 10.23 g of moisture and milligrams of other essential nutrients. These demonstrates the relevance of maize in ensuring food and nutritional security of Ghana.

Although there has been a general increase in maize productivity in recent years primarily due to increase in area of land put under cultivation, increase access to improved seeds, fertilizers and improved technology through enhanced extension service, the increase in production are still below potential yield (MoFA, 2017). This shortfall can be attributed to a number of factors and require the efforts of all stakeholders in order to significantly reduce the gap (MoFA, 2017) and address food security challenges in West Africa (Scheiterle & Birner, 2018). Amidst the production shortfalls, Ghana has over the years introduced a number of policies in the agricultural sector towards improvement in the sector. For instance, Agricultural Sector Rehabilitation Programme and Medium-Term Agricultural Development Programme (MTADP) in 1980s–90s, Food and Agriculture Sector Development Policy (FASDEP) in 2002, Subsidised Fertiliser Policy (SFP) in 2008, Block farm programme in 2009, National Food Buffer Stock Company (NAFCO) in 2010, and the more recent Planting for Food and Jobs (PFJ) program in 2017. Despite these, it still remained a fact that agricultural yield of most staple crops remain lower than expected. This raised important question on what needs to be done in complement or differently. Unfortunately for Ghana, there was Fall Armyworm (FAW) outbreak in 2017.

According to MoFA (2017), about 14,247 ha of cultivated land was destroyed by the fall armyworm outbreak which could possibly account for the wide gap between the potential maize yield and the actual yield for 2017. FAW is a Lepidopteran that feeds on the leaf of grasses such as maize. While the feeding stage (larvae) of the worm can take up to 21 days to develop into pupae, the pupae is able to produce up to 1,500 eggs that develop into larvae. Barros et al. (2010) also revealed that while the larvae causes crop damage, the adult FAW can fly to far distance to spread the worm. The migratory characteristic imply that the virus is not isolated to a particular geographical location. Therefore, within a short period, FAW can substantially multiply with significant destructive impacts. FAW is a major threat to maize production in Ghana considering the insatiable feeding mechanism of the worm (Banson et al., 2019) and unique capability to cause extensive harm across numerous crops (Pasanna et al., 2018). As indicated by the distribution commissioned by the Department for International Development, signs demonstrate that if there are no control strategies, the emergence of FAW in Africa can possibly cause maize yield to decline in a range from 8.3 to 20.6 million tons per annum in only 12 maize growing nations (Day et al., 2017). Baudron et al. (2019) estimated that the impact of FAW on maize yield is between 32 and 48% in Eastern Zimbabwe. A perception data for Ghana shows that there is a potential loss in maize output between 22 and 67%, an average loss of 45%, with an estimated economic loss of about 138–419 million dollars (Day et al., 2017).

FAW has the potential to directly lead to capital costs, through the rise in labour demand and the kind of skills needed to manage the pest. In addition to direct output losses, FAW decreases the capacity of agricultural lands to counter other shocks such as climate/environmental shocks. Financially, FAW increases the cost of production due to costs of managing the pest, cost of technology and its application, and its implications on household income; further deteriorating the poverty levels of the resource poor smallholder farmers. The impacts can also be a destruction of households' social and physical resource and assets (Ibrahim, 2018).

In 2018, over 20,000 hectares of farms were destroyed by FAW in Ghana, leading to a loss of over 64 USDmillion (Fugar, 2019). Initial reactions to the pest in Ghana highlight potentials for negative human and environmental health consequences due to chemical usage (Day et al., 2017). As a pest, farmers have to adopt some control measures. Day et al. (2017) established that the preferred control measure for FAW is joint pest control methods, which involves a mixture of preventive measures. This is grounded on the view that continuous applications of chemical pesticides have serious health implications on the resource poor farmers who have no ability to purchase the appropriate protective clothing to use during chemical application, environmental consequence such as killing of beneficial insects like bee and also natural enemies of the armyworm, and the pest developing resistance to the pesticides. Among the botanicals tested for FAW control, *Azadirata indica, Schinnus molle* and *Phytolacca dodecandra* resulted in the greatest proportion of larval destruction of over 95% after application (Silva et al., 2015). Baudron et al. (2019) also indicated that the impacts of FAW can be reduced through zero tillage and frequent weeding of the farm.

In Ghana, one of the most FAW affected areas is the Nkoranza South district. This has significant negative effects on the farming households of the district. As a new pest to Ghana's agriculture therefore, identifying effective control measures have become a major concern to the stakeholders especially MoFA. A number of control methods have since been used by farmers in their quest to control FAW on their farms. However, concerns remain unresolved following the emergence of FAW, concerns that warrant empirical research to unravel the complexities of the FAW menace and provide effective policy recommendations to MoFA and other stakeholders. Along this line, this study sought to analyse the prevalence of FAW, its effects on maize production, the control measures adopted by farmers and the challenges in controlling FAW in the Nkoranza South Municipality.

2. Methodology

2.1. Study area

The study was conducted in Nkoranza South Municipality in the Bono East region of Ghana. It is located within longitudes 1°10′′W and 1°55′′W and latitudes 7°20′′N and 7°55′′N. The total land area of the Municipality is 923 square kilometres and lies within the transitional zone or wet semi-equatorial region, with a mean annual rainfall between 800 and 1200 mm and average temperature of 26°C (Ghana Statistical Service [GSS], 2014). Agriculture employs 66.6% of the economically active population of the Municipality. The major crops cultivated include maize, yam, rice, groundnut and vegetables (GSS, 2014). An assessment made by Fugar (2019) shows that Nkoranza South Municipality and Nkoranza North Municipality are very high-risk areas to FAW (Figure 1).

2.2. Sampling procedure and data collection

The study used a multistage sampling procedure in selecting the farmers for the study. In the first stage, Nkoranza South municipality was purposively selected due to high maize production and its high risk to FAW. In the second stage, a simple random sampling was used to select five communities engaged in maize production. The communities selected include Bonsu, Akumsa—Dumanse, Ayerede, Bonte and Koforidua. This involved the lottery method.

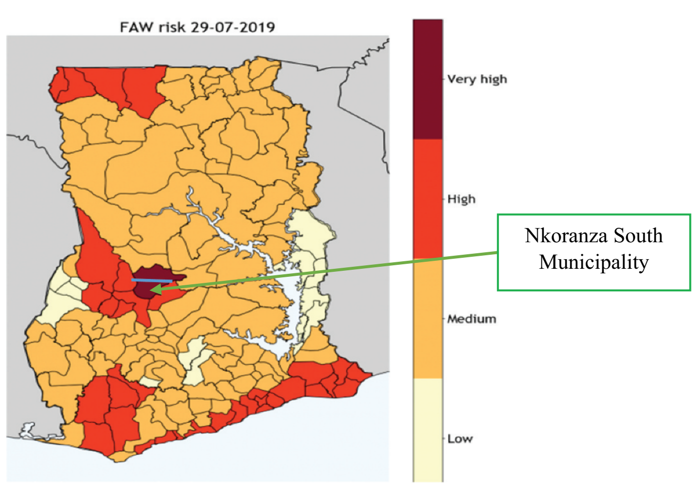
Finally, simple random was used to select 40 maize farmers from each selected community, giving a total sample size of 200.

The data was collected using questionnaire that was administered using face-to-face interviews. The data was collected in 2018 but on 2017 production information. The data collected was on a wide range of indicators including the socio-economic, inputs and output of maize, and information on FAW.

2.3. Data analysis

The data was analysed using descriptive statistic and Kendall's coefficient of concordance. The mean values and percentage of the responses were computed and discussed. The Kendall's coefficient of concordance was used to analyse the challenges confronting the use of chemicals in the control of FAW. This is a nonparametric statistical approach employed to estimate the strength as well as direction of relationship that exist between two or more variables. The variables are ranked from the most important to the least important using an ordinal scale (Hajkowicz, 2007). It is the standardisation of the statistic of the Friedman test and can be used to evaluate

Figure 1.
Map of Ghana and tudy area showing the rate of FAW infestation. Source: Adapted from Fugar (2019).



agreements among variables. Kendall's W ranges from 0 (no agreement) to 1 (complete agreement) from:

$$W = \frac{12S}{p^2(n^3 - n) - pT}$$

where n is the number of objects, p the number of judges, T is a correction factor for tied ranks and S is the sum of squares statistic over the row sums of ranks. The key rational for employing this approach is to establish the summation of the ranks assigned to each ranked parameter that is the constraints confronted by farmers and then evaluate the variability of this sum. The variability among these sums will be at maximum, provided the rankings are in perfect agreement. The challenges are ordered from outmost important to the least important using numerals 1, 2, 3, 4, 5, 6 and 7. Thus, coefficient of concordance (W), which estimates the level of concordance was calculated using the aggregate rank score. The estimated W in this study ensured that the challenges limiting the control of FAW are identified and prioritize. Thus, policy makers are able to determine which challenges to address immediately in order to reduce the impact of FAW on most of the farmers.

3. Results and discussion

3.1. Descriptive statistics

The descriptive statistics of the respondents is shown in Table 1. The result shows that the mean age of the farmers is 41.5 years, while the youngest and oldest farmers were 21 and 82 years, respectively. An observation from the data shows that the majority of the farmers have ages within 40–50 years. These imply that the farmers are in their mid-active working period and may be working assiduously to maintain a decent future. As such, the farmers may put much investment in terms of capital and human efforts in maize production. The average household size among the sampled farmers is 6.5. Thus, there are about six to seven persons in the household of almost all the selected farmers. While some farmers reside alone in their household, others have as high as 16 members. Although some of the farmers had no formal education, others had up to university degrees. On the average however, a farmer in the district had completed primary education. There is a high experience in maize cultivation by the farmers as the average farmer had been into maize production for almost 19 years and the most experienced farmer had cultivated maize for 60 years. Nonetheless, there are some few farmers who had cultivated maize for the first time. The high experience in maize cultivation can be a potential asset in the maize industry as such experience farmers are not only able to increase production or productivity

Table 1. Descriptive statistics of respondents

Variable	Mean[a]	Std. Dev.	Min	Max
Age	41.5	12.4	21	82
Household size	6.5	2.9	1	16
Years of education	6.3	3.3	0	15
Years in maize farming	18.8	11.2	1	60
Maize farm size	5.2	3.8	1	30
Maize output	24.9	21.3	3	160
Fertilizer usage	14.0	8.6	2	60
Family labour usage	0.20[a]	0.4	0	1
Hired labour	0.11[a]	0.31	0	1
Access to extension	0.2[a]	0.4	0	1
Sex of farmer	0.8[a]	0.4	0	1

[a]Indicates proportion of ones against zeros in dummy variables

but also, they are able to easily detect anomalies such as new pests in maize production. The majority (80%) of the respondents are males while 20% are females. Considering the importance of extension service in crop production especially in responding to a devastating pest infestation such as FAW, it is surprising that only 20% of the farmers had access to extension services in the district.

The use of both family labour and hired labour is very low among the farmers. While 20% of the farmers had used family labour, only 11% had used hired labour. The implication is that majority of the farmers engage in most of their farm activities without external labour. Again, this is due to the production of maize for subsistence purposes; as a result, the farmers may not be willing to incur much labour cost in their productions. On the average, a farmer had cultivated 5.2 acres of maize with a minimum and maximum acreage of 1 and 30, respectively. The use of fertilizer is high among the farmers since the average farmer had used 14 bags (50 kg per bag), 2.7 bags/acre, of fertilizer for maize production. The data established that the average farmer had 24.9 bags (100 kg per bag), from their farms. Juxtaposing this with the average farm size, it can be concluded that the average farmer had obtained 4.79 bags (479 kg) of maize from an acre farm. Scheiterle and Birner (2018) estimated that high experience in farming and use of herbicides increases the probability of a farmer having yield above average (1.5 MT/ha).

3.2. FAW infestation and level of infestation

Table 2 shows the level of FAW infestation among the sampled farmers. This shows that 79.5% of the selected farmers had experienced FAW on their farms in the 2018 production season. This suggests that about four in every five sampled farmers have had FAW infestation in the production season. Although this is high, it is not surprising because the worm have very high reproductive rate and thus able to infest more farms within a short period. The national record shows that over 20,000 hectares of farms were destroyed by FAW in Ghana in 2018 (Fugar, 2019). Outside Ghana, De Groote et al. (2020) found that about 83% of farmers in Kenya have had their farms been infected with FAW in the 2018 production season. The findings in this study is contrary to that of Tambo et al. (2019) where they estimated that only a little over one-third of the farmers in Ghana and Zambia had experienced FAW.

In addition to the number of farmers whose farms were infested with FAW, Table 3 shows the extent to which FAW had affected the farms. This revealed that more than half (54.7%) of the farmers had all their farms affected by FAW while an additional 41.5% of the farmers had half of their farms affected by FAW. The remaining 3.7% of the farmers had less than one-third of their farms affected by FAW in the 2018 production season. This distribution showed that the extent of FAW infestation in the area is very high, an observation that was also made by Fugar (2019). Assefa and Ayalew (2019) explained that FAW is a major threat to maize production because of its

Table 2. FAW infestation and level of infestation

Response	Frequency	Percentage
Infestation		
Farm not infested	41	20.5
Farm infested	159	79.5
Total	200	100.0
Extent of infestation		
1/2 of farmland	66	41.5
1/4 of farmland	5	3.1
1/8 of farmland	1	0.6
Entire farmland	87	54.7
Total	159	100.0

Table 3. Seed type and FAW infestation

FAW infestation	Improved seed		Own seed		Total	
	Freq.	%	Freq.	%	Freq.	%
Farm not infested	3	7.3	38	92.7	41	100.0
Farm infested	0	0.0	159	100.0	159	100.0
Total	3	1.5	197	98.5	200	100.0

rapid breeding and migration capabilities. It is important to note that the infection discussed in this study does not account for the specific area of the plant that is infested. This is important to state because Day et al. (2017) indicated that while FAW infestation of only maize leaves does not lead to total yield loss, there is a complete loss if the growing point of the plant is attacked by the worm. Therefore, it is possible that some of the farms that have recorded complete infestation in this study may record some crop output during the season. In a related studies, Tanyi et al. (2020) also found that FAW infestation level on maize farms ranged between 13 and 93% while Sharon et al. (2020) found that there is high incidence and severity of FAW on maize yields of Uganda.

3.3. Seed type and FAW infestation

Table 3 shows the distribution of the farmers based on FAW infestation and the types of seed that was cultivated by the farmers. This shows that all the farmers who cultivated their fields using improved seeds had experienced no FAW infestation while among farmers who had used their own seeds, 92.7% of them had their farms infested with FAW. This is generally to suggest that although the use of improved seeds is low among the farmers, the use of improved seeds leads to zero FAW infestation. This justify the need for the cultivation of improved maize seeds in the Municipality.

3.4. FAW infestation and maize output

Figure 2 is an analysis of the difference in mean output between farmers who had their farms infested with FAW and those whose farms were not infested. The result shows that while the farmers whose farms were infected had an average output of 23.85 bags (100 kg per bag), those whose farms were not infested had an average output of 28.8 bags (100 kg per bag). This means that there is 17.2% output gap between the infested farms and non-infested farms. A test of mean differences shows that there is a statistically significant difference in the mean output values between the two groups of farmers. In most cases, FAW infestation can lead to a zero farm output if it is not contained at the early stages of development. In a related study, De Groote et al. (2020) estimated that there is an output loss of 32% due to FAW infestation.

3.5. FAW mitigation strategies adopted by farmers

The mitigation strategies adopted by the farmers who experienced FAW infestation is shown in Table 4. This shows that all the 159 farmers whose farms were infested with FAW had used chemicals (pesticides) as a mitigation strategy to FAW. The use of pesticides is generally a recommended strategy by the Ministry of Food and Agriculture (MoFA) in the control of FAW among maize farms. It is therefore not surprising that all the farmers had adopted it. Contrary to this study, Tambo et al. (2019) and Kansiime et al. (2019) respectively had estimated that only about 49% and 60% of farmers in their studies had used pesticides in the control of FAW. Assefa and Ayalew (2019) expressed that although the control of FAW is achievable through the use of chemicals, there are challenges to cost, environmental contamination and the possibility of the resurgence of the worm. Assefa and Ayalew (2019) further stressed that the timing in the application of chemicals is crucial to achieve the objective of controlling FAW. According to the Plant Protection and Regulation Service Directorate of MoFA, the chemical brands that are suitable for controlling FAW in Ghana includes Eradicot T, Ema Star 112EC, Control 5WDG, Ataka Super EC, Bypel 1, Agoo, Pyrinex Quick 256EC, Viper 46EC, Adepa, Super top, Thunder 145 OD O-TEQ, K-Optimal EC, Galil 300SC and Chemaprid. However, FAO (2018) cautioned against the use of hazardous chemicals such as Methomyl, Cyfluthrin, Methyl parathion and Endosulfan in the management and control of FAW as this

Table 4. FAW mitigation strategies adopted by farmers

Strategy	Yes		No	
Pesticides	159	100.0	0	0.0
Neem tree	13	8.2	146	91.8
Detergent (e.g. Omo)	96	60.4	63	39.6
Hand picking	21	13.2	138	86.8
Burning affected farm portion	6	3.8	153	96.2

was observed in many African countries. The choice of pesticides for FAW control in a given country should be those that are most effective, lowest-risk, economical, accessible and easily used by smallholders (without sophisticated machinery) (FAO, 2018).

The second most used control strategy involved the application of detergents. The use of detergent in FAW control is done by mixing the detergent with water and applying on the surface of the plants. According to the farmers, this reduces the reproductive rate of the FAW, therefore, able to control it effectively. Contrary, Tambo et al. (2019) estimated that only 0.8% of their Ghanaian sample had used detergents as a control strategy to FAW while 3.51% of farmers from Zambia had used detergents to control FAW. The use of neem tree extracts, hand picking and burning of the affected farm areas is low among the farmers.

3.6 Output comparison based on FAW control strategy

Table 5 shows a comparison of the mean output of farmers who adopted each of the identified FAW control strategies and those who did not adopt any of these strategies. Overall, the result shows that farmers who have adopted any of the control strategies had higher output than those who did not adopt any of the strategies. For instance, while farmers who regularly handpicked the worms and destroy them had 27.05 bags (100 kg per bag) of maize output, those who did not hand-picked had only 23.39 bags; a difference of 3.66 bags. Similarly, there is a difference of 5.78 bags between farmers who used neem extracts for controlling FAW and those who did not use the extract. The highest output difference (13.15 bags) was obtained under burning of affected farm portions while the lowest difference was obtained under the use of detergents (0.62 bags). The *T*-test shows that there is no significant difference in the output levels between the users and non-users of the various control strategies except burning of affected farm portions. The results also show that while farmers who are able to identify farm areas that are affected by the FAW early enough and had burned or destroyed such portions of the farms had 36.5 bags (100 kg per bag) of maize compared to 23.35 bags of those who did not. This is because, burning the affected farm areas increase the probability of reducing the reproduction and spread of the FAW to the entire farm area. Therefore, such farmers are able to control the pest and obtain high yields on the remaining farm lands. Generally, Tambo et al. (2019) estimated that the adoption of a FAW management strategy leads to an increase in maize output and own maize consumption.

3.7. Combination of FAW control strategies and mean output

Farmers have adopted a combination of FAW control strategies discussed from Table 5. The adoption of more than one strategy was aimed at achieving higher results in terms of the control or management of the FAW and thus to obtain expected yields or output. Therefore, Table 6 provide the frequency of farmers who used a particular combination of strategies and the mean output of these farmers. These figures are compared with the sample mean output of 23.85 bags from the farmers whose farms were infested by the FAW. The result shows that pesticides and detergents were used by 60.4% of the farmers. This is the only set of combination for the control strategies that was adopted by over 50%. While 12.6% of the farmers have used pesticides along with hand picking of the worm, 8.2% used pesticides alongside the use of neem extracts. The

Table 5. Output comparison based on FAW control strategy

Strategy	Group	Obs.	Mean output	Std. Err.	Std. Dev.	T-value
Pesticides	Users	159	23.85	19.875	1.576	NA
Neem extract	Non-users	146	23.38	1.67	20.13	1.00
	Users	13	29.15	4.57	16.47	
Detergent	Non-users	63	23.48	3.05	24.20	0.19
	Users	96	24.09	1.69	16.57	
Hand picking	Non-users	139	23.39	1.61	18.93	0.77
	Users	20	27.05	5.78	25.87	
Burning affected farm parts	Non-users	153	23.35	1.60	19.78	1.60*
	Users	6	36.50	7.99	19.57	

*Indicates significance at 10%.

Table 6. Combination of FAW control strategies and mean output

Strategy combination	Frequency	Percentage of 159	Mean output
Pesticides*Neem extract	13	8.2	29.15
Pesticides*Detergents	96	60.4	24.09
Pesticides*Hand picking	20	12.6	27.05
Pesticides*Burning	6	3.8	36.50
Neem extract*Detergents	6	3.8	26.50
Neem extract*Hand picking	2	1.3	18.00
Neem extract*Burning	2	1.3	42.00
Detergents*Hand picking	14	8.8	31.79
Detergents*Burning	3	1.9	32.67
Hand picking*Burning	2	1.3	25.50
Pesticides*Neem extract*Detergents	6	3.8	26.50
Pesticides*Neem extract*Hand picking	2	1.3	18.00
Pesticides*Neem extract*Burning	2	1.3	42.00
Pesticides*Detergent* Hand picking	14	8.8	31.79
Pesticides*Hand picking*Burning	2	1.3	25.50

The mean output from the sample of farmers whose farms were infested was 23.85 bags.

farmers adopted only five triple combinations of the strategies. Among these, the combined use of pesticides, detergents and hand picking recorded an adoption level of 8.8% while the others recorded less than 5% adoption combination levels.

In terms of the impact on output, the result established that all the combinations except neem extract together with hand picking, and pesticides together with neem extract and hand picking recorded mean output levels higher than the 23.85 bags estimated from the sample. The highest output was realised for farmers who used neem extract together with burning of infested farm areas. These farmers recorded a mean output of 42 bags. Lima et al. (2010) observed from an experiment that without weed control, neem extracts and deltamethrin sprays provided highest outcomes. As explained by Lima et al. (2010), the use of tree extracts for pest control is not new but exist prior to the introduction of synthetic insecticides.

The second highest mean output was recorded for the use of pesticides together with burning of infested farm areas. Although the use of pesticides with detergents was high among the farmers, the mean output is relatively lower compared to most of the less-adopted combined strategies. Recalling from Figure 2, it can be concluded that the use of a combination of some strategies leads to higher outputs than even farms that recorded no FAW infestation. For instance, the use of pesticides together with neem extract produced an output of 0.30 bags over the output of farms that were not infested. In their study, Sharon et al. (2020) also concluded that research to integrate indigenous knowledge of pest control, biological control and plant breeding options is needed to ensure effective FAW management.

3.8. Constraints to the use of chemicals in the control of FAW

The choice of a farmer to undertake any appropriate FAW control strategy has been limited by some constraints. These constraints to chemical control were identified and the respondents asked to rank them in terms of the severity of the challenge. A Kendall's coefficient of concordance was estimated to estimate the level of agreement in the rankings. The result as shown in Table 7 revealed that the estimated Kendall's coefficient (W) is 0.972. Thus, there is a 97.2% agreement in the ranking of the challenges by the individual farmers. The estimated Chi-square is statistically significant, thus, the order of ranking of the challenges significantly represent the actual order of severity of these challenges.

The ranking of the constraints involved assigning '1′ to most severe challenge and '7′ to less severe challenge. Meaning, the lower the mean value, the severe the challenge and the higher the mean value, the lower the severity of the challenge. Most pressing constraint ranked among the respondents was high cost of pesticides since it has the least mean rank value of 1.00. This high cost for the pesticide was ascribed to the growing demand for the pesticides. The second most pressing constraint ranked among the respondents was inadequate availability of pesticides, which had a mean rank value of 2.06. This agreement was based on the fact that, the chemicals were not available at the farming communities but mostly at the district capital which affects the access to the chemicals on time. The third constraint ranked among the respondent was insufficient money to purchase the chemical which had the mean value of 2.94. As smallholder farmers, one of the major challenge for maize production is the lack of fund for investment in farm activities. This lack

Figure 2. FAW infestation and maize output.

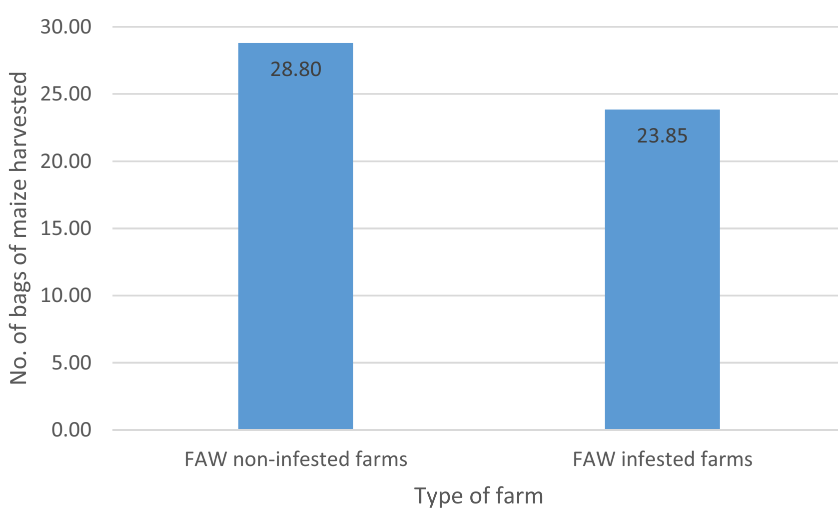


Table 7. Constraints to the use of chemicals in the control of FAW

Constraints	Mean	Rank
High cost of pesticides	1.00	1st
Inadequate availability of chemicals	2.06	2nd
Insuficient money to purchase the chemicals	2.94	3rd
Knowledge as to how to use chemicals	4.34	4th
Detection of early signs of outbreak	4.66	5th
Knowledge as to what infestation threshold to apply chemicals	6.14	6th
Knowledge as to the growth stage of maize	6.86	7th
W(6) = 0.972		
Chi-squared = 1130.91***		

Source: Field survey (2019).

of fund makes it difficult for the farmers to respond to emergencies or shocks such as FAW. Observably, the first-three major challenges involve accessibility and availability. This means that in order to increase the use of chemicals in addressing FAW, price incentives and decentralization of chemical stores for the FAW pesticides must be instituted.

The other four challenges involve lack of knowledge in chemicals, morphology of maize and FAW. While the fourth ranked challenge is the knowledge on how to use the chemicals for controlling FAW, the fifth is the low ability of the farmers to detect the FAW at its early stage. The low knowledge in the morphology of maize limits the ability of the farmers to effectively use chemicals. This is because these farmers may fail to do the right things at the right time due to their low knowledge.

4. Conclusion and recommendations

In addition to the numerous challenges such as climate change, FAW have become a major threat to maize production in countries such as Ghana. Socioeconomic research in understanding the impacts of FAW and its control strategies have become an emerging field of study. In this study, the prevalence of FAW, control strategies and its effect on output were examined in one of the most FAW infested areas of the country, the Nkoranza South Municipality were unfolded using 200 farmers.

This study concluded that there is a high prevalence of FAW in the district. There is also a significant output gap between infested farms and non-infested farms of about 17%. These are expected to trigger action from established institutions such as MoFA in ensuring that they are able to provide more effective mitigation strategies in the future. Chemicals were used by every farmer whose farm was affected by the FAW. The other strategies used by farmers were neem extract, detergents, hand picking and burning of affected farm areas. Despite the 100% use of chemicals, its use is not without challenges. The major challenge that affected farmers' use of chemicals in controlling FAW was the high cost of the chemicals. This is understandable considering that these farmers are smallholders whose capital investment in the farms are low. The study also concludes that among sole mitigation strategies, burning affected farm areas gives the highest impact on output. Nonetheless, a combination of some of the strategies produced a better result in terms of output enhancement than simply relying on a single strategy. For instance, combining neem extracts with burning of infested farm areas leads to significantly high output than the use of only single strategy. Therefore, farmers are encouraged to adopt more than one strategy, especially the use of burning and neem extracts in controlling FAW. In addition to the study of the impact of control strategies on output, there is the need to do a benefit cost analysis to determine the economic feasibility of each FAW strategy.

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