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Trapping *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Moths in Different Crop Habitats in Togo and Ghana

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Abstract

The economic impact of the invasion of *Spodoptera frugiperda* (J.E. Smith, Lepidoptera: Noctuidae) into Africa has so far been limited to maize agriculture but could potentially impact many other crops. Trapping based on pheromone lures provides a cost-effective method for detecting this important pest (commonly known as fall armyworm) and will be essential for large-scale monitoring of populations to determine its geographical distribution and migration behavior as the species equilibrates to its new environment. However, the effective use of pheromone trapping requires optimization for a given location. An earlier report demonstrated that two commercial lures (one 3-component and the other 4-component) that were effective for trapping *S. frugiperda* in maize fields in Togo, Africa. The current study extends these findings to agricultural areas that differ in plant host composition (maize, pasture grasses, rice, and sorghum) in multiple locations in Ghana and Togo. In two seasons, significantly higher numbers of moths were found in maize, and in one season, higher numbers were found in rice than in sorghum and pasture grass systems. The results confirm the effectiveness of pheromone trapping and identify pheromone lures and trapping methods best suited for the different agroecosystems common to West Africa and that are at risk of infestation by *S. frugiperda*.

Key words: fall armyworm, pheromone components, agricultural systems, maize seasons

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith), is an important agricultural pest native to the Western Hemisphere and is reported to be capable of infesting hundreds of host plant species from 76 families, mainly in Poaceae (106), Asteraceae (31), and Fabaceae (31) (Luginbill 1928, Montezano et al. 2018). Crops impacted by this pest include maize, sorghum, rice, and pasture and turf grasses (Sparks 1979, Ashley et al. 1989). Two fall armyworm populations have been identified that differ in their distribution on field crops, with the C-strain preferentially found in maize and sorghum and R-strain in pasture grasses, millet, and rice (Pashley 1988, Nagoshi et al. 2007, Juarez et al. 2012, Murúa et al. 2015).

Efficient monitoring of fall armyworm populations in the Western Hemisphere is facilitated by pheromone trapping, where components of the female pheromone blend are used to attract adult males to traps, thereby providing an estimate of local population presence and size (Tumlinson et al. 1986, Malo et al. 2001, Batista-Pereira et al. 2006, Meagher et al. 2013, Cruz-Esteban et al. 2018). This method is much less labor-intensive than traditional specimen collection by hand or netting and less damaging to the host plant. However, empirical observations indicate that the sensitivity and specificity of a particular pheromone blend can differ between regions, reflecting variability in local fall armyworm populations (Fleischer et al. 2005, Unbehend et al. 2014).

The invasion of fall armyworm into Africa was first reported with the collection of larvae in early 2016 from Benin, Nigeria, São Tomé and Principe, and Togo (Goergen et al. 2016), and by 2018 it was reported to be present in all sub-Saharan African countries except Lesotho (FAO 2018). The pest in Africa has so far been primarily observed in maize and sorghum, with most surveys using the direct collection of larvae from plant hosts (Goergen et al. 2016; Cock et al. 2017; Nagoshi et al. 2017, 2018, 2019; Ganiger et al. 2018). Small holder farmers in West Africa use several management techniques against fall armyworm, including insecticides, bioinsecticides, and physical and habitat management tactics (destruction of eggs and larvae, push–pull systems, trap crops; Hruska 2019, Koffi et al. 2020b, Midega et al. 2018); therefore, the efficiency of management will be through pest monitoring using pheromone trapping. To achieve this objective, a study in West Africa tested three commercial lures that differed in the number of pheromone components. These studies were limited to maize fields in southern Togo, where it was found that a three component (3C) blend was the most attractive for fall armyworm with comparable levels of bycatch (nontarget) moth contamination (approximately 20%) as that observed with two component (2C) and four component (4C) lures (Meagher et al. 2019). However, the generality of these observations for Africa cannot be assumed as there were substantial regional differences in lure efficacy in the United States and geographical variation of pheromone components in female's blends in Mexico (Cruz-Esteban et al. 2018). Another factor to consider is the crop habitat where testing is carried out, as different habitats contain corn or rice strain populations that may respond differently to the lures (Meagher and Nagoshi 2013; Unbehend et al. 2013, 2014). Therefore, there is empirical evidence that the efficacy of different fall armyworm lures is dependent on the moth populations present in each region and habitat, thereby limiting how much the trapping results from one region can be generalized for others.

Given the recentness of the establishment of fall armyworm in Africa, there is much uncertainty as to how this pest will become seasonally distributed on the continent. Accurate and efficient pheromone trapping will greatly facilitate the mapping of fall armyworm populations and the monitoring of their movements and migrations. Tests were conducted in maize systems in southern Togo to compare pheromone trap design and lure catches as well as their cost-effectiveness (Meagher et al. 2019). But due to the timing and spatial limitation of that study, the present study is extended to different regions in Togo and neighboring Ghana and to three more crop systems, sorghum, rice, and pasture grasses. All four crops provide suitable hosts for fall armyworm infestations in the Western Hemisphere and are at high risk for economic damage in Africa. Therefore, our objectives were to monitor populations of fall armyworm using pheromone-baited traps in northern and southern Togo and Ghana. Comparisons were made among different cropping seasons and pheromone lures containing three or four pheromone components.

Materials and Methods

Collection Information

Traps were set over two growing seasons corresponding to the second season that occurs from September to January in 2018–2019 and 2019–2020 in farms in Togo and Ghana. All crop sites were located south of 8°N latitude except for the sorghum sites which were located near 10°N latitude, over 300 km to the north (Fig. 1). Moth collections from maize fields in Ghana were done in Ejura (N 7.388, W –1.356) during 2018–2019 and in Kumasi (N 6.657, W –1.609) during 2019–2020. The two sites are ~100 km apart. Moth collections in maize fields in Togo were carried out in Vogan (N 6.340, E 1.529) for 2018–2019 and near Lomé (N 6.199, W 1.219) during 2019–2020. These two sites are ~50 km apart. Collections from sorghum were made for both trials in Walewale, Ghana (N 10.356, W –0.809) and Tchitchao, Togo (N 9.622, E 1.146). The rice and pasture sites in Ghana were both near Kpong (N 6.15, E 0.67), with the rice site at the Soil and Irrigation Research Centre and the pasture site nearby. The rice site in Togo was in Kovie (N 6.34, E 1.11) and the pasture site was in Avetonou (N 6.8, E 0.8).

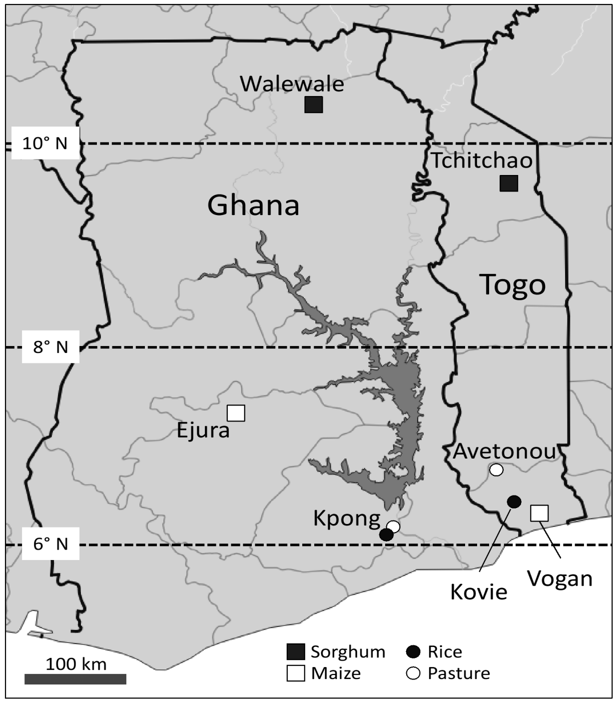

Fig. 1. Map showing collections sites in Ghana and Togo with symbols indicating predominant fall armyworm crop system(s).

Maize grown in the southern regions have two growing seasons during the year, from April to July and September to November, constituting the major and minor rainy seasons, respectively. Rice production is generally year-round in the two irrigated areas selected for this study. There is a single northern sorghum growing season that extends from July to December, and pastures are present year-round. Because of logistical constraints, fall armyworm collections were mostly limited to the period from September to January over 2 yr for all locations. Specifically, traps were used from 15 September 2018 to 12 January 2019 for all Ghana sites (eight sample dates) and from 21 September 2018 to 1 January 2019 for all Togo sites (seven sample dates). The second trial was from 1 September 2019 to 30 January 2020 for both countries (10 sample dates). These collections spanned the full late year growing season for maize and a portion of the growing season for sorghum; rice and pasture grasses were not sampled during 2019–2020.

Traps, Pheromones, and Killing Agent

Unitraps (Great Lakes IPM, Vestaburg, MI) were used for all collections. These are bucket-style traps commonly used in the United States and were previously tested in Togo for fall armyworm (Meagher et al. 2019). Commercially available pheromone lures consisting of rubber septa with either three or four components were placed in the inside basket at the top of the Unitraps. Based on previous chemical analysis (Meagher et al. 2013), the three-component lure (3C) contained (*Z*)-9-tetradecenyl acetate (Z9-14:Ac), (*Z*)-11-hexadecenyl acetate (Z11-16:Ac), and

(Z)-7-dodecenyl acetate (Z7-12:Ac) (Trécé, Adair, OK). The four-component lure (4C) added (Z)-9-dodencenyl acetate (Z9-12:Ac) (L105A or standard FAW lure, Scentry Biologicals, Billings, MT). Since shipping the killing agent (dichlorvos) used in the United States is illegal and is difficult to obtain in Ghana, the killing agent used in Ghana and Togo was abamectin with an active ingredient based on emamectin benzoate (19-g/liter EC; EMACOT 019EC, ANTEOR SARL, Lomé, Togo), diluted with water at 2 ml of product per liter. Cotton (10 g) was soaked with the killing agent and placed in the bucket trap.

Field Trapping Design

Each collection site consisted of six traps (two lures × three blocks) for each crop habitat. Traps were monitored at 2-wk intervals for each site. Traps were initially hanged at 0.30 m above the height of the targeted crop and ~3 m from the main field, with the heights adjusted bi-weekly with respect to the targeted plants. Traps were placed 40 m apart and lures were replaced monthly.

Statistical and Data Analyses

Spodoptera frugiperda and bycatch moths per trap were calculated at each sampling date. All analyses were conducted in SAS 9.4 (SAS Institute, 2012, Cary, NC). All data were first analyzed using Box-Cox (Proc TRANSREG) and Proc UNIVARIATE to find the optimal normalizing transformation (Osborne 2010); as many traps contained no moths, all data were converted to $y + 0.1$ before being transformed. Moths per trap were compared among crop systems and between pheromone lures using a randomized complete block design in Proc GLIMMIX by years and country with crop, lure, and the crop*lure interaction as the fixed variables and site, date, and block as the random variables. In all analyses, LSMEANS with an adjusted Tukey test was used to separate variable means. Geographical maps were generated using QGIS version 2.18.2.

Results

Comparisons Among Crop Systems and Between Pheromone Lures

Crop system and pheromone lure used were important factors in the number of *S. frugiperda* moths captured in traps. During 2018–2019 when four crop systems were sampled in each country, traps in maize (Ghana) and rice (Togo) captured more moths than traps in the other crops (Tables 1 and 2). Low numbers of moths were captured in the sorghum and pasture grass systems. In Ghana, traps baited with 3C lures captured more moths than traps baited with 4C lures (Table 1); however, there was a significant crop by lure interaction ($F = 8.4$; df = 3, 175; $P < 0.0001$). This interaction was explained by large differences in moth capture between the lures in every crop system ($P < 0.001$) except pasture grasses (3C 0.21 ± 0.1 vs. 4C 0.04 ± 0.04; $F = 2.1$; df = 1, 37; $P = 0.1527$). In Togo, traps with 3C lures also captured more moths than traps with 4C lures (Table 2), but the crop by lure interaction was also significant ($F = 13.0$; df = 3, 152; $P < 0.0001$). This interaction was explained by traps with 3C lures capturing more moths than traps with 4C lures in rice and maize ($P < 0.0001$), but statistically similar numbers between the two lures in pasture grasses (3C 0.48 ± 0.27 vs. 4C 0.33 ± 0.21; $F = 0.42$; df = 1, 32; $P = 0.5217$) and sorghum (3C 0.29 ± 0.12 vs. 4C 0.1 ± 0.66; $F = 2.2$; df = 1, 32; $P = 0.1466$).

During 2019–2020, only maize and sorghum systems were sampled, and in both countries traps in maize captured more fall armyworm moths than traps in sorghum (Tables 3 and 4). Traps baited with 3C lures captured more moths than traps baited with 4C lures. The interaction between crop and lure was not significant in either country (Ghana, $F = 2.8$; df = 1, 105; $P = 0.0952$; Togo, $F = 0.78$; df = 1, 105; $P = 0.3806$).

Table 1. *Spodoptera frugiperda* and bycatch moths per trap per date ($n = 48$; 8 dates × 2 lures × 3 blocks) during September 2018 to January 2019 for maize, sorghum, rice, and pasture grass sites in Ghana

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Maize	7.46 ± 0.94 a	0.17 ± 0.07 a	2.2
Rice	2.42 ± 0.38 b	0.46 ± 0.11 a	15.9
Sorghum	0.77 ± 0.17 c	0.23 ± 0.08 a	22.9
Pasture grass	0.13 ± 0.06 d	0.31 ± 0.09 a	71.4
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	4.18 ± 0.57 a	0.34 ± 0.07 a	7.6
4C	1.21 ± 0.24 b	0.24 ± 0.06 a	16.5

Pheromone lures included three component (3C) and four component (4C) blends ($n = 96$; 8 dates × 4 crops × 3 blocks).

[a]Data were log ($Y + 0.01$) transformed; $F = 90.8$, df = 3, 175, $P < 0.0001$; means followed by the same letter are not significantly different.

[b]Data were $(Y + 0.01)^{-2}$ transformed; $F = 1.96$, df = 3, 175, $P = 0.1215$; means followed by the same letter are not significantly different.

[c]Number of bycatch moths/total number of moths captured × 100.

[d]Data were log ($Y + 0.01$) transformed; $F = 78.3$, df = 1, 175, $P < 0.0001$; means followed by the same letter are not significantly different.

[e]Data were $(Y + 0.01)^{-2}$ transformed; $F = 0.53$, df = 1, 175, $P = 0.4679$; means followed by the same letter are not significantly different.

Table 2. *Spodoptera frugiperda* and bycatch moths per trap per date ($n = 42$; 7 dates × 2 lures × 3 blocks) during September 2018 to January. 2019 for maize, sorghum, rice, and pasture grass sites in Togo

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Rice	16.8 ± 4.07 a	0.29 ± 0.10 a	1.7
Maize	5.31 ± 1.32 b	0.26 ± 0.10 a	4.7
Pasture grass	0.40 ± 0.17 c	0.12 ± 0.07 a	22.7
Sorghum	0.19 ± 0.07 c	0.19 ± 0.07 a	50.0
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	9.83 ± 2.22 a	0.25 ± 0.07 a	2.5
4C	1.54 ± 0.53 b	0.18 ± 0.06 a	10.4

Pheromone lures included three component (3C) and four component (4C) blends ($n = 84$; 7 dates × 4 crops × 3 blocks).

[a]Data were log ($Y + 0.01$) transformed; $F = 53.3$, df = 3, 152, $P < 0.0001$; means followed by the same letter are not significantly different.

[b]Data were $(Y + 0.01)^{-2}$ transformed; $F = 0.9$, df = 3, 152, $P = 0.4450$; means followed by the same letter are not significantly different.

[c]Number of bycatch moths/total number of moths captured × 100.

[d] Data were log ($Y + 0.01$) transformed; $F = 55.5$, df = 1, 152, $P < 0.0001$; means followed by the same letter are not significantly different.

[e] Data were $(Y + 0.01)^{-2}$ transformed; $F = 0.77$, df = 1, 152, $P = 0.3828$; means followed by the same letter are not significantly different.

Table 3. *Spodoptera frugiperda* and bycatch moths per trap per date (n = 60; 10 dates × 3 lures × 3 blocks) during September 2019 to January 2020 for maize and sorghum sites in Ghana

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Maize	5.25 ± 0.73 a	0.43 ± 0.09 a	7.6
Sorghum	0.80 ± 0.14 b	0.15 ± 0.05 b	15.8
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	4.78 ± 0.76 a	0.38 ± 0.08 a	7.4
4C	1.27 ± 0.22 b	0.20 ± 0.06 a	13.6

Pheromone lures included three component (3C) and four component (4C) blends (n = 60; 10 dates × 2 crops × 3 blocks).

[a]Data were log (Y + 0.01) transformed; F = 93.0, df = 1, 105, P < 0.0001; means followed by the same letter are not significantly different.

[b]Data were $(Y + 0.01)^{-2}$ transformed; F = 7.3, df = 1, 105, P = 0.0080; means followed by the same letter are not significantly different.

[c]Number of bycatch moths/total number of moths captured × 100.

[d] Data were log (Y + 0.01) transformed; F = 39.5, df = 1, 105, P < 0.0001; means followed by the same ltter are not significantly different.

[e]Data were $(Y + 0.01)^{-2}$ transformed; F = 3.2, df = 1, 105, P = 0.0746; means followed by the same letter are not significantly different.

Table 4. *Spodoptera frugiperda* and bycatch moths per trap per date (n = 60; 10 dates × 3 lures × 3 blocks) during September 2019 to January 2020 for maize and sorghum sites in Togo

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Maize	4.28 ± 0.58 a	0.40 ± 0.10 a	8.5
Sorghum	0.53 ± 0.11 b	0.13 ± 0.05 b	20.0
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	3.33 ± 0.58 a	0.37 ± 0.09 a	9.9
4C	1.48 ± 0.33 b	0.17 ± 0.06 a	10.1

Pheromone lures included three component (3C) and four component (4C) blends (n = 60; 10 dates × 2 crops × 3 blocks).

[a]Data were log (Y + 0.01) transformed; F = 94.6, df = 1, 105, P < 0.0001; means followed by the same letter are not significantly different.

[b]Data were $(Y + 0.01)^{-2}$ transformed; F = 4.6, df = 1, 105, P = 0.0335; means followed by the same letter are not significantly different.

[c]Number of bycatch moths/total number of moths captured × 100.

[d]Data were log (Y + 0.01) transformed; F = 19.2, df = 1, 105, P < 0.0001; means followed by the same letter are not significantly different.

[e]Data were $(Y + 0.01)^{-2}$ transformed; F = 2.8, df = 1, 105, P = 0.0970; means followed by the same letter are not significantly different.

Population Profiles in Crop Habitats

The data from traps baited with 3C and 4C lures in all crop systems were pooled and the total captures graphed over time during 2018 October to 2019 January (Fig. 2). In Ghana maize, fall armyworm numbers increased rapidly in October, peaked during November and December, and then declined sharply in January. In Togo maize, the increase to a peak and the following decline occurred 2–4 wk earlier than in Ghana. Numbers in rice systems in Ghana had a small peak at the end of October and then remained constant for the rest of the sampling period. In Togo rice, there was a consistent population increase from the initiation of trapping to the last sampling date, with the highest number of moths trapped in January 2019. Populations in sorghum and pasture grass were low throughout the sampling period.

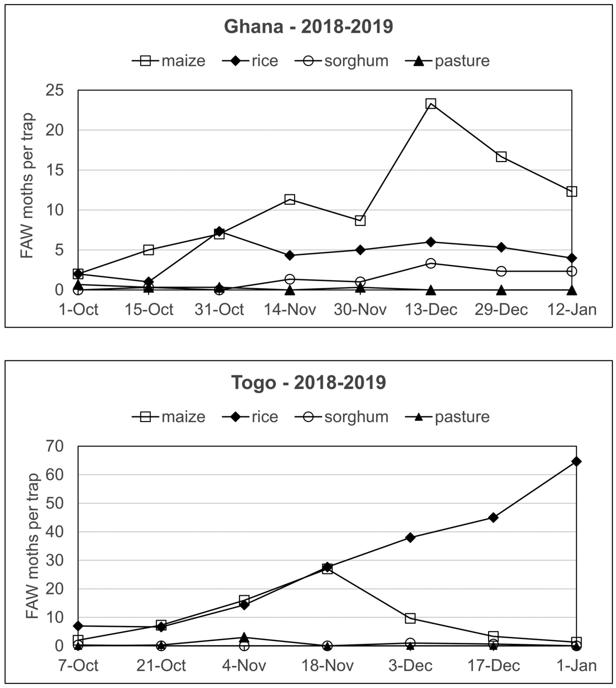

Fig. 2. Mean number of *Spodoptera frugiperda* (FAW) moths captured by pheromone-baited traps in four different crop systems during October 2018 to January 2019 in Ghana (top) and in Togo (bottom). For each data point, moths from both the 3C and 4C traps were combined, n = 6.

During 2019 September to 2020 January, trapping was conducted in only maize and sorghum systems (Fig. 3). In Ghana, relatively high numbers of moths were found in maize from mid-November through the end of December before declining. Like the year before in Togo, numbers of moths in maize were high from the end of October through the end of November, two weeks earlier than in Ghana. Traps in sorghum habitats captured low numbers of moths in both countries throughout the sampling period.

Comparison of 3C and 4C Lure Specificity

A comparison of lure specificity was obtained by analysis of bycatch lepidopteran trap captures that occurred contemporaneous with the fall armyworm collections. Based on past work, it was not expected that there would be much of a difference between lures in bycatch captures, but it was not known if different crop systems might contain higher populations of moth species other than fall armyworm. During 2018–2019, a total of 1472 fall armyworm moths were collected in the study plus 92 moths of other species. Thus 5.9% (92/(1,472 + 92)) of moths captured across crop systems and lures were not *S. frugiperda*. There was no difference in numbers of bycatch moths among crop systems or between lures (Tables 1 and 2), and none of the interactions were significant (P > 0.44). The percentage of moths collected that were bycatch in Ghana ranged from 2.2% (maize) to 71.4% (pasture grass), whereas in Togo, the range was from 1.7% (maize) to 50.0% in sorghum. During 2019–2020, a total of 652 fall armyworm moths were collected plus 67 bycatch moths (9.3%). However, more bycatch moths were found in maize than sorghum fields in both countries (Tables 3 and 4). As expected, the numbers of bycatch moths were similar in 3C-baited and 4C-baited traps. There was no significant interactions in either country between crop and lure (P > 0.23).

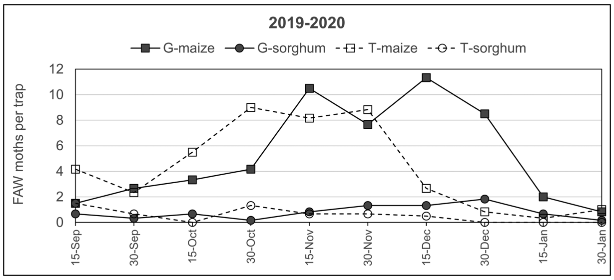

Fig. 3. Mean number of *Spodoptera frugiperda* (FAW) moths captured by pheromone-baited traps in two different crop systems during September 2019 to January 2020 in Ghana and Togo. For each data point, moths from both the 3C and 4C traps were combined, *n* = 6.

Discussion

Even though Ghana and Togo are countries with small land areas (Ghana is slightly smaller than the state of Oregon, United States; Togo is slightly smaller than the state of West Virginia, United States), they have a varied agricultural landscape from south to north. The maize, rice, and pasture sites were all located over 300 km to the south of the sorghum sites. This part of West Africa has two rainy seasons (April–July and September–November) and two dry seasons (August and December–March) (Koffi et al. 2020a) in the coastal areas, and one rainy season (April–September) and one dry season (October–March) in the north. The average temperature is between 25 and 30°C with annual rainfall of 1,100–2,400 mm and relative humidity of 85% in the south and 71% in the north (Koffi et al. 2020b), which means that fall armyworm would be able to have uninterrupted generations throughout both countries if host plants were available (Garcia et al. 2018).

There was substantial variation in the number of fall armyworm moths captured between maize and the other crop systems, reflecting differences in the attractiveness of the host plants (Meagher and Nagoshi 2004, Nagoshi and Meagher 2004, Unbehend et al. 2013), the geographical distribution of fall armyworm (Meagher et al. 2013), environmental conditions (Rojas et al. 2004), or a combination of these factors. During 2018–2019, capture rates in the maize fields were about 3-, 10-, and 60-fold higher than in rice, sorghum, and pasture grasses in Ghana, and 28- and 13-fold higher than sorghum and pasture grasses in Togo. Rice fields in Togo had threefold higher captures than maize fields, and populations increased through the end of the study with the highest numbers of moths per trap. During 2019–2020, capture rates in maize were about sevenfold higher than in sorghum fields in both countries. Our data compares to a 10-fold higher capture rate in maize than in sorghum in 2017 (Meagher et al. 2019).

This study agrees with previous indications that the 3C lure (Z9-14:Ac, Z11-16:Ac, and Z7-12:Ac) is more attractive to fall armyworm found in Togo (Meagher et al. 2019) than the 4C (with Z9-12:Ac) blend, and extends this finding to show that this effect is consistently true in multiple crop habitats in Togo and Ghana. In Mexico, a 3C lure was also reported to be one of the best pheromones for monitoring fall armyworm (Malo et al. 2001, 2004), although in the southeastern United States, the 4C lure generally attracted similar numbers (Meagher et al. 2013). The brand of the particular 3C lure we used was chemically analyzed in an earlier study and contained relatively high amounts of the Z7-12:Ac component (Meagher et al. 2013); however, the lures we used were not subjected to chemical analysis. Fall armyworm males from West Africa (Benin and Nigeria) showed higher antennal sensitivity to this component than males from the United States (Florida) (Haenniger et al. 2020). It is well known that the pheromone blend released by females and the response by males can vary by host strain and geographical region (Groot et al. 2008; Lima and McNeil 2009; Unbehend et al. 2013, 2014; Cruz-Esteban et al. 2020), so perhaps males in West Africa are more attracted to blends that have higher ratios of Z7-12:Ac.

Equally important for more efficient pheromone trapping are the findings on lure specificity, i.e., the proportion of bycatch moth compared to fall armyworm captures. Indeed, variations of pheromone components influence the number of the captured bycatch species (Meagher and Mitchell 1999, Spears et al. 2016). In our study the 3C-baited traps had 5.5% bycatch rate compared to 12.8% in the 4C-baited traps. The higher bycatch rates in 4C-baited traps and traps in sorghum and pasture grasses was a result of low numbers of fall armyworm, as the actual number of bycatch moths was slightly higher for 3C traps (99) than 4C traps (60). Our numbers are lower than the percentage of bycatch found in the earlier study, as 20.8% (3C) and 6.3% (4C) of trapped moths were not fall armyworm (using only data from Unitraps, Meagher et al. 2019). Producing lures that lower bycatch numbers is important in Africa to reduce the impact of potential false-positives through misidentification of species.

The comparison of the temporal capture profiles between Ghana and Togo, which have similar climate and cropping seasons that vary south to north, provides an opportunity to look at how populations develop over time. In both sampling years, there is an earlier increase and peak of fall armyworm in maize systems in Togo that preceded the equivalent change in Ghana populations by 1–4 wk. In 2018–2019, the peak in moth capture in Togo is 18 November, whereas in Ghana, it is 13 December (Fig. 2). In 2019–2020, there is a two-week lag from higher moth numbers in Togo than ones in Ghana (Fig. 3). These adult data agree with higher larval populations found in Togo than in Ghana (Koffi et al. 2020a). There is a possibility that fall armyworm in Togo, particularly in maize systems, could contribute to the seasonal infestation in Ghana, although much more information concerning moth populations, larval populations, cropping seasons, and wind patterns, will need to be documented. It is not known if this scenario in West Africa is similar to migration in the Western Hemisphere, where pheromone trapping can predict the arrival of migrating populations (Westbrook et al. 2019). The lead time for growers in Ghana for the information from Togo would be short; therefore, continued monitoring of fall armyworm population dynamics and an investigation into seasonal wind patterns between these two countries over additional years is needed to confirm this possibility.

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