A Safe Haven or a Temporary Alternative Host? - The Displaced Mango Fruit Fly, *Ceratitis cosyra* in the African Peach Plant

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Abstract

One of the difficulties in controlling fruit flies in cultivated crops is the use of alternative host plants as refugia when the preferred hosts are not in season. This study was aimed at collecting fruits and vegetables in localities across the five northern regions of Ghana (Northern, North-East, Savannah, Upper-East, and Upper-West regions) to catalogue the diversity of fruit flies and their host plants. A total of 1,722 fruits from all localities across the five regions were incubated, with 29.13% turning out to be fly-positive, yielding 1,141 individuals in four genera (*Bactrocera*, *Ceratitis*, *Dacus*, and *Zeugodacus*) and four species (*Bactrocera dorsalis* (Hendel), *Ceratitis cosyra* (Walker), *Dacus bivittatus* (Bigot), and *Zeugodacus cucurbitae* (Coquillet)). The African Peach plant, *Nauclea latifolia*, showed the highest incidence level of infestation, with the Mango fruit fly, *Ceratitis cosyra* as the dominant species, accounting for 97.19% (974) of the flies. The Oriental fruit fly, *Bactrocera dorsalis* and the Melon fly, *Zeugodacus curcurbitae* accounted for 1.23% (14 each), and *Dacus bivittatus* 0.35% (4). With evidence of displacement of *C. cosyra* from mango by the invasive *Bactrocera dorsalis* in most African countries, our results point to a plant that has hitherto not been known to be associated with fruit flies in Ghana for the displaced Mango fruit fly. Since information of previous fruit fly records is scanty, especially in the northern parts of the country, it is not known whether the African Peach has always been a host plant to *C. cosyra*, and served as a suitable alternative host during the long dry season, or is pointing to the new home after its displacement by *Bactrocera dorsalis*. There is therefore the need for an extended all-year-round collection to ascertain the host status and pattern of utilization of the African peach, as well as confirm the suspected host shift and displacement status of *C. cosyra*.

Keywords: *Ceratitis cosyra*; *Bactrocera dorsalis*; displacement; host shift; alternative host; African peach, *Nauclea latifolia*

Introduction

Fruits flies (Diptera: Tephritidae) cause enormous losses through direct damage to fruits and vegetables. Larvae that feed and develop within the fruit cause the most damage. They also introduce bacteria and fungi which facilitates rotting in infested fruits causing them to fall to the ground prematurely (Christenson and Foote, 1960; Fletcher, 1987). Losses of up to 40 % have been recorded in mango in East Africa and 12-50 % in Benin (Lux et al., 2003a; Vayssières et al. 2005). Loss of lucrative market opportunities results from imposition of strict quarantine regulations by importing countries to prevent entry and establishment of fruit flies. This situation is further aggravated by the introduction of the invasive species *Bactrocera invadens* of Asian origin into mainland Africa. Despite the economic significance associated with these insects, knowledge of their host spectrum remains scanty especially for northern Ghana. One of the difficulties of controlling these fruit flies is the fact that when major crops of economic importance such as mango,

cashew and shea nuts are not in season, they find refuge in alternative host plants till their preferred host plants are in season. This study was aimed at cataloguing the host ranges of fruit fly species, their preferred host plants and any natural enemies associated with them from both cultivated and wild fruits and vegetables from the five northern regions of Ghana. The information will help to plan effective fruit fly management strategies. Knowledge of associated biological control agents will also be useful in understanding where they live during the crop off-season.

Materials and methods

Study area

Northern Ghana is located within latitudes 8°- 11°N and longitudes 0.5°-3°S. This area consists of the Northern, North-East, Savannah, Upper-East, and Upper-West regions. It is bordered to the north by Burkina Faso, East by Togo, West by the Ivory Coast, and in the south by Ghana's Brong-Ahafo region (to the west), Bono East region (in the middle), and the Oti region (to the east) (Figure 1). The northern regions are located in the guinea savannah vegetation belt. The vegetation consists of grass with scattered drought resistant trees such as the shea, the baobab, and neem trees. Major cultivated crops include mango and cashew. There are two main seasons, the dry and the wet seasons. The wet season commences from early April and ends in October. The dry season, characterized by the cold and hazy harmattan weather, starts from early November and ends in the latter part of March when the hot weather begins, with intensity and ends only with the onset of the early rainfall in April. Temperatures fall to as low as 15 °C in the night during the harmattan season and as high as 40 °C in the day during the host season.

Fruit collection and incubation

Fruits were sampled at the beginning of the dry season in November when major cultivated fruits such as mango, cashew and shea nuts were out of season. Fruits were sampled randomly throughout the study period. Due to the fact that this program had no definite sampling interval as a result of variation in fruit availability during the sampling period, number of fruit samples collected varied considerably, and only from areas where trees were fruiting. The number of fruits in each sample and the number of samples incubated depended mainly on fruit availability and abundance. Fruits were sampled from backyard gardens, roadside, forest areas, orchards, and irrigated farmlands. Fruits from each sample

Figure 1 Map of the five northern regions of Ghana and their boundary regions.
(Modified from source: https://www.ghanamissionun.org/wp-content/uploads/2020/09/Ghana_Regional_Map.png)

were kept in plastic bags with labels indicating sampling number, locality, sampling date and fruit name, if known. In the laboratory, fruits in each sample were counted, weighed and each set of the same fruits kept in the same chamber for bulk incubation. The incubation chambers were made from plastic containers measuring 18 cm x10 cm x 13.5 cm. Holes were made at the base of one of the plastic containers. A section of the cover was cut open and fitted with an organza material for ventilation purposes. This container was then nested into another container provided with moistened sand (Figure 2). Prior to usage, the sand was sieved to remove debris and gravels, washed to remove dust and heat-sterilized at 100 °C for 2 hours. Duplicate labels of the ones made in the field were affixed to incubation chambers. Occasionally samples were sprinkled with water as and when needed to prevent fruits from drying up. Incubation chambers were observed at 3-day intervals for puparia, and any puparia collected were counted, kept in petri dishes lined with moistened filter papers, and held in holding cages till fly and/or parasitoid emergence. Holding cages were made from 3 mm thickness perspex sheets with measurements 14 cm x 15 cm x 10 cm. Circular holes (8-10 cm diameter) were made on one side of each cage and fitted with a fine netting sleeve to provide easy access to flies in the cage by hand. One side of each cage was also covered with a netting material to enhance ventilation. Petri dishes in cages were checked daily for fly and/or parasitoid emergences, which were then counted and released into appropriately designated cages (Figure 3). Fly cages were provided with artificial diet of

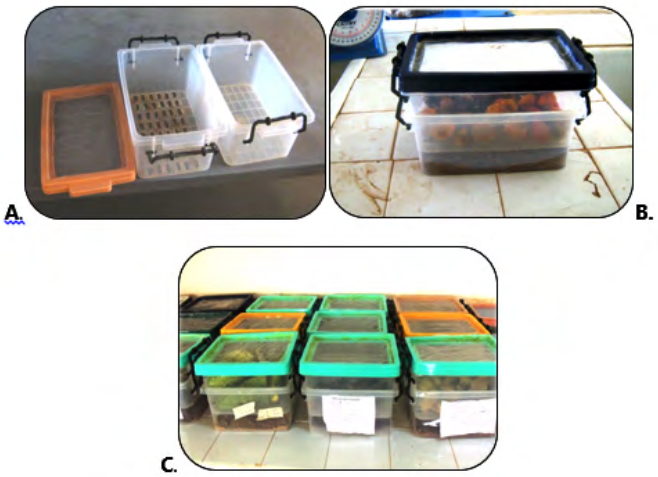

Figure 2 Improvised plastic containers used as incubation chambers. A = Plastic containers with holes made in the bottom of one (to hold fruits) and the other left intact (to hold sand). Lid of one cut and fitted with netting material for ventilation, B = Nested incubation chamber with fruits, C = Arrangement of labeled incubated chambers in a rearing room

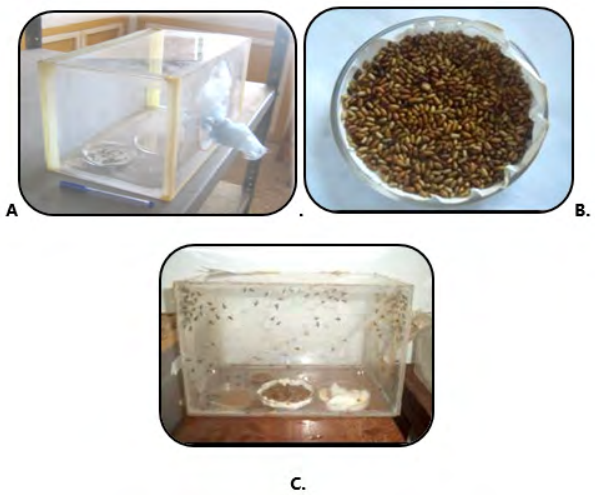

Figure 3 Cages for holding puparia and flies from incubated fruits. A = Cage for holding petri dishes with puparia, B = Freshly-collected puparia in a petri dish lined with filter paper, C = Emergence of flies in a Holding cage

hydrolysate yeast and sugar in a ratio of 1:3, while parasitoid cages were provided with a streak of pure honey on the inside of the top side of each cage. Two balls of cotton wool were also provided - one soaked in a 20% honey solution and the other in water (Ekesi and Billah, 2007). Emerged insects were held for at least four days (to ensure development of full adult features) before they were freeze-killed and preserved in 70% ethanol for subsequent identification.

Identification of materials

Plants were identified by staff of the Herbarium of the Plant and Environmental Health Department of the University of Ghana, Legon, while fruit flies and their natural enemies were identified using keys by Billah et al. (2007), with the help of a digital Leica EZ 4HD stereomicroscope.

Data analysis

Infestation indices were calculated in two different ways (i) by dividing the total number of puparia obtained in a given sample by the number of fruits in the sample (puparia per fruit); and (ii) by dividing the total number of puparia by the total mass (g) of fruits in the sample (puparia per kg) as international standards require (IAEA, 2003, 2009).

Results

From 103 samples, a total of 1,722 fruits and vegetables were collected, weighing 50.98 kg, and representing 15 species in 11 plant families (Table 1). Fruit flies emergence was detected in 30 field samples (29.13%), producing a total of 1,141 individuals from four fruit fly genera (*Bactrocera*, *Ceratitis*, *Dacus* and *Zeugodacus*) and four species (Table 1) - *Bactrocera dorsalis* (Hendel), *Ceratitis cosyra* (Walker), *Dacus bivittatus* (Bigot), and *Zeugodacus cucurbitae* (Coquillet). Out of the identified flies, 1,109 were *C. cosyra* representing 97.19%, 14 individuals each of *B. dorsalis* and *Z. cucurbitae* - representing 1.23%, while 4 individuals of *D .bivittatus* were recorded, representing 0.35% (Table 2). The highest level of infestation was recorded by *C. cosyra* reared from *Nauclea latifolia*. It was the highest in both puparia per fruit and puparia per gram (Table 2). *Ceratitis cosyra* was recorded in four of the five northern regions (Northern, Savannah, Upper-East, and Upper-West) where fruits were collected, with the highest average level of infestation in terms of puparia per fruit recorded from the

TABLE 1

List of sampled hosts, indicating number of samples and total weight of each sample

Host Plant	Common and/or Vernacular Name	Family	No. of samples	Weight (kg)
Mangifera indica	Mango	Anacardiaceae	1	0.85
Carica papaya	Pawpaw	Caricaceae	1	0.65
Cucumeropsis mannii	White seed melon or "Egushi"	Cucurbitaceae	1	0.50
Luffa aegyptiaca	Vietnamese gourd or Sponge gourd	Cucurbitaceae	7	6.70
Diospyros mespiliformis	Jackalberry or African Ebony	Ebenaceae	10	5.75
Strychnos spinosa	The Spiny or Green Monkey Orange	Loganiaceae	5	4.50
Ficus sur	Cape fig or Broom cluster fig "Kankana"	Moraceae	34	10.00
Ziziphus abyssinica	-	Rhamnaceae	1	0.20
Ziziphus mauritiana	Jujube or Indian plum	Rhamnaceae	1	0.35
Gardenia ternifolia	"Kundozugo"	Rubiaceae	2	0.75
Nauclea latifolia	African Peach	Rubiaceae	31	17.55
Blighia sapida	Akee apple	Sapindaceae	4	1.90
Pachystela brevipes	-	Sapotaceae	1	0.10
Capsicum annum	Pepper	Solanaceae	2	0.18
Lycoperiscum esculentum	Tomato	Solanaceae	2	1.00
		Total	**103**	**50.98**

TABLE 2
Host plants that were positive for fruit flies and levels of infestation by species

Family	Host Plant	No. fruits	Weight (g)	No. puparia	Puparia/fruit	Puparia/g	No. flies	Fruit Fly Species			
								C. cosyra	*B. dorsalis*	*D. bivittatus*	*Z. cucurbitae*
Cucurbitaceae	*Luffa aegyptiaca*	26	6,700	36	1.38	0.010	18			4	14
Ebenaceae	*Diospyros mespiliformis*	579	5,250	10	0.02	0.002	8		8		
Moraceae	*Ficus sur*	512	9,650	32	0.06	0.003	31	31			
Rhamnaceae	*Ziziphus mauritiana*	121	350	24	0.20	0.070	6		6		
Rubiaceae	*Nauclea latifolia*	290	13,670	2,505	8.64	0.180		1,078			
Total number of flies							1,141	1,109	14	4	14
Percentage Emergence								97.19	1.23	0.35	1.23

TABLE 3
Level of infestation of African Peach by *C. cosyra* from the four northern regions

District	Locality	No. fruits	Weight (g)	No. puparia	Puparia per fruit	Puparia per g
		Northern Region				
Gushiegu	Gushiegu	17	750	119	7.00	0.16
Gushiegu	Gushiegu	12	600	197	16.42	0.33
Yendi	Yendi	9	1500	242	26.89	0.16
Yendi	Puriya	8	750	54	6.75	0.07
Tolon-Kumbungu	Gbrimani	4	550	125	31.25	0.23
Karaga	Karaga	11	450	91	8.27	0.20
Karaga	Gaa	13	200	28	2.15	0.14
Karaga	Digblah	9	950	115	12.78	0.12
Total		**83**	**5,750**	**971**	**11.70**	**0.17**
		Savannah Region				
East Gonja	Kpabulsi	17	1950	266	15.65	0.14
West Gonja	Mole	3	100	89	29.67	0.89
West Gonja	Achuburnyo	10	450	53	5.30	0.12
Central Gonja	Yapei	14	650	218	15.57	0.34
Central Gonja	Buipe	16	450	65	4.06	0.14
Central Gonja	Buipe	7	200	7	1.00	0.04
Central Gonja	Buipe	12	120	19	1.58	0.16
Central Gonja	Buipe	5	350	30	6.00	0.09
Bole-Bamboi	Bamboi	10	400	218	21.80	0.55
Bole-Bamboi	Banda-Nkwanta	3	300	27	9.00	0.09
Bole-Bamboi	Malawe	4	350	132	33.00	0.38
Bole-Bamboi	Sakpa	6	150	15	2.50	0.10
Bole-Bamboi	Kiape	12	250	23	1.92	0.09
Bole-Bamboi	Gboddae	7	250	22	3.14	0.09
Bole-Bamboi	Mankuma	21	550	148	7.05	0.27
Total		**147**	**6,520**	**1,332**	**9.06**	**0.20**
		Upper-East Region				
Bawku East	Tilli	7	300	36	5.14	0.12
Bawku West	Zebillah	14	250	8	0.57	0.03
Builsa	Kpabense	12	250	23	1.92	0.09
Total		**33**	**800**	**67**	**2.03**	**0.08**
		Upper-West region				
Sissala East	Sakai	17	250	47	2.76	0.19
Sissala West	Lilixsi	10	350	88	8.80	0.25
Total		**27**	**600**	**135**	**5.00**	**0.23**

Northern region (11.7 puparia/fruit), followed by the Savannah region (9.06 puparia/fruit), Upper-West region (5.0 puparia/fruit), and the least from the Upper-East region (2.03 puparia/fruit) (Table 3). Both *B. dorsalis* and *C. cosyra* were recorded from two host plants belonging to two different families. *Luffa aegyptiaca* was the only host plant that recorded two fruit fly species, *D. bivittatus* and *Z. cucurbitae*.

Discussion and Conclusion

Even though a comprehensive catalogue of host plants of fruit flies does not exist in the country, especially for the fauna of northern Ghana (Billah, unpublished data), studies by Oyinkah (2012), Nboyine (2012), and Badii et al. (2014, 2015a,b) are good enough to form the basis of building a comprehensive database for the region. These findings may serve as new records of fruit fly host plants in the northern regions, and add up to the numerous discrete host record data scattered in Ghana. Aside from *Luffa aegyptiaca*, from which *D. bivittatus* and *Z. cucurbitae* have reportedly been reared, all the other host plants may be new records as White and Elson-Harris (1992) did not list them as host plants. This is particularly important especially for the recording of *B. dorsalis* from the African Ebony plant, *Diospyros mespiliformis* and the Jujube or Indian plum plant, *Ziziphus mauritiana*. These plants belong to two different families supporting the polyphagous nature of this recently introduced invasive species to the African continent and elsewhere (Clark et al., 2005; Rwomushana et al., 2008; Oyinkah, 2012; Badii et al., 2014, 2015a, 2015b; Billah & Wilson, 2016; Rwomushana & Tanga, 2016; Tanga & Rwomushana, 2016). With evidence of a displacement of *C. cosyra* by *B. dorsalis* in mango (Ekesi et al., 2009), the detection and recording of the high numbers of *C. cosyra* in the African peach plant, *Nauclea latifolia* may be an indication of a new home for *C .cosyra* or suitable alternative host plant, especially during the long dry season in Ghana. The African peach plant, *Nauclea latifolia* is found in the Sudano-Guinean agro-ecological zone, which is abundantly available in all inter-tropical Africa, and its distribution has been confirmed in the four regions in northern Ghana. Discussions about pest invasions, new host records, and host ranges have always involved consideration of agro-ecological zones, proper sampling methodologies, and careful taxonomic considerations (Lux et al., 2003b; Clark et al., 2005; Ekesi and Billah, 2007; Nboyine et al., 2012; Mwatawala et al., 2006, 2009a, 2009b, 2015).

This observation should be the subject of critical investigation to identify the factors contributing to the variability in dominance of *C. cosyra* in the different agro-ecological zones (Papadopoulos, 2014). One possible reason for this could be the ability of *C. cosyra* to use wild hosts such as the African peach, *Nauclea latifolia* Smith, False yam, *Icacina senegalensis Juss*. and the Broom cluster figs, *Ficus sur* Forsk. in the northern regions. These important wild hosts should be considered in future fruit fly management strategies in that region, considering the fact that they were sampled around mango plantations. These plants may thus be serving as alternative hosts for *C. cosyra*, particularly during the dry seasons (Billah & Wilson, 2016). The three host plants, which are shrubs/small trees of about 4 m high, are abundant in the dry savanna zones, and could be important refugia for *C. cosyra*, should the displacement trend in mango continue. It would, therefore, be very important to sample fruit flies across different agro-ecological zones and compare infestation levels all-year-round to confirm the potential alternative host status of these wild plants for *C. cosyra*. Until these studies have been conducted, it still remains as a preferred host plant of *C. cosyra*. The African peach therefore may be an important host plant to be considered in the formulation or development of strategies for the management of fruit flies, since it produced over 97 % of the displaced pest. This may also indicate the crucial need for all-year-round surveys to determine the population dynamics of fruit flies associated with those plants.

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