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The U.S. Government's Global Hunger & Food Security Initiative

FALL ARMYWORM (FAW) MANAGEMENT REPORT

EVALUATING LEAST TOXIC AND COST-EFFECTIVE APPROACHES TO FAW MANAGEMENT

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GHANA ADVANCE II PROJECT

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Contents

ACRONYM LIST

ADVANCE	Agricultural Development and Value Chain Enhancement
AEA	Agricultural Extension Agents
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FAW	Fall Armyworm
FAMEWS	Fall Armyworm Monitoring and Early Warning System
MoFA	Ministry of Food and Agriculture
PERSUAP	Pesticide Evaluation Report and Safe Use Action Plan
PPRSD	Plant Protection and Regulatory Service Department
USAID	United States Agency for International Development

Project Background

ADVANCE II USAID is the primary mechanism for value chain support under Ghana's Feed the Future strategy, with the objective of developing sustainable, private sector driven agricultural transformation that will increase rural household income.

In mid-February of 2016, the fall armyworm (*Spodoptera frugiperda)* invaded Ghana. It appeared that the Fall armyworm (FAW) might wipe out much of the gains in maize productivity associated with ADVANCE programs. To mitigate the impact of FAW, ADVANCE initiated a nationwide program focused on training agricultural professionals on FAW biology and integrated FAW management using monitoring and scouting. In 2017, ADVANCE pilot tested a FAW early warning system and initiated a public awareness campaign.

In 2018, the Ministry of Food and Agriculture (MOFA) Plant Protection and Regulatory Service Department (PPRSD) formed a national FAW Taskforce. ADVANCE/USAID is a member of the taskforce. The FAW Taskforce has initiated a nationwide, community based FAW monitoring system. ADVANCE is working to integrate and harmonize FAW control efforts.

The Ghanaian agricultural community is shifting focus with regards to FAW. In 2017, the primary focus was on tracking the spread of FAW, promoting awareness of the new pest in the farming communities, and providing an early warning of FAW arrival. Today, most scientists recognize that FAW is established in Africa and cannot be eradicated. The focus now turns toward evaluating least toxic, cost effective approaches to FAW management.

Monitoring Systems

There are two types of FAW monitoring systems being tested in Africa. The Desert Locust Control Organization "community based" monitoring system for the African armyworm (*Spodoptera exempta*) is now being applied to the FAW across the continent. It involves the distribution of thousands of inexpensive pheromone traps (Universal Bucket or Delta Traps). Moth counts are determined and reported by farmer-volunteers using a phone application. The primary focus of community based monitoring program is to detect the arrival and spread of FAW, and to provide an early warning to farming communities.

The second type of monitoring system was pilot-tested in 2017 in Ghana. It is based on monitoring systems commonly used in the United States for migratory pests. The program involves the distribution of high quality pheromone traps (Heliothus style) at a relatively low density (about one trap per district). Trained agricultural professionals report weekly data to regional coordinators, maintain the traps, and scout the field next to the pheromone trap.

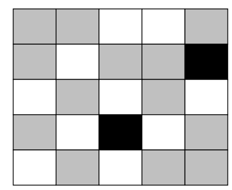
The agricultural professional managed monitoring system was tested in four regions in Ghana in 2017. The primary focus was to determine the level of egg laying intensity (high, moderate, low), in order to inform pest management decisions.

In the 2017 pilot test, the average regional moth counts were based on five to ten monitoring sites per region.

- Moth counts (which represent egg-laying) and percent plants with small, fresh, windowpanes (which represents egg-hatch) were highly correlated (Appendix B). In this regard, regional average field data validated regional average moth counts.

- The regional averages ranged from 0.0 to 1.5 moths per trap per day. There were differences by region, with higher moth counts in Brong Ahafo and lower moth counts in the Upper East and Upper West. These trends need further evaluation in the years to come.

“patchy”



The average moth counts remained relatively low, even during the peak of the FAW egg laying. The explanation for the low, average, regional counts is that moth density is very “patchy.” The average takes into account high and low moth counts, including sites that reported zero moths.

I recommend that scouts look at both the local and regional trends when assessing risk. Given the patchiness of FAW moth distribution, the regional average moth count may be a more useful assessment of egg-laying pressure than a moth count from a single field-side pheromone trap. Local moth counts couple with a regional average moth count increases the confidence of the scout, especially when making a no-spray decision.

- If one finds few or no FAW moths in the local trap, and regional moth counts are also low, one can be confident that egg-laying pressure is low.

- Low moth counts plus low levels of small, fresh windowpanes supports a “double safe” no-spray decision. (There are no worms hatching in the field, and there are no incoming moths.)

During my visit in April and May of 2018, we worked closely with the National FAW Taskforce and FAO program specialists to integrate and harmonize the two approaches to FAW monitoring. We believe that the changes we proposed will meet the needs of both the early warning system and the needs of pest management decision makers.

Scouting Schools

In 2017, the majority of monitoring and scouting trainings were short (half-day) field trainings. The purpose of these trainings was to introduce agricultural professionals and farmers to FAW, and to enroll them in generating FAW data for an early warning system. In 2018, the trainings were longer (two days) and more in-depth. The purpose of the trainings was to prepare agricultural professionals and lead farmers to make pest management decisions, using monitoring, scouting, and an action threshold. The goal of the in-depth training is to reduce unneeded pesticide applications.

In the morning of day one, participants were taken directly to a maize field where they set up pheromone traps, scouted the maize, and used an action threshold to assess whether or not a control measure should be applied. Participants took into account the growth stage of the crop, prior application of insecticides, and the probability of rain. The afternoon was spent in the classroom where the field experience was "debriefed" and FAW biology, monitoring, and field scouting were discussed in some detail.

The following morning, participants returned to the field and scouted again. They entered data into the FAO early warning system phone application called FAMEWS (Fall Armyworm Monitoring and Early Warning System). In the afternoon of the second day, we debriefed the field training again and solicited participant suggestions on how to improve the scouting protocol and the FAO phone application (See Appendix C).

Delta Traps

The FAW Task Force is using an inexpensive pheromone trap called a "Delta Trap" for the community based monitoring program.

I wrote a new handout on the "Delta Trap" that will be used for the MOFA/FAO monitoring project (attached) and incorporated instruction on managing the Delta trap into our training curriculum.

Field Scouting Instructions

I revised the scouting instructions and the scouting FORM. to better accommodate smallholder farmers who plant maize in hills.

- The revised scouting instructions direct the scout to make five stops and at each stop examine either ten individual plants (row planting) or examine ten hills (hill planting). If there were small, fresh windowpanes on any plant within the hill, that counts as one sample.

- In the revised scouting instructions, scouts are directed to focus on the newest 2-3 leaves coming out of the whorl. They count small, fresh, round windowpanes (whorl stages) or small, fresh, elongated windowpanes (reproductive stages). They encouraged to ignore old feeding damage.

The revised scouting instructions include a brief discussion of action thresholds. Although the instructions offer specific action thresholds for each plant growth stage, scouts are encouraged to adjust the threshold (within specified ranges) based on their experience and their risk management style.

Finally, the revised scouting instructions invite scouts to work with some of the larger farmers to establish an untreated control area in the vicinity of the pheromone trap, an area of five by five meters square marked with stick and string. No control measures are applied in the control plot. At the end of the growing season, comparing yield in the farmer's field and the untreated plot give the farmer a first, rough estimate of the impact of her control efforts.

- Scouts were encouraged to enroll several farmers applying the same control method, so that the simple paired comparison could be replicated across several farms.

Field Trials 2017-18

In the first 2017 insecticide trial, candidate insecticides were applied six times on a two-week interval. In the second trial, candidate insecticides were applied four times, two applications during the early whorl stage, plus two applications at the early tassel stage (Appendix A - Tables One and Two).

- The products evaluated in the first trial were K Optimal (lambda cyhalothrin plus acetamiprid), Conserve (spinosad), and Bypel (Bacillus thuringiensis plus granulosis virus)

- Peak FAW moth counts during the trials exceeded 0.5-1.0 moths per trap per day, on average, for the Brang Ahafo region (See Appendix B). Percentage of infested plants exceeded eighty percent.

Treatments were applied six times at the high label rate with a backpack sprayer at a two-week interval. Results were as follows:

- K Optimal (lambda cyhalothrin plus acetamiprid) applied six times resulted in 33% cob damage compared to the untreated control, which had 88% cob damage.

- Bypel applied six times at a two-week interval resulted in 13% cob damage.

- Tracer/Conserve (spinosad) applied six times resulted in complete FAW control (zero cob damage).

In the second trial, products tested included Lambda Super (lambda cyhalothrin), Porcelen (5% ememectin benzoate), Ema Star (ememectin benzoate plus acetamiprid), Conserve (spinosad), Bypel (Bacillus thuringiensis plus granulosis virus), and K Optimal (lambda cyhalothrin plus acetamiprid).

The insecticides were applied four time during two high-risk periods, early whorl (2&4 weeks after planting) and early tassel and silk (8&10 weeks after planting).
Results were as follows:

- K Optimal (lambda cyhalothrin plus acetamaprid) applied four times resulted in 28% cob damage compared to the untreated control that had 48% cob damage.
- Lambda cyhalothrin applied four times resulted in 15% cob damage compared to the untreated control that had 48% cob damage.
- Bypel (Bacillus thuringiensis plus granulosis virus) applied four times resulted in 8% cob damage.
- EmaStar (ememectin benzoate plus acetamiprid) applied four times resulted in 5% cob damage.
- Porselen (ememectin benzoate) applied four times resulted in 3% cob damage.
- Spinosad applied four times resulted in 3% cob damage.

ADVANCE agricultural production officer (APO) Gabriel Ahlidza has expressed willingness to establish and manage the 2018 field trial as long is the work is integrated into his work plan agreed to by his immediate supervisor.

Isaac and John will help Gabriel establish the trial. Gabriel has agreed to establish a pheromone trap, scout the field once per week, make the scheduled insecticide applications, and keep good records. Isaac and John would help him harvest and assess the trial.

I suggest we use a single, effective insecticide (emamectin benzoate or spinosad) while varying the timing and number of applications. I recommend that we test two and three spray programs. Treatments could include the following:

1. Two sprays – 2&4 weeks after planting (WAP)
2. Two sprays – 8&10 weeks after planting
3. Two sprays – at 2 WAP and 8 WAP
4. Three sprays – 2&4 WAP plus 8 WAP
5. Three sprays – 2 WAP plus 8&10 WAP
6. Four sprays – 2&4 WAP plus 8&10 WAP
7. Five sprays – 2,4,6,8, and 10 WAP
8. Untreated Control

(See attached "Instructions for Insecticide Timing Trial 2018").

Pesticides Recommendations

In the United States, there are many insecticides used to control FAW in corn including: chlorantraniliprole, emamectin benzoate, spinosad, spinetoram, chlorpyrifos, indoxacarb, and methomyl.

- During an FAW outbreak, even highly effective insecticides must be applied more than once to reduce crop damage.

- Lambda cyhalothrin and other pyrethroid insecticides are still used in the United States, but their performance on FAW is mediocre due to insecticide resistance.

- Systemic insecticides in the neonicotinoid family (examples: imidacloprid and acetamiprid) are not registered for use on FAW in the United States because they are ineffective.

- Chlorpyrifos and methomyl are highly toxic, and not recommended for use by inexperienced applicators.

Best controls available in Ghana

Based on visits to pesticide dealers in Ghana from 2016-2018, the most commonly available insecticides for FAW control are ememectin benzoate, Bacillus thuringiensis, lambda cyhalothrin, and chlorpyrifos. They vary in toxicity and effectiveness.

Ememectin benzoate

Ememectin benzoate is the most effective insecticide on FAW available in pesticide stores that we visited in Ghana. It is moderately toxic. It is expensive.

- Use monitoring, scouting, and an action threshold to reduce the number of applications and the cost of FAW control with ememectin.

- Many of the products containing ememectin benzoate are premixes containing less effective insecticides (examples: lambda cyhalothrin, acetamiprid or imidacloprid). Less effective insecticides dilute the ememectin and raise the cost of the product.

- When possible, chose products that are undiluted. One example is Porselen (5% ememectin benzoate).

Bacillus thuringiensis

Although Bacillus thurindiensis (Bt) is only moderately effective on FAW, I recommend it because it is very low in toxicity (> 5000 mg/kg).

- Bt is gentle on the natural enemies that help to regulate FAW.

- Bacillus thuringiensis (Bt) is derived from naturally occurring organisms in the soil. In the United States, it is used in certified organic farming systems.

- Bacillus thuringiensis is effective on small worms (1st, 2nd, and 3rd instar).

- Multiple applications of B. thuringiensis are required to reduce crop damage.

Lambda cyhalothrin

Lambda cyhalothrin is moderate to poor at controlling FAW. It is more toxic than emamectin benzoate and should be used with caution. Cyhalothrin is inexpensive and widely available in Ghana.

- When lambda cyhalothrin is applied to FAW infested maize, about 15-25% of the worms survive due to insecticide resistance. If the maize is in the early whorl stage (V1-V6), the worms will pupate before the plants begin to tassel. The surviving worms, therefore, do not pose a threat to the cobs during the early whorl stage.

- When FAW pressure is high, maize is in the early whorl stage, and insecticide options are limited, lambda cyhalothrin may be a better choice than doing nothing.

Indoxacarb

- Indoxacarb is moderate to poor at controlling FAW and moderately toxic. It is not common in Africa, but I am told that indoxacarb is available in some parts of Ghana.

- If indoxacarb is applied during the early whorl stage, the surviving worms will pupate before the plants begin to tassel. They do not threaten the cobs. When percent infestation is high during the early whorl stage, an application of indoxacarb may be better than nothing.

- I recommend that MOFA make this insecticide available in Ghana to increase the insecticide rotation options for farmers to better manage insecticide resistance.

Chlorpyrifos

- Chlorpyrifos is highly toxic, and not recommended for use by inexperienced applicators.

Recommended Insecticides Not Currently Available in Ghana

Ghanaian growers need more insecticide choices for controlling FAW, especially materials that are more effective and less toxic.

In addition to the insecticides above, I recommend that USAID/PERSUAP and MOFA work together to bring three additional insecticides into Ghana: Coragen (chlorantraniliprole), Tracer (spinosad), and Radiant (spinetoram).

Coragen (chlorantraniliprole)

Chlorantraniliprole is very effective on FAW and very low in toxicity (LD50 > 5000mg/kg).

Tracer (spinosad) and Radient (spinetoram)

Spinosad and spinetoram are very effective on FAW and very low in toxicity (LD50 > 5000mg/kg).

- Spinsad and spinetoram are fermentation products of the bacteria *Saccharopolyspora spinosa*. In the United States, they are used in organic production systems.

- Spinosad and spinetoram are effective, organic alternatives to ememectin benzoate and chlorantraniliprole.

- Spinosad and spinetoram should be used in combination with monitoring, scouting, and action thresholds to reduce the number of applications and the cost of FAW management.

Strategies for least toxic control

Use effective Insecticides.

- When insecticides are not effective on FAW (example: malathion), farmers tend to increase the dosage and increase the number of applications.

- Insecticides “that work” on FAW require fewer applications and lower dosages.

Apply insecticide at the right time.

- Apply insecticides when FAW worms are small.

- Once the worms are large and established in the whorl, they are very difficult to control, even when using effective insecticides.

- Use scouting, monitoring, and an action threshold to adjust the timing and improve the effectiveness of insecticide applications.

- Short residual, lower toxicity insecticides (example: botanical insecticides), decompose rapidly when exposed to light and heat. Therefore, apply them at dusk.

Use an effective application technique.

- During the whorl stage, direct the insecticide toward the whorl. It is not, however, necessary to fill the whorl with spray fluid.

- During the tassel stage, direct the insecticide toward the leaf axils in the cob-bearing zone of the maize plant.

Use the least toxic insecticides that are effective on FAW

- Ememectin benzoate is more effective and less toxic than lambda cyhalothrin or chlorpyrifos.

Use monitoring, scouting, and action thresholds to reduce use

Climate factors including temperature and rainfall will effect the distribution and movement of FAW across the regions on an annual basis.

- FAW may survive in southern Ghana during the dry season then migrate north each year during the rainy seasons. This may result in a "discrete start date."

- Use monitoring and scouting to identify opportunities to reduce pesticide applications prior to the start dates.

Natural enemies and diseases that control African armyworm will switch over and begin to regulate FAW; this may result in extended periods of low egg-laying pressure and occasional outbreaks. This "boom and bust" pattern is typical of armyworm populations in the Americas and in Africa.

- During periods of low egg-laying pressure, one may be able to prevent significant crop loss with one-spray or two-spray programs. Use monitoring, scouting, and action thresholds to identify low risk periods when pesticide applications can be reduced without putting the crop at risk.

- If you are prepared to apply a FAW insecticide and a rainstorm is imminent, you may want to hold off. An intense rainstorm will kill most of the small worms. Scout the field following a rainstorm to determine if you still need to spray.

Summary of Recommendations Moving Forward

Awareness campaign messages

I recommend that MOFA/ADVANCE communicate to farmers and agricultural professionals that fall armyworm (FAW) is now established in Africa. Farmers need to learn to manage FAW with the least toxic and most cost effective approaches available.

Key messages include:

- "Just because you have FAW in your maize, doesn't mean you need to spray."
- "Use monitoring, scouting, and action thresholds to reduce unnecessary pesticide applications."

Least Toxic FAW Control

I recommend that monitoring, scouting, and action thresholds be promoted as a means to reduce pesticide use by identifying when it is safe to skip a spray.

- Least toxic control of FAW requires the use of effective, least toxic insecticides, applied with the right technique, at the right time.
- Bacillus thuringiensis (Bt) is moderately effective on FAW and requires multiple applications. However, Bt may be the best insecticide for use by inexperienced pesticide applicators because it has very low toxicity. Bt only works on small worms.
- I recommend that MOFA and USAID work together to bring other products containing Bacillus thuringiensis into Ghana.
- I recommend that MOFA and USAID work together to bring Chlorantraniliprole (Coregen), spinosad (Tracer), and spinetorum (Radient) into Ghana. They are effective on FAW and very low in toxicity.

Cost Effective FAW Control

I recommend that monitoring, scouting, and action thresholds be promoted as a means to reduce the cost of FAW control.

- For example, the most effective pesticide available in the market today in Ghana is emamectin benzoate. It is expensive. It makes sense to reduce the number of applications by optimizing the timing of the applications.

Phone Based Monitoring and Early Warning System

John Laborde wrote: "The phrase on the phone application "plants with FAW" is ambiguous. Does this include FAW at any of its life stages (eggs, larvae, moths)? Does "plants with FAW" include plants with windowpanes, whorl damage, frass, and scraping, tearing, shot holes? We assume so, but it isn't immediately clear."

- Risk assessment based on "plants with FAW" tends to over-estimate the current level of infestation and risk of crop damage, because scouts tend to count current feeding damage plus old feeding damage.

- By targeting signs of egg-hatch (small, fresh windowpanes) on new foliage, scouts are measuring the current level of infestation.

- I recommend that in addition to reporting plants "with FAW," FAO add a column labeled plants "with SFW" (small, fresh window panes).

Two Types of FAW Phone Application

I recommend that FAO consider developing two versions of the FAWNEW phone-application.

- The first version would be "FAWMEW-LTE". The purpose of the light version would be to provide early warning to farming communities of the annual arrival and spread of FAW. Scouts would report GPS coordinates and FAW moth counts.

- The second version would be "FAWNEW-IPM." The purpose of IPM version would be to reduce pesticide applications by informing no-spray decisions. The IPM version would require more detailed data entry: GPS coordinates, moths per trap per day, maize growth stage, rain events, percent plants with small, fresh windowpanes (SFM), percent plants with infested whorls, and other notes relevant to making a yes/no control decision.

Historical Records

I recommend that MOFA keep and analyze historical records of FAW moth counts in order to characterize egg-laying pressure during the growing season and from year to year.

- As FAW becomes established in Africa, disease and natural enemies will regulate its population. There will be extended periods of low egg-laying pressure and occasional outbreaks.

- Several years of records are required in order to characterize normal, above average, and below average moth counts.

Two Types of Monitoring Programs

The community based monitoring model where farmer volunteers manage hundreds or thousands of inexpensive pheromone traps has strengths and weaknesses. The same is true of a monitoring system that is managed by agricultural professionals. I recommend a hybrid approach.

- The purpose of the community based monitoring system is to provide early warning of the annual arrival of FAW moths. Community based monitoring by farmer volunteers will engage farming communities and produce "early warnings" close to where the warnings are needed. The density of traps might approach ten or more traps per district, and several hundred traps per region.

- A complimentary monitoring system could be established and managed by trained professionals. The purpose of the professionally managed monitoring system is to provide reliable data useful to pest management decision makers. The traps could be distributed at a density of about one per district using more reliable (and more expensive) pheromone traps. The professionally managed monitoring system would be especially important during extended, low-pressure periods when volunteer enthusiasm (and agency funding) may decline.

Two Types of FAW Training

I recommend that Ghana develop two types of FAW training formats, a short field training, and a more intensive two-day scouting school.

- Develop a half-day field training for individuals who want to contribute data to the national Fall Armyworm Monitoring and Early Warning System (FAWMEWS).

- Develop a two-day intensive training for agricultural professionals and lead farmers who want to use monitoring, scouting, and action thresholds to make pest management decision.

- Incorporate pesticide safety and insecticide resistance management into scouting school curricula when ever possible.

I recommend that the paper-based Field Scouting FORM (see attached) continue to be used for training purposes.

- In our field trainings in April of 2018, participants used the paper FORM for their first scouting experience and the FAO phone application for their second scouting experience.

Collaborative On-Farm Research

Farmers learn by seeing and doing, but sometimes they are misled. The interaction between FAW and maize is complex. Uncontrolled experimentation can lead to "false negative" and "false positive" results.

- For example, if an effective insecticide is applied once, when FAW worms are large and protected in the whorl, the effective insecticide may “appear” to fail.

- For example, if an ineffective insecticide is applied right when large worms are leaving the maize plants to pupate in the soil, the ineffective insecticide may “appear” to succeed.

One of the fastest ways to identify false-negative and false-positive results is to establish an untreated control.

- When setting up a pheromone trap at a FAW monitoring site, use four sticks and string to cordon off an “untreated control” plot.

- Untreated control plots allow the scouts to “calibrate” their trap, giving them a rough estimate of the relationship between moth count, % plants with small, fresh, windowpanes, and crop damage. At harvest, farmers can compare cob damage in the control versus a treated field. Consider replicating the simple, paired-comparisons across several farms.

- Smallholder farmers with less than one hectare of maize may be reluctant to put any of their crops at risk. Untreated control plots may not be appropriate for small farms.

- Larger farmers may be willing to establish untreated control plots and may also be willing to host multiple-treatment, small-plot trials with a randomized complete block design.

- I recommend that a new series of training workshops be developed for agricultural professionals. The workshops should focus on field plot technique and on-farm research.

Large-plot simple paired comparisons replicated across farms may be the best approach for evaluating cultural practices.

- Researchers and agricultural professionals report that good agricultural practices (GAP) are among the most effective cultural controls of FAW. They assert that GAP yields of maize during an FAW outbreak can exceed yields of conventionally grown maize in the absence of FAW. This deserves further investigation in Ghana.

- Push pull growing systems may be appropriate for some smallholder farms. Push pull growing systems deserve further investigation in Ghana.

Appendix A – Field Observation Trial Results

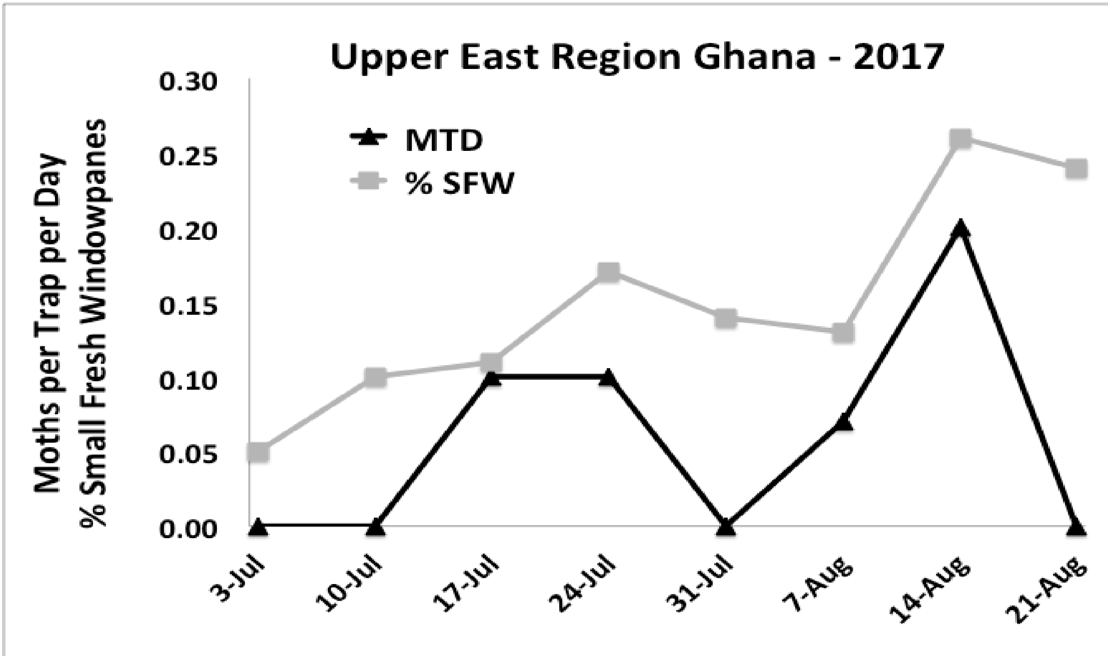
Table One

Treatment (six applications)	Damaged Ears (Count out of Ten)	Damaged Ears (Percentage)
K Optimal (acetamiprid & lambda cyhalothrin)	**3.3 ± 0.5 c**	**33%**
Bypel (B. thuringiensis & granulosis virus)	**1.3 ± 0.6 b**	**13%**
Tracer (Spinosad)	**0.0 b**	**0%**
Untreated Check	**8.8 ± 0.3 a**	**88%**
* Randomized complete block design with four replications. Treatments followed by the same letter are not significantly different. ANOVA: F = 19.23; Pr > F 0.001		

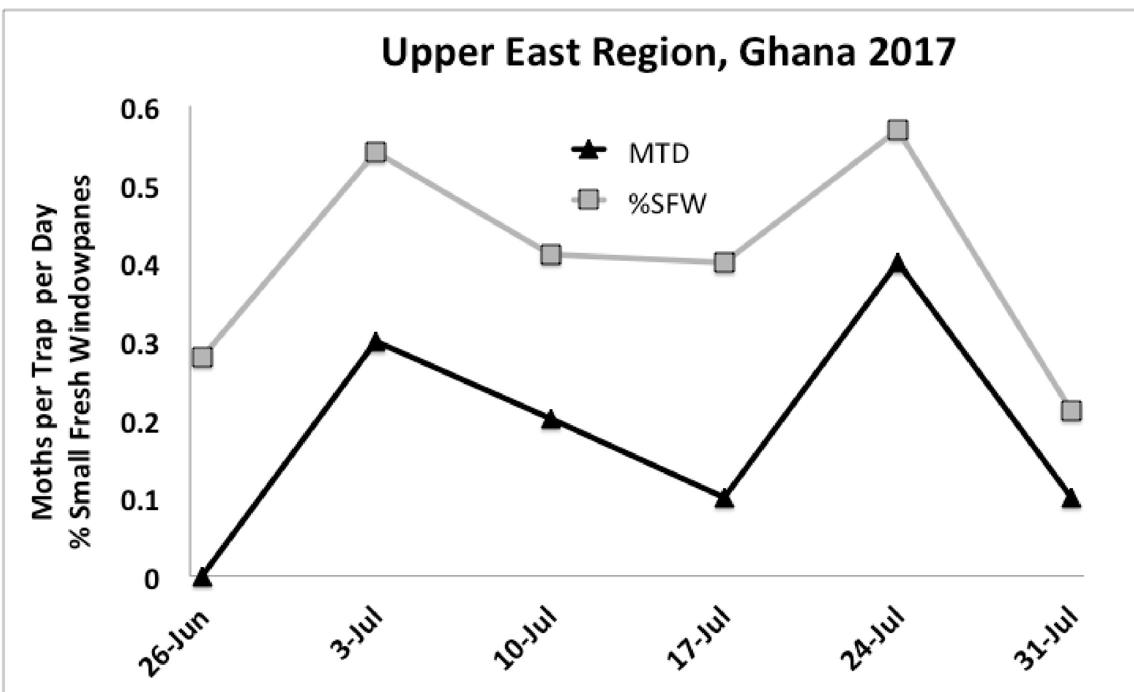
Table Two

Treatment (four applications)	Damaged Ears (Count out of Ten)	Damaged Ears (Percentage)
K Optimal (acetamiprid & lambda cyhalothrin)	**2.8 ± 0.5 c**	**28%**
Lambda (lambda cyhalothrin)	**1.5 ± 0.7 bc**	**15%**
Bypel (B. thuringiensis & granulosis virus)	**0.8 ± 0.5 b**	**8%**
Porcelen (ememectin benzoate)	**0.3 ± 0.3 b**	**3%**
Tracer (Spinosad)	**0.3 ± 0.3 b**	**3%**
Untreated Check	**4.8 ± 0.3 a**	**48%**
* Randomized complete block design with four replications. Treatments followed by the same letter are not significantly different. ANOVA: F = 11.11; Pr > F 0.001		

Appendix B – Regional Pest Monitoring Pilot Test

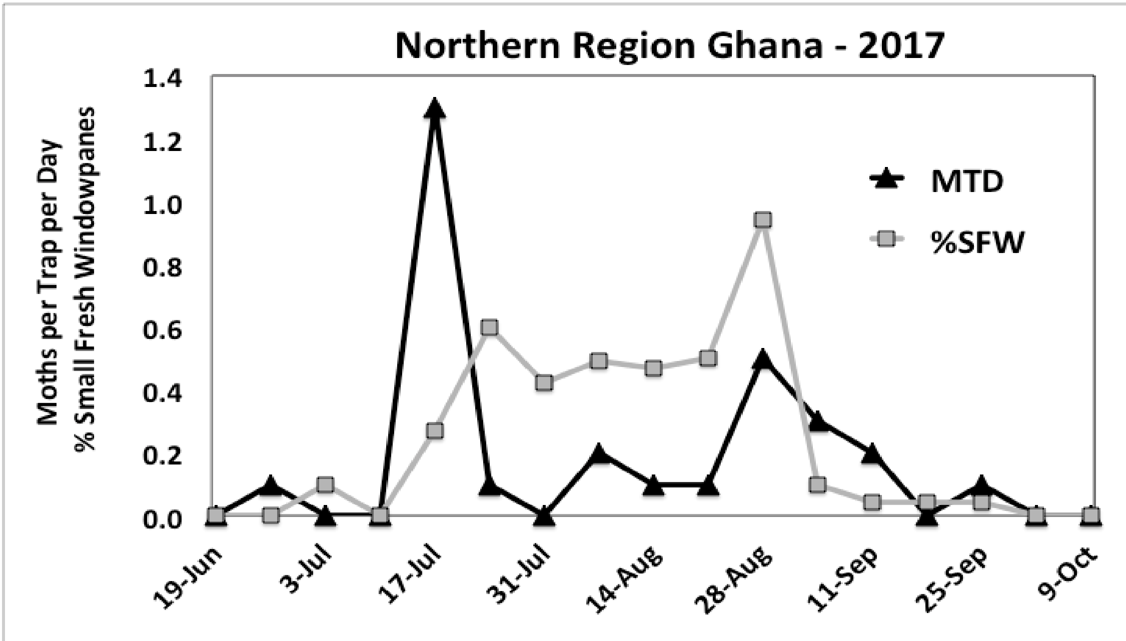


Plot of weekly regional average moth/trap/day (MTD) and weekly average % plants with small, fresh windowpanes (SFW).

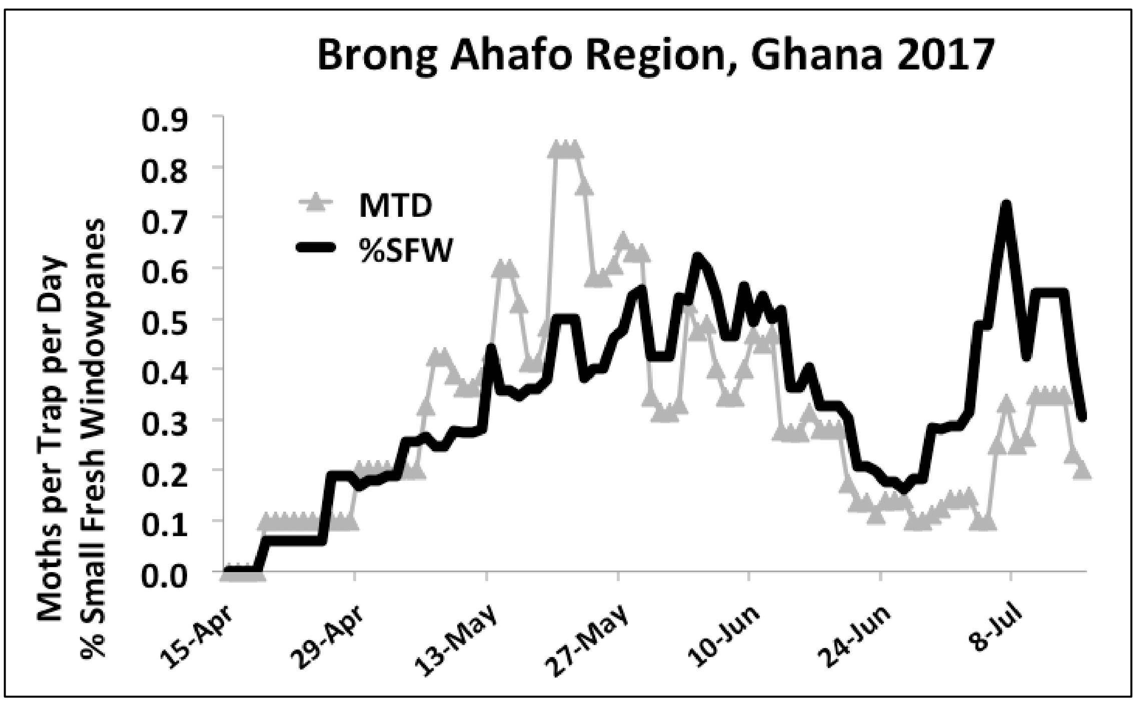


* Plot of weekly regional average moth/trap/day (MTD) and weekly average % plants with small, fresh windowpanes (SFW).

Appendix B – Regional Pest Monitoring Pilot Test



* Plot of weekly regional average moth/trap/day (MTD) and weekly average % plants with small, fresh windowpanes (SFW).



* In this graph, moth counts and % plants with windowpanes are reported as a "rolling ten-day averages" from ten sites.

Appendix C - Scouting School Participant Comments

At the end of each scouting school, participants were divided into groups and asked for their concerns and suggestions. The following is a summary of their comments.

What farmers need to know

- Farmers need to be encouraged to move from an "eradication" mindset to a "pest management" mindset.
- Farmers need to know that just because one has FAW does not mean they need to apply an insecticide.
- Farmers need to know that control measures should be applied when FAW worms are small (1st, 2nd, and 3rd instar). Large worms buried in the whorl are very difficult to control, even with effective insecticides.
- Farmers need to know that large FAW worms (5th and 6th instars) are ready to pupate, hatch as moths, and disperse. It is generally not worth the effort or expense of applying control measures when worms are large.
- Farmers need to know that FAW, under the right environmental conditions, attacks both the vegetative and reproductive stages (cobs) of maize.
- Farmers need to know the relative toxicity of various FAW insecticides. For example, lambda cyhalothrin and Bacillus thuringiensis (Bt) are moderately effective on FAW. However, lambda cyhalothrin is much more toxic than Bt.

Technical Comments

- Action thresholds are designed to reduce pesticide applications by eliminating unneeded sprays.
- Spray decisions should be based not only on the presence or absence of FAW, but also on intensity of egg-laying, percentage of plants showing signs of egg-hatch, maize growth stage, weather forecast, and other factors.
- FAW populations can develop on the grasses on the field margins. Before a no-spray decision is made, check the field margins.
- Inexperienced applicators need to be discouraged from applying highly toxic insecticides after tasseling begins (example: chlorpyrifos).

Educational Resources Needed

- We need community level training for farmers on FAW biology and least toxic approaches to FAW management.

- Agricultural Extension Agents need material support (traps, lures, fuel, phones, airtime, etc.) in order to be effective at educating farmers about FAW management.

- The ratio of agricultural professionals to farmers is low. Ghana needs more agricultural extension agents and more spray service providers at the community level.

Access to Less Toxic Insecticides

- Effective, less toxic insecticides for FAW control are not available in the market place, especially in northern Ghana. Farmers, agricultural professionals, and MOFA need to work together to bring less toxic insecticides into Ghana (Examples: Coragen, Spinosad, and various products containing *Bacillus thuringiensis*).

Appendix D: Table of approved active ingredients and FAW recommendations

Approved Active Ingredients	Commercial Products in Ghana (on the market)	FAW Recommendations
Acetamiprid + Lambda-cyhalothrin	1. K-Optimal	Acetamiprid is not effective on FAW. Lambda cyhalothrin is moderately effective to poor at controlling FAW. In controlled and replicated trials, K Optimal was applied six times. There was still over 25% cob damage.
Bacillus thuringiensis (Bt) + Granulosis virus	• Bypel	Bt is moderately effective at controlling FAW. Bt is very low in toxicity and gentle on the natural enemies of FAW. Bt only works on small FAW worms, 1st, 2nd, and possibly 3rd instars. Multiple applications are needed to significantly reduce crop damage. Bypel is a premix containing Bt plus Granulosis Virus. Granulosis virus does not work on FAW.
Deltamethrin	• Deltapaz 1.25EC • Deltacal 12.5EC • K-Othrine 250WG	Not recommended for FAW
Cypermethrin + Dimethoate	• Cyperdim EC • Cypasect Super • Cydim Super EC • Cypadem 43.6 EC	Not recommended for FAW

Emamectin benzoate (5%)	• Porcelen	Emamectin benzoate is highly effective on FAW. It is moderately toxic. There are several premixes on the market containing ememectin plus other insecticides that are ineffective on FAW. The ineffective insecticide dilutes the emamectin and increases the cost of the product.
Acetamiprid + emamectin benzoate.	• Ema Star	Acetamiprid is not effective on FAW. In some markets, Ema Star is the only product available which contains emamectin.
Imidacloprid + emamectin benzoate	• Dean	Imidacloprid is not effective on FAW. In some markets, Dean is the only product available which contains emamectin.
Lambda-cyhalothrin (25g/L)	• Sunhalothrin • Lambda Super • Lambdacot • Striker • Lambda Master • Bonlambda • Bossmate 2.5EC • Clear 2.5EC	Lambda cyhalothrin is moderately effective to poor at controlling FAW. FAW is somewhat resistant to lambda cyhalothrin and other insecticides in the pyrethroid family of chemicals. Lambda cyhalothrin kills about 75-80 percent of small worms. The surviving 20-25% infest the whorls and complete their life cycle. If cyhalothrin is applied early (V1-6) the surviving worms will pupate before tassel formation and will not threaten the developing cobs. If the level of plant infestation is high during the early whorl stage and cyhalothrin is the only available insecticide, it may be better to apply cyhalothrin than nothing.
Azadirachtin	• Kumto Mmoaduro • Neemazal	Azadirachtin is not very effective on Lepidopteran pests (moths and butterflies). It has not been adequately tested on FAW, and we can not recommend it at this time. Azadirachtin is most effective on small worms, (1st, 2nd, and 3rd instar). Botanical insecticides such as Azadirachtin, are rapidly deactivated by the sun. Therefore, apply botanicals in the late afternoon or early evening when it is cooling down and the insecticide is on the leaves overnight.
Indoxacarb + Acetamiprid	• Viper	Indoxacarb is moderately effective to poor at controlling FAW. It is moderately toxic. Acetimiprid is not effective on FAW. Indoxacarb deserves further testing on FAW.

Cypermethrin + Acetamiprid	• Chemaprid	Cypermethrin is moderately effective to poor at controlling FAW. It is moderately toxic. Actetamiprid is not effective on FAW Lambda cyhalothrin kills about 75-80 percent of small worms. The surviving 20-25% infest the whorls and complete their life cycle. If cyhalothrin is applied early (V1-6) the surviving worms will pupate before tassel formation and will not threaten the developing cobs. If the level of plant infestation is high during the early whorl stage and cyhalothrin is the only available insecticide, it may be better to apply cyhalothrin than nothing.
Spinosad	• Tracer • Success	Spinosad is highly effective on FAW. Spinosad is very low in toxicity. Spinosad is toxic to bees and should be applied when bees are not active.