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Research Article

FLUCTUATIONS OF BACTROCERA DORSALIS HENDEL (DIPTERA: TEPHRITIDAE) AND CERATITIS COSYRA WALKER (DIPTERA: TEPHRITIDAE) IN THREE TYPES OF PLANT FORMATIONS DURING THE MANGO FRUITING SEASON IN WESTERN BURKINA FASO

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A B S T R A C T

This study was carried out during two consecutive mango seasons (2017 and 2018) in six localities, Western Burkina Faso. It aimed at assessing the fluctuations of *Bactrocera dorsalis* Hendel (formerly classified as *Bactrocera invadens*) and *Ceratitis cosyra* Walker populations in three types of plant formations (mango orchards, agroforestry parks and natural fallows). A trapping system experiment consisting of 144 Tephri Trap types operating with two types of parapheromones including methyl eugenol, terpinyl acetate and an insecticide, the Dichlorvors (DDVP) which were used for attracting and killing insect pests. The results revealed that the two fruit fly species fluctuate in a similar way in the three types of plant formations. The average catch indices (FTD) of each of the two tephrid species were approximately equal at each survey date in the three types of plant formations. We did not observe any significant difference between the three types of plant formations in the FTD. However, the higest populations levels of *B. dorsalis* were recorded in the agroforestry parks (35.84 ± 7.08 and 47.09 ± 6.49 FTD in 2017 and 2018, respectively) and the lowest FTD were observed in natural fallows (28.63 ± 6.14 and 38.50 ± 7.49 FTD in 2017 and 2018, respectively). The highest FTD of *C. cosyra* were recorded in mango orchards during the two consecutive mango seasons (10.63 ± 3.81 and 15.80 ± 6.95 FTD in 2017 and 2018, respectively) and its lowest population levels were obtained in the agroforestry parks (4.63 ± 1.55 and 5.94 ± 2.16 FTD in 2017 and 2018, respectively). The implementation of control methods only in the mango orchards during the mango fruiting season does not ensure the effective and sustainable control of these insect pests.

INTRODUCTION

Tephritid fruit flies, or 'true' fruit flies (Diptera: Tephritidae), include approximately 500 genera and 4800 valid species, the vast majority (95%) of which are phytophagous (Aluja and Norrbom 1999). Of all tephritid species 25-30% are frugivorous. In Africa, there are approximately 400 species of frugivorous tephritids of which more than 50 are economically important (Virgilio *et al*. 2014). Economically importanttephritid fruit flies in Africa are distributed within three genera: *Bactrocera* Macquart, *Ceratitis* MacLeay and *Dacus* Fabricius (White and Elson-Harris 1992). Mango (*Mangifera indica* L.) is the most widely cultivated fruit tree in the Sahel and one of the most important tree crops in tropical and sub-tropical Africa (Rwomushana *et al*., 2008). In Burkina Faso, Mango is the main cultivated fruit tree representing 62.50% of domestic fruit production (Ouédraogo *et al*. 2010).

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However, the sustainability of this lucrative business is threatened by infestations of fruit flies that annually inflict heavy economic losses to the industry. According to Ouédraogo (2011), seven fruit fly species attack mango fruits including *Bactrocera dorsalis* Hendel and *Ceratitis cosyra* Walker which are responsible for about 96% of damage recorded on mangoes in Western Burkina Faso. Since then, control options are deployed in the mango orchards during the mango season. These control products specificaly target *B. dorsalis* and *C. cosyra* in mango orchards during the mango season. However, in Western Burkina Faso, the mango orchards are surrounded by other plant formations such as agroforestry parks and natural fallows. The research questions are therefore (i) What is the distribution of these two fruit fly species in the three types of plant formations (mango orchards, agroforestry parks and natural fallows) during the mango fruiting season? (ii) Does the application of control methods only in the mango orchards contribute to the effective and sustainable control of these insect pests during the mango season?

MATERIALS AND METHODS

Study sites

The study was carried out in six localities belonging to three provinces (Fig. 1) during the two consecutive mango seasons (from May to July) in 2017 and 2018 in Western Burkina Faso: Koloko and Badara in Kénédougou province; Dindéresso and Péni in Houet province; Bérégadougou and Toumousséni in Comoé province. Table 1 presents the GPS coordinates of the localities of the study sites. In each site, three types of plant formations were selected for data collection: a natural fallow, a mango orchard and an agroforestry park. This study zone belongs to the South-sudanian climatic zone and is characterized by an annual average rainfall between 900 and 1,200 mm and average monthly temperatures ranging from 25 to 32 °C. There is an alternation of two distinct seasons: a wet season that lasts for five to six months (from May to October) and a dry season including a cold period from December to February and a hot period from March to May in this area. Figure 2 shows the average monthly rainfall in the Comoé, Houet and Kénédougou provinces during the study period. Weather data were obtained from the National Agency of Meteorology (Burkina Faso).

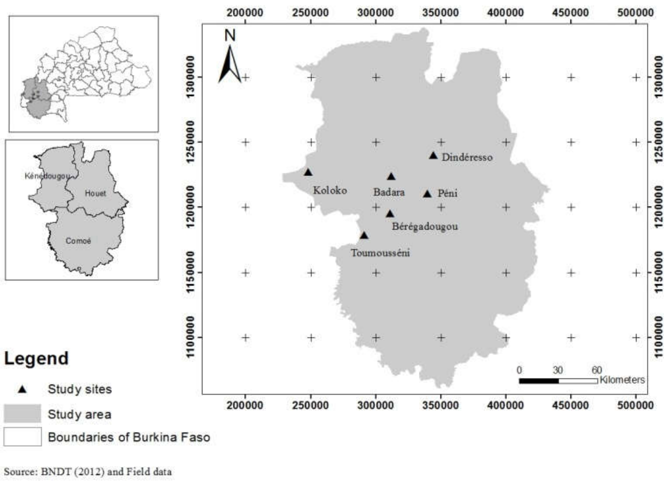


Figure 1 Localisation of the study sites

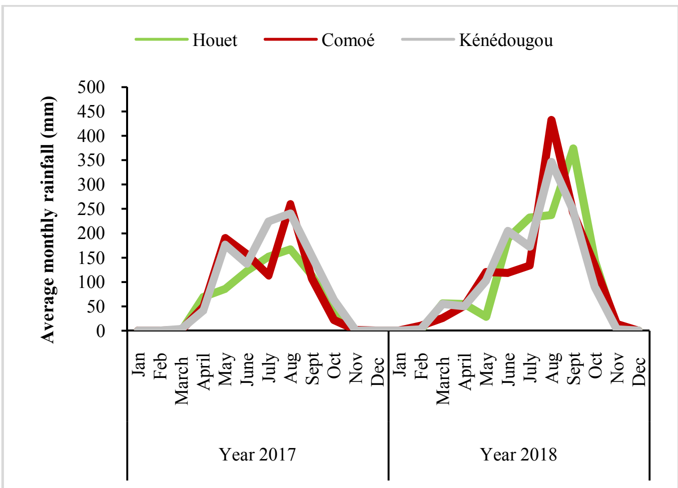


Figure 2 Average monthly rainfall in the three provinces during the study period

Table 1 GPS coordinates of the localities of the study sites

Region	Province	Study sites	GPS Coordinates		Altitude (m)
Hauts Bassins	Houet	Dindéresso	11°21'93.2" N	4°42'55.7'' E	348
		Péni	10°96'36.3" N	4°44'52.6" E	501
	Kénédougou	Badara	11°05'85.3" N	4°71'75.3" E	449
		Koloko	11°09'32.6" N	5°30'15.9" E	510
Cascades	Comoé	Bérégadougou	10°81'75.0" N	4°72'63.9" E	402
		Toumousséni	10°65'89.7" N	4°90'90.8" E	294

METHODS

Mass trapping

Trap used in this study were Tephri Trap types (SORYGAR S.L. Quinta delSol nº 37 Las Rozas, Madrid 28230 España). This is a yellow cylindrical container with an opaque lid. The trap has four equidistant openings (2.8 cm in diameter) on the upper third. The capacity of the Tephri trap was 450 cm^3 and its dimensions were: total height, 142 mm; yellow base diameter, 110 mm; height of top, 40mm; holes diameter, 22 mm and invaginated hole diameter, 26mm.

The attractants used for insect capture were two male lures solid (parapheromones): (i) terpinyl acetate(2-(4-Methyl-3-cyclohexenyl)-2-propyl Acetate) was used to attract *Ceratitis cosyra* (Walker) and related species; (ii) methyl eugenol (4-allyl-1,2-dimethoxybenzene) for *B. Dorsalis* Hendel and representatives of the subgenus *Pardalaspis*.

Experimental layout

During this study, a total of 144 Tephri Trap types were hung on tree branches at 1.5-2 m above the ground in the six mango orchards, the six agroforestry parks and the six natural fallows for insect capture over two consecutive mango seasons (2017 and 2018). At each of the six sites, twenty-four traps were implemented, i.e. eight traps per plant formation. In each plant formation, a trap containing the same male lure was repeated four times. The experimental design was a completely randomized block with two treatments and four repetitions. Distance between the rows was approximately 50 m (every 5^{th} row), and distance between the traps within the row was approximately 20 m (every 2^{nd} tree) in mango orchards and agroforestry parks. In natural areas, distances between rows and between traps varied according to the distribution of the trees. However, the minimum distance was 50 m between lines and 10 m between traps. Each trap contained a single attractant with an insecticide, Dichlorvos strip (Dichlorvos (0,0 - diméthyl-0-(2,2-dichloro) phosphate) (DDVP) to kill any attracted fly. The attractant was set up on a support in the upper part of the trap and the insecticide in the lower part. The central coil of wire holding up the trap was coated with thick grease to prevent any predatory activity on dead adult flies in the bottom of the trap. Traps were checked for fruit flies and emptied on a two weeks basis thereafter. Specimens collected in traps were emptied in vials which were labelled by site, trap/attractant type, plant formation and date of checking. All attractants and all DDVP were replaced after 4 weeks. Precautions were observed during trap placement and servicing in the field to prevent cross-contamination of attractant dispensers and traps.

Fruit fly identification

Fruit fly adults were identified using published identification keys. *Bactrocera dorsalis* samples were identified using the key by White (2006), while other fruit fly species were identified to either genera or species level using an electronic key (Virgilio *et al*. 2014). The number of specimens of each fruit fly species was recorded.

Data processing and analysis

Average catch indices were calculated by survey date to assess population density of each fruit fly in plant formations during the study period. For this purpose, the number of all specimens captured was counted per fruit fly species, per date according to the plant formations. Data on specimens of all species were averaged for each attractant/trap combination at each site on 2-week interval basis. The average catch per trap was then converted to average catch per trap per day (FTD) by dividing the average trap catch by the number of days that the traps were operating.

Excel 2013 from Microsoft's Office 2013 was used for data capture and producing the various graphics. Statistical analysis of the data was performed using Statitisca 7.1. The statistical analysis was based on an analysis of variance (ANOVA), followed by a Student Newman-Keuls test using a probability threshold of 5%.

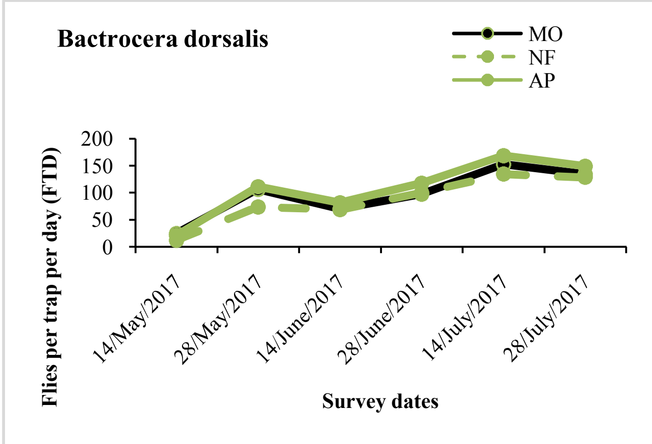
RESULTATS

Abundance of fruit fly species in the plant formations during the mango fruiting season

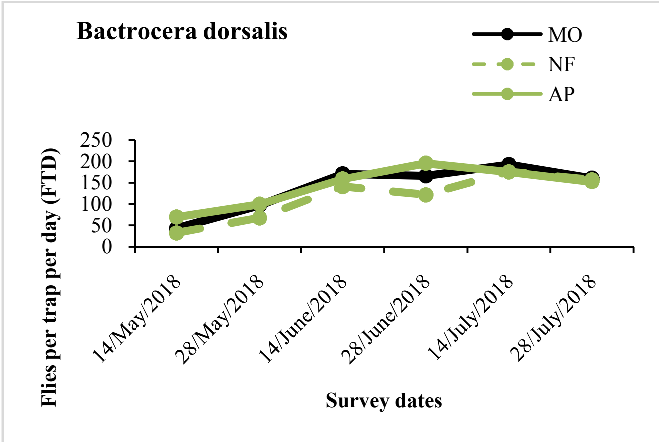
By using trapping system, we were able to catch 1,971,719specimens of adult fruit fly species during the two consecutive mango seasons (2017 and 2018). The tephritid adults caught belonged to 23 fruit fly species of four genera (*Bactrocera*, *Ceratitis*, *Dacus* and *Zeugodacus*). Among them, *Bactrocera dorsalis* with 1,413,357 adult individuals (71.68%) and *Ceratitis cosyra* represented by 432,281 adult individuals (21.92%) were the most important fruit fly species in terms of number of adult individuals captured. These two species accounted for 93.60% of the total number of specimens caught in plant formations during the two consecutive mango seasons.

Fluctuations of the populations of Bactrocera dorsalis according to the plant formations during the mango fruiting season

Figure 3 shows the FTD of *B. dorsalis* in three types of plant formations during the two consecutive mango seasons. It can be seen that the FTD evolved similarly in the three types of plant formations. The FTD recorded at the beginning of the mango season were lower than those observed at the end of the season. In 2017, the highest FTD were recorded on July 14 in the three types of plant formations (Fig. 3a). In 2018, we recorded the highest FTD on June 28 in the agroforestry parks and on July 14 in both mango orchards and natural fallows (Fig. 3b). The agroforestry parks recorded the higher FTD while the natural fallows presented the lower FTD. The mango orchards showed the intermediate FTD during the mango season 2017. During the mango season 2018, we observed that the lower FTD were recorded in the natural fallows during the first two months of the study while the FTD recorded in the mango orchards and the agroforestry parks were approximately equal during the study period.



(a)



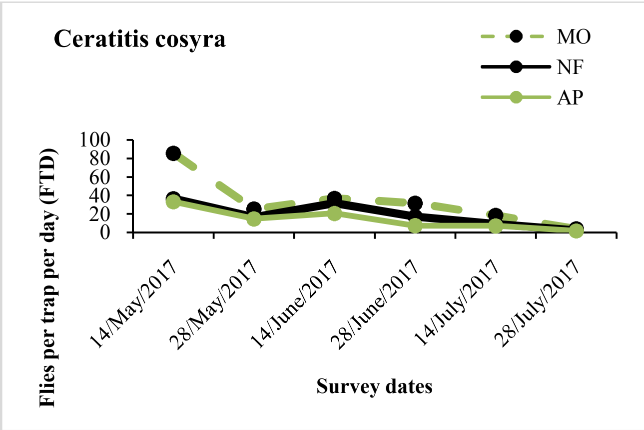
(b)

Figure 3 Fluctuations of *Bactrocera dorsalis* population according to the plant formations. (a) during the mango season 2017 ; (b) during the mango season 2018

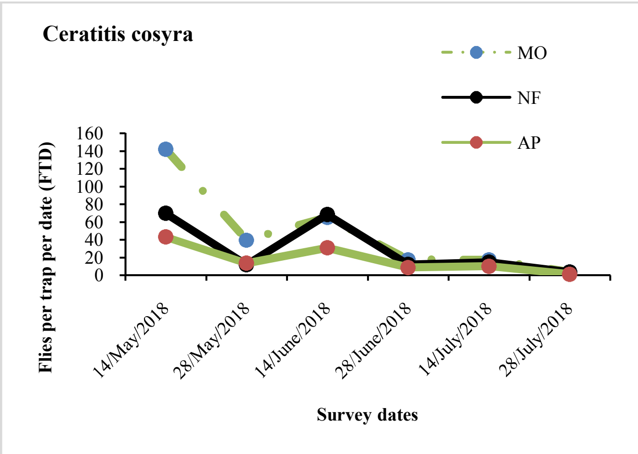
MO: mango orchards, NF: natural fallows, AP: agroforestry parks

Flutuations of Ceratitis cosyra population according to the plant formations during the mango fruiting season

Figure 4 illustrates the FTD of *C. cosyra* in the three types of plant formations during the study period. It can be seen that the FTD evolved similarly in the three types of plant formations during the mango season. Unlike the FTD of *B. dorsalis*, the FTD of *C. cosyra* were high during the early mango season and decreased gradually until the end of the season. The highest population levels of *C. cosyra* were observed on May 14 during the mango seasons 2017 and 2018 in the three types of plant formations. During the mango season 2017, the average catch indices were higher in the mango orchards and lower in the natural fallows (Fig. 4a). In 2018, the FTD were higher in the mango orchards from May 14 to June 14. From June 28 the average catch indices became approximately equal in the three types of plant formation until the end of the season (Fig. 4b).



(a)



(b)

Figure 4 Fluctuations of *Ceratitis cosyra*population according to the plant formations. (a) during the mango season 2017, (b) during the mango season 2018
MO: mango orchards, NF: natural fallows, AP: agroforestry parks

Average catch indices (FTD) of Ceratitis cosyra according to the plant formations

Table 2 illustrates the FTD of *C. cosyra* over the two years according to the plant formations. The highest population levels were recorded in the mango orchards while the agroforestry parks presented the lowest FTD during the two consecutive mango seasons (2017 and 2018). However, we did not observed significant difference between the three types of plant formations (F = 1.436, P =0.263 and F = 1.047, P = 0.375 in 2017 and 2018, respectively) in the average catch indices.

Table 2 Flies per trap per day (FTD) of *Ceratitis cosyra* according to the plant formations

Plant formations	Year 2017	Year 2018
Natural fallows	6.24 ± 1.77 a	9.95 ± 4.16 a
Agroforestry parks	4.63 ± 1.55 a	5.94 ± 2.16 a
Mango orchards	10.63 ± 3.81 a	15.80 ± 6.95 a
F	1.436	1.047
P	0.263	0.375

Means followed by the same letter are not significantly different at 5% probability

Average catch indices of B. dorsalis according to the plant formations

Table 3 shows the FTD of *B. dorsalis* according to the plant formations. It can be seen that the highest population levels of *B. dorsalis* were observed in the agroforestry parks while the natural fallows presented the lowest average catch indices during the two consecutive mango seasons (2017 and 2018). However, no significant difference was recorded in the average catch indices between the three types of plant formations (F = 0.307, P = 0.739 and F = 0.413, P = 0.668 in 2017 and 2018, respectively).

Table 3 Flies per trap per day (FTD) of *Bactrocera dorsalis* according to the plant formations

Plant formations	Year 2017	Year 2018
Natural fallows	28.63 ± 6.14 a	38.50 ± 7.49 a
Agroforestry parks	35.84 ± 7.08 a	47.09 ± 6.49 a
Mango orchards	32.36 ± 6.22 a	45.92 ± 7.68 a
F	0.307	0.413
P	0.739	0.668

Means followed by the same letter are not significantly different at 5% probability

DISCUSSION

Bactrocera dorsalis and *C. cosyra* were present in the three types of plant formations during the mango fruiting season. Our findings revealed that during the mango season, the population levels of these two fruit fly species showed reverse evolutions. In fact, the average catch indices of *B. dorsalis* increased gradually until the end of the mango season while those of *C. cosyra* decreased gradually as the mango season draws to a close. Average catch indices of the two species varied significantly between survey dates. According to Vayssières *et al.* (2005) and Ouédraogo *et al.* (2011) *C.cosyra* is better adapted to dry conditions and its population density is positively correlated with temperatures; this is the reason why its highest populations were recorded on May 14 at the end of the dry season when temperatures were high. The peak of *B. dorsalis* populations was recorded on June 28 or July 14 according to the year, which is associated with maximum rainfall in the study area. This finding could be explained by the fact that this species prefers moister environments (Gnanvossou *et al.* 2017). Furthermore, as precipitation increases from May to a peak in July sometimes in August, there is a consistent increase in relative humidity and a decrease in air temperature in the study area. Geurts *et al.* (2014) and Bota *et al.* (2018) stated that rainfalls significantly influence *B. dorsalis* population density.

The highest average catch index of *B. dorsalis* was recorded in the agroforestry parks (35.84 ± 7.08 and 47.09 ± 6.49 flies per trap per day in 2017 and 2018, respectively) followed by the mango orchards (32.36 ± 6.22 and 45.92 ± 7.68 flies per trap per day in 2017 and 2018, respectively). The weak variation of the average catch indices of this species could be explain by the availability of its fruit hosts in each of the three types of plant formations. In agroforestry parks the presence of shea fruits (*Vitellaria paradoxa* C.F. Gaertn.) which are the indigenous fruits the most infested with *B. dorsalis* could be explain by the high population level recorded in these types of plant formations (Zida *et al.* in press). In addition, towards the end of the mango season (July), mango fruits are becoming scarce in the orchards, which could force *B. dorsalis* to move to the agroforestry parks where there are still oviposition sites at this time of the year. Mango orchards are home of many mango cultivars which are the main fruit hosts of *B. dorsalis*. According to Ndiayes *et al.* (2012), Vayssières *et al.* 2009; 2011), *B. dorsalis* was considered to be the main insect pest associated with mangoes during the rainy season, this is the reason why its population density was also high in the mango orchards. The lowest FTD recorded in the natural fallows is the consequence of the low presence of fruit hosts of *B. dorsalis* in these types of plant formations.

As far as *C. cosyra* is concerned, mango orchards recorded the highest FTD (10.63 ± 3.81 and 15.80 ± 6.95 flies per trap per day in 2017 and 2018, respectively) followed by the natural fallows (6.24 ± 1.77 and 9.95 ± 4.16 flies per trap per day in 2017 and 2018, respectively). These findings could be explain by the fact that mangoes are the preferential oviposition sites for this indigenous species. Previous studies indicated that *C. cosyra* caused damage on early mango cultivars in Burkina Faso (Ouédraogo *et al*., 2011) and in Benin (Vayssières *et al*., 2005). Natural fallows are home to several fruit species including *Annona senegalensis* Pers., *Sarcocephalus latifolius* (Sm.) E.A.Bruce, *Saba senegalensis* A. DC., *Sclerocarya birrea* (A. Rich.) Hochst which are the main suitable indigenous fruit hosts for *C. cosyra* (Copeland *et al*., 2006; Mwatawala *et al*., 2009, Ouédraogo *et al*., 2010). This reason explains the average catch indices of *C. cosyra* recorded in natural fallows. The agroforestry parks are mainly populated with shea trees (*V. paradoxa*) and the shea fruits are not favorable to the development of immature stages of *C. cosyra* (Zida *et al* in press). This fact explains the low average catch indices of this species recorded in the agroforestry parks as compared to the two other types of plant formations. In general, there is a strong correlation between the availability of fruiting host plants and population dynamics of fruit flies. (Aluja and Manga, 2008).

In general, the results revealed that the FTD recorded during the 2018 mango season were higher than those obtained during the 2017 mango season in the three types of plant formations. The difference in the amount of rainfall recorded between the two years of study could be explained by the significant difference observed in the FTD. In fact, the amount of rainfall obtained in 2018 was much higher than in 2017. For example, 747.9 mm were recorded in 2017 against 1,320.2 mm of rainfall in 2018 in the Houet province. In Comoé province, 898.5 and 1278.5 mm were recorded in 2017 and 2018, respectively and in Kenedougou province, 1081.7 mm of rainfall were obtained in 2017 against 1,364.5 mm in 2018. According to Aluja and Manga (2008), temperature, relative humidity and rainfall are the major climatic factors influencing fruit fly populations.

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