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Species range of fruit flies associated with mango from three agro-ecological zones in Ghana

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ABSTRACT
Objective: A trapping exercise to assess the range of fruit fly species from mango orchards in three agro-ecological zones in Ghana (Coastal Savanna (CS), the Transitional (TT) and Guinea Savanna (GS) zones) where mango is commercially grown was undertaken for two successive fruiting seasons in 2009 and 2010.
Methodology and results: Using traps baited with three different attractants (Methyl eugenol (ME), Terpinyl acetate (TA) and Trimedlure (TML), a total of 39,011 fruit flies were collected, with 9,398 (24.1%) and 29,613 (75.9%) flies collected during the 2009 and 2010 seasons, respectively. Five fly species (in two genera), *Bactrocera invadens, B. cucurbitae, Ceratitis cosyra, C. ditissima* and *C. capitata* were identified. The highest relative fly densities (number of flies per trap per day, F/T/D) ranged from 1.86-31.40 and 16.25-121.39 in the 2009 and 2010 seasons, respectively.
Conclusion and application: The most abundant flies in all six localities of the three zones were *B. invadens*, followed by *C. cosyra* and *C. capitata*. Even though all three zones had three species in common, the proportions varied. These variations are important with respect to formulating management strategies to mitigate the fruit fly situation.
Key words: species composition, agro-ecological zones, fruit flies, attractants, relative fly density, Ghana

INTRODUCTION
There are 4,257 fly species in the family Tephritidae and of this number; about 1,400 species are known to develop in fruits (White and Elson-Harris, 1992). The family is grouped into 484 genera. The family includes 4,448 recognized species and subspecies of fruit flies. The actual number of species is much higher as many are yet to be described. Out of these, about 250 species already are or may become pests by inflicting severe damage to fruits of economic value (White and Elson-Harris, 1992; Ekesi and Billah, 2009). However, fruit flies of major economic importance in Africa can be divided into two categories, that is, indigenous species and invasive species, which are listed in Ekesi and Billah (2009). The invasive species among them are the Melon fly, *Bactrocera cucurbitae* (Coquillett), the Africa invader fly, *Bactrocera invadens* Drew, Tsuruta & White, the Solanum fly, *Bactrocera latifrons* (Hendel) and the Peach fruit fly, *Bactrocera zonata* (Saunders). The Marula fly, *Ceratitis cosyra*, (Walker) (Diptera; Tephritidae) was reported to be the key pest of mango across Africa prior to 2003 (Lux *et al.*, 2003a; Ekesi *et al.*, 2006). It is broadly distributed across Eastern, Central, Western, and also in parts of Southern Africa (Lux *et al.*, 2003a). However, in

2003, a new fruit fly species, morphologically very similar to *Bactrocera dorsalis,* (Hendel), was reported to be spreading rapidly in Africa (Lux *et al*, 2003b), and in certain situations, displacing some known indigenous species. This study was therefore aimed at cataloguing the species of fruit flies associated with mango orchards from three major ecological zones in Ghana where mango is commercially produced and determining their proportions and density levels in the field.

MATERIALS AND METHODS

Study site: The study was conducted in three major agro-ecological zones in Ghana: the Coastal Savanna (Ayenya No.1 and Akorley), the Transitional (Boasu-Wenchi and Ejura) and the Guinea Savanna (Dalun and Yag-yili) zones. Two mango-producing districts were selected, where a mango farm was chosen from each of them and geo-referenced for the field studies (Table 1).

Table 1: Geo-referenced readings of study sites.

Ecological Zone	Study Site	GPS Reading		
		Latitude	Longitude	Altitude (m)
Coastal Savanna	Akorley	06°02'17 N	000°00'20 W	81
	Ayenya No. 1	05°56'43 N	000°01'37 W	53
Transitional Zone	Ejura	06°02'17 N	000°00'20 W	130
	Boasu-Wenchi	05°56'43 N	000°01'37 W	299
Guinea Savanna	Yag-yili	09°19'48 N	000°51'40 W	158
	Dalun	09°37'54 N	001°00'22 W	130

Attractants and trap layout : Trapping was undertaken for two successive fruiting seasons in 2009 and 2010, using traps baited with three different attractants (Methyl eugenol, ME), Terpinyl acetate, TA) and Trimedlure, TML). The attractants were in the slow-releasing polymeric plug form. ME attracts *Bactrocera* and *Dacus* species, while TA and TML attract *Ceratitis* species (Ekesi & Billah, 2009). The plugs were dispensed in improvised 500ml mineral water bottle traps (Figure 1), with two windows (3×2) cm made on opposite sides of the bottles at 7cm from the top.

Figure 1: Improvised fruit fly trap used in the study.

The lid of the trap was perforated and a nylon thread knotted and passed through to prevent the thread from slipping through. A thin cotton thread was fastened to the nylon thread from the knotted end and the polymeric lure plug tied at the opposite end of the cotton thread. The suspended plug on the cotton thread was held inside the trap at 7cm from the knot. A strip of Dimethyl 2, 2-DichloroVinyl Phosphate (DDVP) was placed at the bottom of the trap as a killing agent to kill attracted insects that enter the trap. Each field had two (2) of each trap (that is, 6 per plot). In all, seventy two (72) attractant plugs (twenty four (24) of each type), were used for the three (3) agro-ecological zones for the two trapping seasons, with seventy two (72) strips of DDVP. Traps were hanged at heights of 2.0-4.0 m above the ground (depending on tree age and canopy architecture) and at a distance of 50 m apart to avoid interference with each other (Ekesi and Billah, 2009). Traps were placed in an alternating fashion in semi-shaded spots in the upwind part of the canopy, with branches and leaves near but not touching the traps to serve as landing places before entering the trap (Ekesi and Billah, 2009). Grease was applied to the middle-third portion of the nylon thread to prevent ants from preying on insect catches.

Fly catches and Identification: Traps were emptied weekly into plastic collection vials and preserved in 70% ethanol and transported to the laboratory at the African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon, where they were stored in a dark room to avoid discoloration of the catches. Identification was done using a Motic

SMZ-143 series light microscope. The insects were identified using the taxonomic keys developed by Billah *et al.* (2009). Voucher specimens of identified flies are deposited at the Entomology Museum of the Department of Animal Biology and Conservation Science, University of Ghana, Legon.

Data analysis: For relative fly abundance, counts were expressed as number of flies per trap per day (F/T/D) (IAEA, 2003) to facilitate comparison across the different localities and zones. Analysis of variance was performed using GENSTAT Release version 9.2, after the data had been log-transformed on the total number of different fruit fly species captured. Non-target captures were also analyzed.

RESULTS

Fruit fly captures: A total of 39,011 fruit flies were collected during the study, out of which 9,398 (24.09%) flies were collected during the 2009 season and 29,613 (75.90%) flies during the 2010 season. Five species of fruit flies (belonging to two genera) were identified, including *Bactrocera invadens* (Africa Invader fly), *Bactrocera cucurbitae* (Melon fly), *Ceratitis cosyra* (Mango fruit fly), *C. ditissima* (West African citrus fly), and *C. capitata* (Mediterranean fruit fly) (Figure 2.).

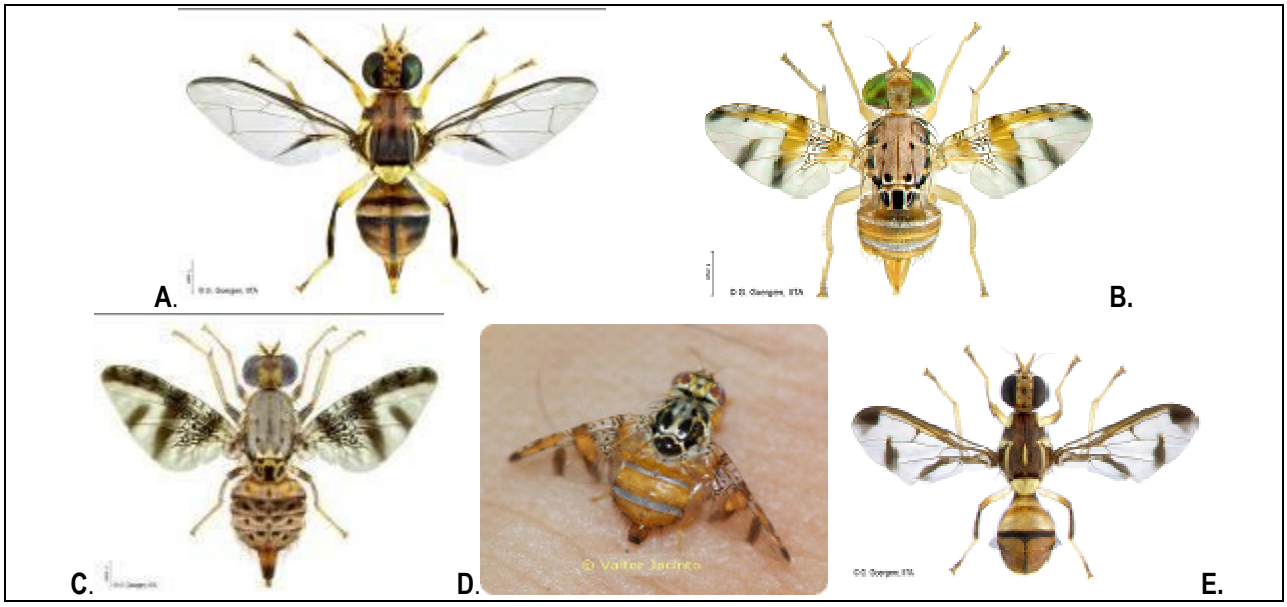

Figure 2: Fruit flies identified from the study. A = *Bactrocera invadens*, B = *Ceratitis cosyra*, C = *C. ditissima*, D = *C. capitata* and E = *B. cucurbitae*. (Sources of photos indicated on individual shots).

In the Coastal savanna zone, there was statistical difference between the number of *Bactrocera invadens, Ceratitis cosyra* and *Ceratitis capitata* collected from Akorley, and also between the two *Ceratitis* species during the 2009 season. In the 2010 season, *B. invadens* was significantly different from *C. cosyra*. No *C. capitata* was collected. In Ayenya No.1, *B. invadens* dominated the collections and there was no difference between the *Ceratitis* species for both seasons. A single specimen of *B. cucurbitae* was collected in an ME-baited trap. In the Transitional zone, only one species of *Ceratitis* (together with the dominant *B. invadens*) was recorded in the 2009 season in the two localities, while 3 and 2 *Ceratitis* species were recorded together with *B. invadens* in the 2010 season at Ejura and Boasu-Wenchi, respectively. These species included *C. ditissima,* which was recorded in both localities in the 2010 season. In the Guinea savanna zone, three species (*B. invadens, C. cosyra* and *C. capitata*) were consistently recorded in the 2 localities during the 2 seasons, and there were significant differences between the 3 species at each of the localities for the 2 seasons. In all cases, *B. invadens* was the dominant species, followed by *C. cosyra* and *C. capitata*. The relative abundance of flies ranged from 0.02-22.25 and 0.08-121.39 flies per trap per day in the Coastal savanna zone during the 2009 and 2010 seasons, respectively. Those in the Transitional zone

ranged from 0.02-31.40 during the 2009 season and 0.01-104.23 in the 2010 seasons. In the Guinea savanna zone, the ranges were 0.05-19.86 for the first season and 1.14-16.25 in the second season.

The highest density levels from the Coastal savanna zone in both seasons were recorded from Ayenya No.1, while Ejura recorded the highest density figures for the two seasons in the Transitional zone. In the Guinea savanna zone, Dalun also recorded the highest density figures for both seasons, but with a 20% decrease in density in the 2010 season. Ayenya No.1 and Ejura on the other hand, recorded increases in the 2010 season over the previous season, with differences of up to 5.5 times more (550%) and 3.3 times more (330%), respectively. The overall trend showed a population density range of 19.89-31.40 in the 2009 season and 16.25-121.39 in the 2010 season. Table 2 shows a summary of the data on the species of fruit flies collected during the study.

Table 2: Fruit fly catches (mean values) from traps and their relative density levels.

Location and Flies	2009 season		2010 season	
	Mean No. of flies	Flies/trap/day	Mean No. of flies	Flies/trap/day
Coastal Savanna Zone				
1. Akorley				
Bactrocera invadens (ME)	469.5 (2.67a)*	11.18	1,136.0 (3.06a)	27.05
Ceratitis cosyra (TA)	18.0 (1.28b)	0.42	4.0 (0.70b)	0.10
C. capitata (TML)	5.5 (0.81c)	0.13	0	-
LSD (P<0.005)	0.150		0.034	
2. Ayenya No.1				
Bactrocera invadens (ME)	934.5 (2.97a)	22.25	5,098.5 (3.71a)	121.39
C. Cosyra (TA)	3.0 (0.60b)	0.07	4.0 (0.69b)	0.10
C. capitata (TML)	1.0 (0.30b)	0.02	3.5 (0.65b)	0.08
*B. cucurbitae***	1.0	-	0	-
LSD (P<0.005)	0.004		0.260	
Transitional Zone				
1. Ejura				
Bactrocera invadens (ME)	1,319.0 (3.12a)	31.40	4,377.5 (3.64a)	104.23
C. cosyra (TA)	0	-	1.0 (0.30b)	0.02
C. capitata (TML)	1 .0 (0.30b)	0.02	0.5 (0.15b)	0.01
C. ditissima (TA)	0	-	1.0 (0.30b)	0.02
LSD (P<0.05)	0.004		0.296	
2. Boasu-Wenchi				
B. invadens (ME)	576.5 (2.71a)	13.73	2,456.5 (3.39a)	58.49
C. cosyra (TA)	3 (0.60b)	0.07	0	-
C. capitata (TML)	0	-	1.5 (0.39c)	0.04
C. ditissima (TML)	0	-	3.0 (0.60b)	0.07
LSD (P<0.05)	0.250		0.160	
Guinea Savanna Zone				
1. Yag-yili				
Bactrocera invadens (ME)	504.5 (2.70a)	12.01	654.0 (2.82a)	15.57
C. cosyra (TA)	5.0 (0.77b)	0.12	92.0 (1.97b)	2.19
C. capitata (TML)	2.0 (0.48c)	0.05	48.0 (1.69c)	1.14
LSD (P<0.05)	0.190		0.092	
2. Dalun				
Bactrocera invadens (ME)	834.0 (2.92a)	19.86	682.5 (2.77a)	16.25
C. cosyra (TA)	17.5 (1.27b)	0.42	199.0 (2.30b)	4.74
C. capitata (TML)	3.5 (0.65c)	0.083	48.5 (1.69c)	1.15
LSD (P<0.05)	0.130		0.056	

*Figures in brackets are means of the $\log_{10}(x+1)$ transformed raw values. **A single specimen of *B. cucurbitae* (not known to be attracted to ME) was discounted in analysis.

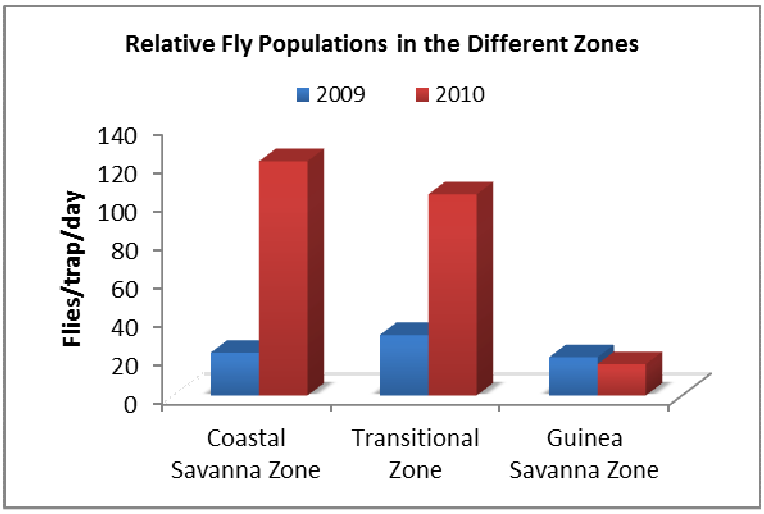

Figure 2: Highest fruit fly density levels attained from three agro-ecological zones in Ghana.

Non-target captures: Two hundred and seventy-one (271) non-target organisms in five orders (Coleoptera, Diptera, Hymenoptera, Orthoptera and Arachnida) were captured, with 93.4 % (253) coming from Methyl eugenol traps (Table 3). This was followed by a 4.1 % (11) contribution from Terpinyl acetate traps and the Trimedlure traps contributing 2.6 % (7). The non-targets formed only 0.61 % of the total number of organisms (39,011 + 271) collected and targeted flies 99.39 % (39,011). Diptera (flies) had the highest contribution, followed by Coleoptera (beetles and weevils), Orthoptera (grasshoppers, crickets and locusts), Hymenoptera (ants, bees and wasps) and Araneae (spiders) (Figure 3).

Table 3. Non-target catches and their percentage contributions (% in brackets).

Attractant	Non-target species					
	Araneae	Coleoptera	Diptera	Hymenoptera	Orthoptera	Total
Methyl eugenol	3	27	209	9	5	253 (93.4)
Terpinyl acetate	3	3	0	0	5	11 (4.1)
Trimedlure	1	0	3	0	3	7 (2.6)
Total	7 (2.6)	30 (11.1)	212 (78.2)	9 (3.3)	13 (4.9)	271

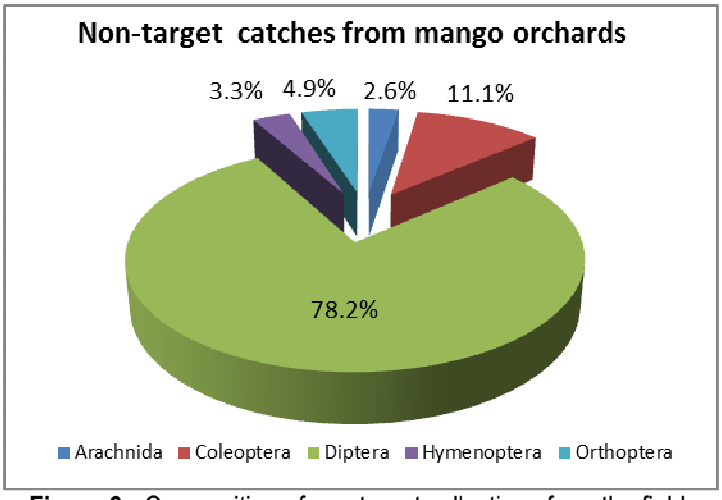

Figure 3: Composition of non-target collections from the field.

DISCUSSION

During the minor season of 2008, poor flowering and fruiting in mango was observed in the southern sector of the country, but started improving during the major season of 2009 (when the trial started). The situation, however, got better in 2010 and was expected to get back to normal by the close of the 2011 season (Stonehouse *et al*., 2008; Billah *et al*., 2009). It was therefore not surprising that a very high difference in the number of flies collected was observed in the two seasons of the Coastal savanna and Transitional zones (which are in the southern sector of the country), indicating the strong relationship between resource availability (fruits) and the number of flies. In the Guinea Savanna zone (in the northern sector of the country) however, the catches were comparable. Again, the very high difference in numbers in the southern sector zones (Coastal savanna and Transitional) collections and those from the Guinea savanna zone is as a result of the fact that the southern sector of the country enjoys what has been described as a 'double-maximum' or bi-modal regime of rainfall that occurs from March to July/August and from September to October/November, resulting in semi-deciduous and rain forest vegetation types in the southern sector thereby supporting a wild range of alternative fruits and providing sufficient reproductive base for the flies. With the high competitive ability and potential displacement capabilities of *B. invadens* (Ekesi *et al*., 2009), most of the other species tend to shift from mango onto other alternative fruits, which could be an indication of a gradual displacement trend in those localities. Prior to the arrival of *B. invadens* in Africa, *C. cosyra* was the major pest on mango Although the mango fly, *C. cosyra,* had widely been reported to be the major pest of mango before 2003 in Africa (Lux *et al*., 2003a, b; Ekesi *et al.*, 2006), the results from this study show that its presence in the mango orchards in Ghana is nearly absent. A 'single-maximum' or uni-modal regime is found in the northern sector (Guinea savanna zone), where there is only one rainy season from May to September. These regimes make Ghana enjoy two mango seasons in the southern sector and one in the northern sector.

During the long dry season from November to May in the northern sector (Guinea savanna zone), there is very little variety in terms of suitable alternative fruits to support high fly populations, leading to the low numbers recorded (Figure 2). With very little choice, the flies tend to share the same limited resources (mango) when they are available and hence, the relatively high proportion of the other species in the dry Guinea savanna zone.

B. invadens was the most dominant species, contributing to over 97.95-99.9% of flies collected in all localities and seasons, except for collections from the Guinea savanna zone in 2010, where *C. cosyra* and *C. capitata* contributed 22.48% of the collections. The dominance of *B. invadens* further corroborates the findings by Lux *et al.,* (2003a, b), Ekesi *et al.,* (2006), and Mwatawala *et al.,* (2009) that the mango ecosystem has been dominated by this pest since its introduction into Africa in 2003. Apart from the three species commonly recorded from all the localities, *C. ditissima* was recorded from the two localities in the Transitional zone. In Ghana, this species is known to be a major pest of citrus and is attracted to Methyl eugenol (ME) (White & Elson-Harris, 1992; Billah *et al*., 2009). A single specimen of the Melon fly, *B. cucurbitae* was recorded at Ayenya No. 1 in the Coastal savanna zone. The species, which is not known to be attracted to ME, might have come from the nearby vegetable farms that were observed in that locality. Ayenya No. 1 is noted to be a place where the local farmers, in addition to their mango plantations, they do cultivate other fruits and vegetables like cucumbers, melons and squash, pepper and tomatoes for export or to supply to the supermarkets in Accra. The invasive nature of *B. invadens* is demonstrated by the huge number of flies per trap per day recorded during the study as compared to the levels recorded in 2005 by Billah *et al.,* (2006), when the pest was first detected in Ghana.

Non-targets: Most of the flies collected were drosophilids, phorids, sphaerocerids and carrion-related ones (i.e. families that are known to be associated with rotting, decaying and/or fermenting organic matter). They were very tiny in size and were attracted in large numbers to the dead and decaying fruit flies in the traps. No beneficial organisms such as honey bees or fruit fly parasitoids were captured. All the Hymenoptera collected were foraging ants. A few predatory spiders, preying on arriving flies or spinning their web around the trap entrances, were knocked down by the killing agent (DDVP) in the traps (especially when traps were left for long periods (3-7 days).

CONCLUSIONS

In all six locations, catches of *B. invadens* were dominant over the other species, followed by *C. cosyra* and *C. capitata. B. cucurbitae* and *C. ditissima* were the least in numbers, and were limited to the Coastal savanna and Transitional zones. In the Coastal zone, Akorley and Ayenya No.1 recorded three (*B. invadens, C. cosyra* and *C. capitata)* and four (*B. invadens, B. cucurbitae, C. cosyra* and *C. capitata*) species, respectively. Even though *B. cucurbitae* is not known to be attracted to ME, the presence of the single specimen in the ME trap suggests a relatively high population in the area. In the Transitional zone, the two localities (Ejura and Boasu-Wenchi) recorded four species of the same kind - B. *invadens, C. cosyra, C. ditissima* and *C. capitata.* The Guinea Savanna zone (Yag-yili and Dalun) also recorded three species of the same kind - *B. invadens, C. cosyra* and *C. capitata*. Catches of *C. cosyra* and *C. capitata* in the Guinea Savanna zone were higher than those from the Coastal Savanna and Transitional zones. *C. ditissima* was only recorded in the Transitional zone (and has been reported in the Coastal savanna zone), there is no record of its presence in the Guinea savanna zone in Ghana (Billah *et al*., 2010). The species is known to be a major pest in citrus - a crop which is not known to do well in the dry Guinea Savanna zone. Even though all three zones had three species in common, the proportions varied. This is important information to consider when formulating management strategies.

It can be said that the attractants used were highly specific and had very minimal effect on non-targets. The non-target collections may more or less be as a result of their feeding and breeding activities rather than as a result of their direct attraction to the attractants used. No reasons could be assigned to the presence of beetles and crickets in the traps, and future consideration of a study in that aspect is warranted. The current management situation in Ghana is mainly targeted at *B. invadens*, with the use of only Methyl eugenol in traps. To mitigate the situation, adoption of an integrated management strategy (including attractants that target the other species), will be the best option for their management in the country.

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