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ORIGINAL RESEARCH ARTICLE

Dominance of *Bactrocera dorsalis* Hendel on *Ceratitis cosyra* Walker (Diptera: Tephritidae) in orchards in Bujumbura, Burundi

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ABSTRACT

The aim of this study was to investigate the population fluctuations of *Bactrocera dorsalis* and *Ceratitis cosyra* in mango, citrus, and mixed orchards in Bujumbura city. Data was collected from six sites from December 2018 and December 2019 using trapping methodology. Two attractants (methyeugenol and terpinyl acetate), insecticide (dichlorvos DDVP 70%) and tephri traps were employed to attract and kill flies. The results indicate that *B. dorsalis* was more abundant in all sites (97.91%) than *C. cosyra* (2.09%). Fluctuation peaks for *B. dorsalis* were observed in April, October and December. A significant difference was noted in the monthly catches of both species ($p<0.05$). For *C. cosyra*, significant differences were observed in catches across all sites ($p<0.05$), whereas for *B. dorsalis* no such differences were found ($p>0.05$). The population fluctuations of *B. dorsalis* were observed during the maturation of mango and citrus fruits. *B. dorsalis* dominated in all sites.

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INTRODUCTION

Fruit production provides significant opportunities for employment and revenue, increased access to education, healthcare, food, and nutritional security, and socio-economic development opportunities, particularly benefiting women and children (Weinberger & Lumpkin, 2007). In Burundi, fruits are cultivated primarily in the Imbo plain, a warm agro ecological zone, in the western region. The major fruits include mango, oranges, mandarins, avocado, guava, lemon and papaya. However, fruit production faces substantial losses due to fruit flies (Ndayizeye *et al*., 2017). Economic losses due to fruit flies occur in two ways, direct and indirect. Oviposition and larval tunneling cause fruits to be unsuitable for consumption and unmarketable (Ekesi & Billah, 2007). A single oviposition can cause considerable internal damage, creating larval tunnels and very visible droppings. Moreover, fruits damaged by fruit flies become vulnerable to pathogenic microorganisms. Economic loss is also caused indirectly through quarantine restrictions which are imposed to countries with the presence of fruit flies. Upon detection of infested fruits whole consignments are rejected which seriously reduces access to international markets (Salazar *et al*., 2020). *Bactrocera dorsalis* and *Ceratitis cosyra*, have been recorded in Bujumbura city (Ndayizeye *et al*., 2017). These species are primary pests of mango in sub-Saharan Africa (Ekesi *et al*., 2006) and share several host plants, including Annona spp., guava, citrus spp., marula plum, and tropical almond (Ekesi *et al*., 2009). *B. dorsalis* is an exotic species known for its rapid spread in newly established areas, causing enormous loss to fruit production. *C. cosyra*, an indigenous African species, was a major threat to mango production before the arrival of *B. dorsalis* (Aketarawong *et al*., 2014; De Meyer, 1998). Both species thrive in warm weather (Ekesi, 2015). Despite their status as major mango pests, it has been observed in several studies that the cohabitation of the two species is complex. In fact, *B. dorsalis* is believed to outcompete species of the *Ceratitis* genus on their host plants.

C. cosyra is one of the species displaced from mango in Kenya and Tanzania (Ekesi *et al.*, 2009; Mwatawala *et al.*, 2006), negatively impacting its abundance (Ekesi *et al.*, 2009). However, research in Senegal and Mozambique indicated that the two species can coexist on mango, with population fluctuations depending on host availability, seasonality, and ecological zones (Bota *et al.*, 2018; Dieng et al., 2019).

Due to the complexity of their cohabitation, understanding variations in their abundance is crucial for effective integrated pest management. Therefore, the overall objective of this study was to investigate the abundance of *B. dorsalis* and *C. cosyra* in mango, citrus, and mixed orchards. Specifically, the study investigated (i) the abundance of *B. dorsalis* and *C. cosyra* across all sites and (ii) the monthly abundance of *B. dorsalis* and *C. cosyra* in mango, citrus, and mixed orchards. The results of this research will contribute to the management of these species for quality fruit production.

MATERIALS AND METHODS

Study sites

The study was conducted in six orchards located in the urban area of Bujumbura (Table 1). Samples were collected from December 2018 to December 2019. Each orchard was less than 1 hectare in size. The study area experiences two distinct seasons: the rainy season (September-May) and the dry season (June-August). The average annual temperature ranges from 18°C to 25°C, with higher temperatures occurring during the dry season. Coordinates were recorded using a Garmin Global Positioning System (GPS).

Sample collection

Fruit flies were captured using two parapheromones namely methyl eugenol (ME) and terpinyl acetate (TA) attracting, *B. dorsalis* and *C. cosyra*, respectively. These parapheromones attract only male individuals (Tan & Nishida, 2012). A total of 12 traps (Tephri-trap type) were installed, with each site having two traps containing ME and TA respectively, set on different trees at a height of 1.30 meters above the ground. Insecticide (dichlorvos, DDVP 70%) was placed in each trap to kill trapped flies. Trap servicing was conducted every two weeks, and parapheromones and insecticides were replaced every six weeks. Samples were preserved in tubes containing 70% alcohol for further identification. Data collection followed the trapping guidelines of Ekesi & Billah (2007). Individuals were identified using fruit fly identification key by Bota *et al.* (2018). Accidental introductions of other species than *C. cosyra* and *B. dorsalis* were not considered in this study.

Data analysis

Data was processed using IBM SPSS Statistics 20. An ANOVA test was conducted, and an F-test was utilized to determine variations between sites for the two species throughout a year.

Table 1. Study sites description.

Sites	Coordinates	Elevation	Fruit trees
Site 1	S: 03°20.770' E: 029°22.388'	810masl	Mango trees
Site 2	S: 03°23.312' E: 029°22.745'	844masl	Mango trees
Site 3	S: 03°23.513' E: 029°21.745'	810masl	Mango and orange trees
Site 4	S: 03°25.007' E: 029°21.281'	801masl	Mango, lemon, orange and cherimoya trees
Site 5	S: 03°21.578' E: 029°21.441'	784masl	Orange and mango trees
Site 6	S: 03°22.192' E: 02923.960'	953masl	Mango, orange and tangerines trees

Table 2. Species abundance per sites.

Species	Sites						Total	%
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6		
B. dorsalis	28674	15472	17733	22592	21055	23529	129055	97.91
C. cosyra	370	374	504	423	941	144	2756	2.09
Total	29044	15846	18237	23015	21996	23673	131811	100

RESULTS AND DISCUSSION

A total of 131,811 individuals were collected from the study sites. The captured species were *Bactrocera dorsalis* Hendel and *Ceratitis cosyra* Walker. *B. dorsalis* accounted for 129,055 individuals (97.91%), while C. cosyra accounted for 2,756 individuals (2.09%). The highest captures were at site 1 (29,044 individuals) and the lowest at site 2 (15,846 individuals). The results showed that *B. dorsalis* was was significantly more abundant than *C. cosyra* (Table 2). Similar results were found by Canhanga *et al*. (2020) in Manica, Mozambique with 70.66% for *B. dorsalis* and 28.9% for *C. cosyra* (Walker) from mango fruits.

Abiotic factors and biotic factors are responsible of this dominance. Abiotic factors like temperature play a crucial role in the population increase of fruit flies (Zida *et al*., 2020; Rashmi *et al*., 2020; Facon *et al*., 2021; Mnguni, 2021). Indeed, the warmer the weather in a given area, the higher the ability of *B. dorsalis* to maintain its population (Motswagole et al., 2019; Ullah et al., 2022; Fiaobe *et al*., 2021). Although the study area is a warm agro-ecological zone, the absence of an Integrated Pest Management (IPM) program in the study area likely contributed to the abundance of *B. dorsalis*. Without an eradication program, *B. dorsalis* can significantly increase in numbers, dominating other species (Moquet *et al*., 2021; Hassani *et al*., 2022). Even tough, *C. cosyra* also prefers warmer weather, the abundance of *B. dorsalis* might have caused the decline of *C. cosyra* populations (Mutamiswa *et al*., 2021). Before the arrival of *B. dorsalis* in Africa, *C. cosyra* was the main mango pest. Currently, the two species use mango host differently. For example, research in Kenya concluded that *C. cosyra* had been displaced from its primary host by *B. dorsalis*. (Ndlela *et al*., 2020; Billah *et al*., 2023). However, studies in Burkina Faso showed that *B. dorsalis* and *C. cosyra* coexist on mango (Zida *et al*., 2019). The difference in abundance for the two species would be due to mango varieties within the orchards. In Mali, Rahinatou *et al*. (2020) concluded that the preference on mango varieties were different for the two species. *B. dorsalis* preferred Keitt, Brooks and Smith varieties whereas *C. cosyra* preferred Valencia, Amelie and Davis Haden varieties. Kent variety was common for the two species. However, research conducted in 2023 in Bujumbura on four mango varieties (Kent, Boribo, Valencia and Sindano) showed that all emerged fruit flies were exclusively *B. dorsalis* (Ndayizeye, unpublished data). These results confirm that apart from host plants, there are other factors influencing the abundance of *C. cosyra* and *B. dorsalis*. According to Rahinatou *et al*. (2020), temperature and humidity have an influence on the reproduction of *B. dorsalis* and *C. cosyra*.

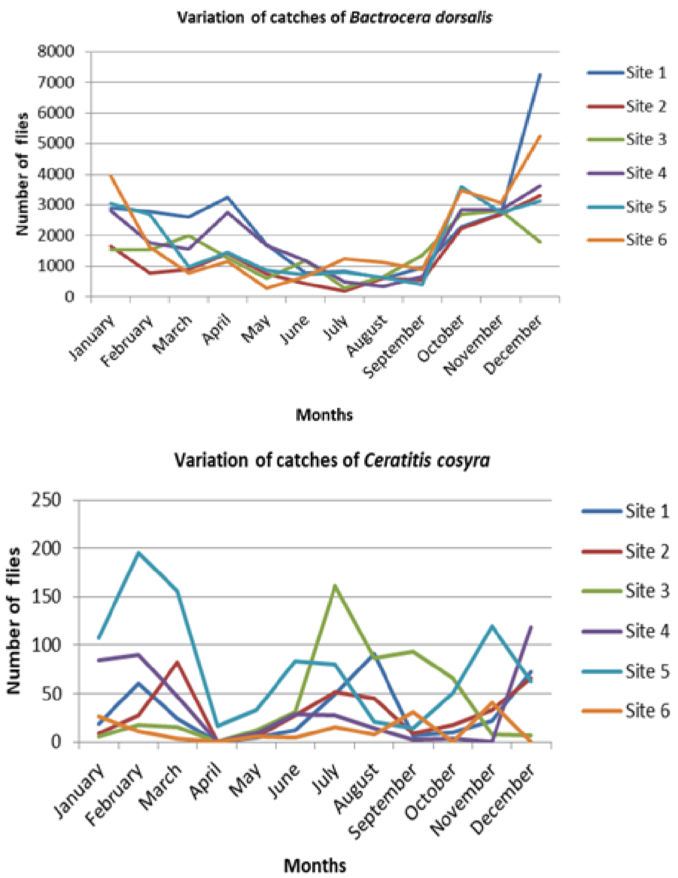

Figure 1. *Annual abundance variation of B. dorsalis and C. cosyra in all sites.*

Apart from abiotic factors, biotic factors such as host plants influence the dominance of *B. dorsalis* over *C. cosyra* (Moquet *et al*., 2021, Hassani *et al*., 2022). Indeed, the preferred hosts, mango, oranges and tangerines are present in the study sites. It is possible that *B. dorsalis* relied on cultivated hosts during the rainy season and on wild hosts during the dry season. In their study in Bujumbura, Ndayizeye and Sibomana (2023) showed that Terminalia catappa was an alternative host for *B. dorsalis* in the absence of mango or citrus. According to the same authors, Terminalia catappa is often planted along roadsides, in public and home gardens for shade and ornamental purposes. Generally, *B. dorsalis* has a wider range of hosts compared to *C. cosyra*, allowing it to switch to other hosts in the absence of its preferred ones (Zida *et al*., 2020; Rasolofoarivao *et al*., 2022; Moquet et al., 2021).

Fluctuations in the populations of the two species during the year

During the study, catches of *B. dorsalis* and *C. cosyra* varied from month to month and from site to site. In all sites, the catches of *B. dorsalis* were more abundant than those of *C. cosyra* (Figure 1). The graphs show that the fluctuations in the populations of *B. dorsalis* and *C. cosyra* are different across all sites and for all months. In general, the populations of *C. cosyra* are very low. At some sites and during certain months, no individuals were captured. For example, no *C. cosyra* individuals were captured in April at sites 1, 2, 3, 4, and 6; in November at site 4; and in October and December at site 6. Unlike at other sites, *C. cosyra* was present throughout the study period at site 5, which recorded the highest number of *C. cosyra* individuals. Site 6 had particularly low catches of *C. cosyra*.

For *B. dorsalis*, catches increased from October to December at all sites, with peaks in December except for sites 3 and 5, which showed peaks in November and October, respectively. These catches decreased from January to March at all sites, followed by another peak in April. The April peak was succeeded by a significant decrease in catches from May to September.

The variation in the abundance of *B. dorsalis* during our study depended on the availability of host plants. In all sites, populations increased from October through December, corresponding to the fruiting season of mango (from physiological maturity to ripeness). *B. dorsalis* is more abundant during harvesting stages (Canhanga *et al*., 2020). The peaks observed in April were due to the fruiting period of citrus (oranges and mandarins) inside or in the vicinity of the sites, which are secondary hosts of *B. dorsalis* (Nebie *et al*., 2021; Theron *et al*., 2023; Moquet *et al*., 2024). The period from May to September corresponded to the dry season causing a decrease in the *B. dorsalis* catches, although the species can move to a few wild hosts such as *T. catappa*.

Influence of sites and period of year on the distribution of the two species

To understand the influence of the sites and the period of the year on the distribution of the two species, an analysis of variance test (ANOVA Test) was conducted. The analysis of the variance of *C. cosyra* catches compared to sites showed a significant difference (df = 5, F = 3.808, p <0.05). On the contrary, no significant difference was observed for monthly catches (df = 11, F = 1.394, p> 0.05). The difference between sites could be attributed to the presence of alternative hosts inside or near the orchards. Cherimoya is known to be one for the preferred hosts of C. coysra. The rearing of Cherimoya in 2015 resulted in the emergence of *C. cosyra* at 100% (Ndayizeye, unpublished data). For *B. dorsalis*, no significant difference was found for catches compared to the sites (df = 5, F = 1.090, p> 0.05), while a significant difference is observed for the catches compared to the months (df = 11, F = 11.650, p <0.05). The significant difference observed between months could be due to the availability of hosts. In the study sites, fruits are available during the rainy season, leading to an increase in fruit fly populations. Some months coincided with fruiting, others with maturation and ripeness causing variations in the capture of individuals. During the dry season, fruits were not available, contributing to very low captures. In fact, fruit availability corresponding to months and phenology stages has an influence on the population fluctuations of fruit flies (Rahinatou *et al*., 2020).

Conclusion

The study showed that Bactrocera dorsalis is more abundant than Ceratitis cosyra throughout a year in Bujumbura. The population fluctuations of *B. dorsalis* are linked to months when fruits are available. During the dry season the population of B. dorsalis decreased but remained more abundant than *C. cosyra*.

DECLARATIONS

Author contribution statement

Conceptualization: N.L and M.O; Methodology: N.L.; Software and validation: N.L., S.C. and N.D.; Formal analysis and investigation: N.D and S.C; Resources: N.L.; Data curation: M.O and N.L; Writing-original draft preparation: N.L; Writing-review and editing: M.O, N.D, S.C and N.D; Visualization: N.L; Supervision: N.L. All authors have read and agreed to the published version of the manuscript.

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