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Contribution of *Terminalia catappa* L. to the survival of *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) in Bujumbura city, Burundi.

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ABSTRACT

Bactrocera dorsalis (Hendel, 1912) is an invasive species abundant in western Burundi. It is a polyphagous pest species, and is of a specific interest to vegetable and fruit crops of economic importance. However, the development of this fruit fly species is also made possible by non-commercial hosts fruit crops. In order to show the contribution of *Terminalia catappa* to the survival of *B. dorsalis*, a study based on fruit flies incubation was done in Bujumbura city from June to September 2017. *B. dorsalis* was collected from incubated fruits infested by flies. Fruits were collected in neighbourhoods according to the population and fruit trees density. Results show that neighbourhoods with low population density and high number of fruit trees have higher infestation rates than those with high population density and few number of fruit trees. This study showed that *T. catappa* contributes significantly to the survival of populations of *B. dorsalis* in Bujumbura city as the latter uses its fruits as hosts especially in the dry season. *T. catappa* can be considered as an alternative host plant for *B. dorsalis* used in the absence of its preferred host plants.

Key words: *Bactrocera dorsalis*, *Ceratitis cosyra,* fruit flies, host plant

RESUME

Bactrocera dorsalis (Hendel, 1912) est une espèce envahissante abondante à l'Ouest du Burundi. C'est un ravageur polyphage d'intérêt particulier pour les cultures végétales et fruitières d'importance économique. Le développement de cette espèce de mouche des fruits est rendu possible aussi par des plantes hôtes sauvages. Afin de montrer la contribution de *Terminalia catappa* Linn à la survie de *B. dorsalis*, une étude basée sur l'incubation des fruits a été réalisée dans la ville de Bujumbura de Juin à Septembre 2017. Les fruits ont été collectés dans les quartiers en tenant compte de la densité de la population et des arbres fruitiers. Les quartiers à faible densité de la population et un grand nombre d'arbres fruitiers ont un niveau d'infestation élevé par rapport aux quartiers avec une densité de la population élevée et peu d'arbres fruitiers. Cette étude a montré que *T. catappa* contribue significativement à la survie des populations de *B. dorsalis* dans la ville de Bujumbura étant donné que cette dernière utilise ses fruits spécialement pendant la saison sèche. *T. catappa* peut être considérée comme une plante hôte alternative pour *B. dorsalis* utilisée en l'absence de ses plantes hôtes préférées.

Mots clés : *Bactrocera dorsalis*, *Ceratitis cosyra,* mouches des fruits, plante hôte

I. INTRODUCTION

Fruit flies are among the most damaging pests of fruits and vegetables in the world (White and Elson-Harris, 1992; IAEA, 2003; Ekesi and Billah, 2007). Among them, the oriental fruit fly *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) is a polyphagous pest species first identified in Africa in 2003 (Lux et al., 2003). Nevertheless, this species shows preference for ripe mango (*Mangifera indica*) (Rattanapun et al., 2009). It is an invasive species considered as fruit pest attacking a wide range of host plants causing huge damage to both local and export production (Vayssières et al., 2005; Ekesi et al., 2006; Mwatawala et al., 2006; Goergen et al., 2011; Rwomushana et al., 2008a). In Burundi, *B. dorsalis* was first detected in Kigwena, south-western Burundi in 2009 and is abundant in the western part of Burundi in the Imbo region along the shore of Lake Tanganyika and Rusizi river (Ndayizeye et al., 2017).

The western Burundi is a home to a wide variety of edible fruit crops such as mango (*Magnifera indica* L.), avocado (*Persea americana* L.), orange (*Citrus sinensis* L.), tangerine (*Citrus reticulata* L.), and guava (*Psidium guajava* L.) which are potential hosts of *B. dorsalis* (Ndayizeye, unpublished data). It makes use of soft fleshy parts of the fruit and vegetable becoming a pest of economic importance. The short generation cycle of this species allows multiple generations within a fruiting season while the absence of seasonal fruits hosts within a region makes adult *B. dorsalis* make use of alternative host plants such as *Terminalia catappa* L. whose fruits are available during the whole dry season.

Terminalia catappa, frequently referred to as "tropical almond", belongs to the family *Combretaceae* and originates from Southern India to coastal South-East Asia (Smith, 1971). These trees are widely cultivated in tropical and subtropical coastal areas and used by local communities for a number of household uses. The tree is planted for shade and ornamental purposes in urban environments (Chen et al. 2000; Hayward, 1990; Kinoshita et al., 2007). *Terminalia catappa* is generally known as host of some fruit fly species within the *Bactrocera* genus (Tsuruta et al., 1997; Clarke et al., 2005).

For this plant, flowering and fruiting occur throughout the year, but ripe fruits are available from May to October, a period spanning the dry season. It produces brown or violet-brown drupes which remain on the tree for a long time. In spite of their attractive colour and smell, they are not actually consumed by local population except some children from poor families. During rainy season (September to May), some trees can be seen with sparse amounts of ripe fruits. In Burundi, the dry season is considered as an off-season period for most of fruit crops. Due to its preference to warm climate regions, *Terminalia catappa* is largely distributed in the western Burundi especially in the city of Bujumbura where it is often planted along avenues, in public and home gardens for shade and ornamental purpose. In addition, the flesh of the fruit is often fibrous and not tasty in spite of the pleasant smell (Heinsleigh, 1988) and like in other countries, fruits are not commonly consumed by Burundian population.

The main fruit trees that are used by *B. dorsalis* as hosts do not bear fruit during the dry season. The survival of *B. dorsalis* would be compromised during this season if there are no other plants that this fruit fly species would use as a host. Given its fruition that occurs during the dry season on the trees found in the city of Bujumbura, *T. catappa* is a potential host that would help *B. dorsalis* to survive in this season. Most of the cases, ripe fruits are often observed remaining on the tree or decomposing on the ground. However, few studies have evaluated to which extent *T. catappa* contributes to the survival of *B. dorsalis* especially in urban areas. The present study investigates the contribution of *T. catappa* to the survival of *B. dorsalis* in Bujumbura city during the dry season.

II. MATERIALS AND METHODS

II.1 Study sites

This study's sample collection was conducted from June to September 2017, a period spanning the dry and fruiting season for *Terminalia catappa,* in three communes of Bujumbura city (Muha, Mukaza and Ntahangwa). *T. catappa* fruits were collected at three sites in each neighbourhood taking into account the presence of other trees, potential fruit flies hosts especially mango trees (table 1). The sites altitude ranges from 783 to 884m with a warm climate and temperatures ranging from 23°C to 28°C. The location was determined using a Garmin Global Positioning System (GPS) device (fig. 1).

Table 1. Sampling sites location and present fruit trees

Communes	Sites	Coordinates	Altitude (masl)	Fruit trees
Muha	Kibenga	3°25′13″ S 29°21′4″ E	793	mango tree (*Mangifera indica* L.), avocado tree (*Persea americana* L.), orange tree (*Citrus sinensis* L.) and lemon tree (*Citrus lemon tree* L.), papaya tree (*Carica papaya L.*), coconut tree (*Cocos nucifera* L.)
	Kinindo	3°24′41″ S 29°21′22″ E	796	mango tree (*Mangifera indica* L.), orange tree (*Citrus sinensis* L.*)*, avocado tree (*Persea americana* L.), papaya tree (*Carica papaya L.*)
	Kanyosha	3°25′21″ S 29°21′23″ E	806	mango tree (Mangifera indica L.), avocado tree (*Persea americana* L.), orange tree (*Citrus sinensis)*, lemon tree (*Citrus lemon* L.*)*, papaya tree (*Carica papaya L.*), coconut tree (*Cocos nucifera* L.*)*
Mukaza	Kiriri	3°23′24″ S 29°22′39″ E	884	avocado tree (*Persea americana* L.), citronier (*Citrus lemon* L.), orange tree (*Citrus sinensis* L.*)*, mango tree (*Mangifera indica* L.)
	Mutanga	3°22′40″ S 29°23′4″ E	857	mango tree (*Mangifera indica* L.), avocado tree (*Persea americana* L.), orange tree (*Citrus sinensis* L.*)*, lemon tree (*Citrus lemon* L.*)*, guava tree (*Psidium guajava* L.), pomegranate (*Punica granatum* L.)
	Rohero	3°23′10″ S 29°22′23″ E	822	mango tree (*Mangifera indica* L.), avocado tree (*Persea americana* L.), orange tree (*Citrus sinensis* L.*)*, citronier (*Citrus lemon* L.*)*, guava tree (*Psidium guajava* L.) and coconut tree (*Cocos nucifera* L.)
Ntahangwa	Ngagara	3°20′51″ S 29°21′35″ E	794	avocado tree (*Persea americana* L.), mango tree (*Mangifera indica* L.), orange tree (*Citrus sinensis* L.*)*, lemon tree (*Citrus lemon tree* L.*)*, papaya tree (*Carica papaya L.*) and coconut tree (*Cocos nucifera* L.)
	Quartier Industriel	3°21′26″ S 29°20′37″ E	783	mango tree (*Mangifera indica* L.), coconut tree (*Cocos nucifera* L.), avocado tree (*Persea americana* L.) and lemon tree (*Citrus lemon* L.*)*
	Mutakura	3°20′31″ S 29°22′6″ E	811	mango tree (*Mangifera indica* L.), avocado tree tree (*Persea americana* L.), orange tree (*Citrus sinensis* L.*)*, lemon tree (*Citrus lemon tree* L.*)*, papaya tree (*Carica papaya L.*), coconut tree (*Cocos nucifera* L.) and pomegranate (*Punica granatum* L.)

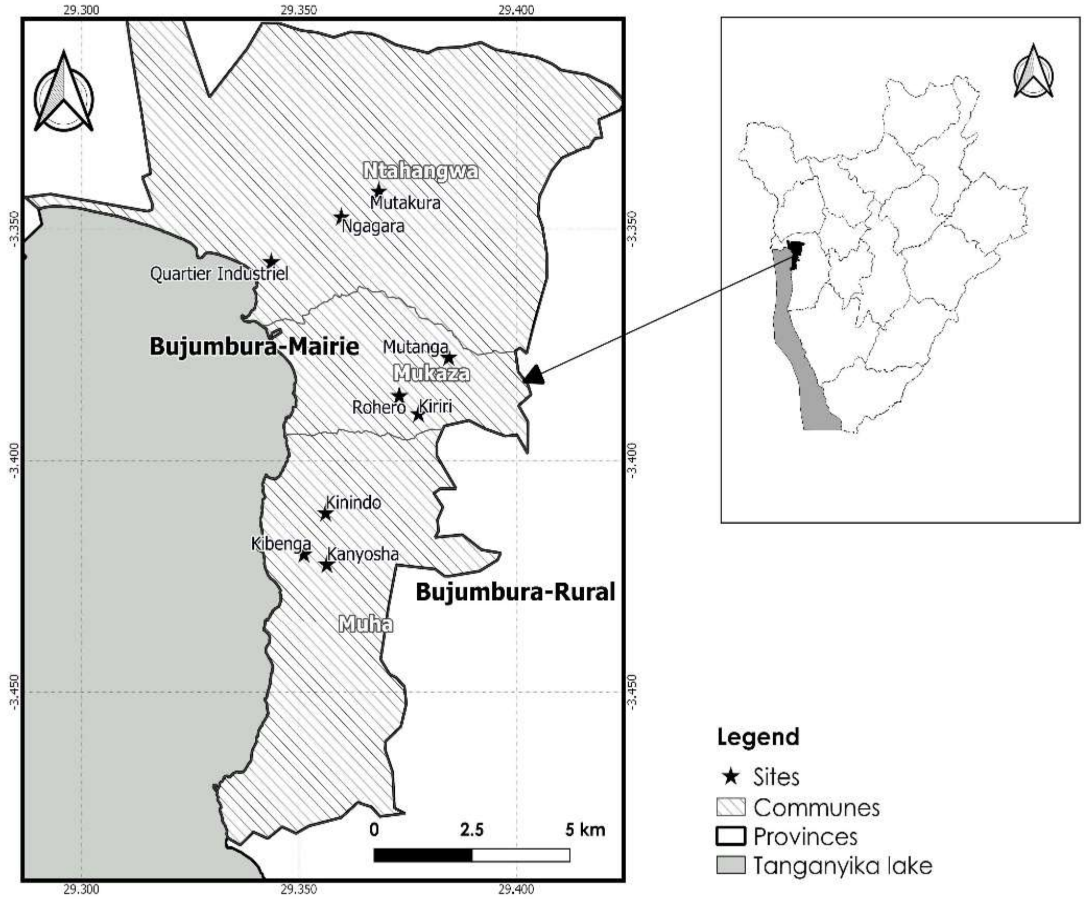

Figure 1: Map of Bujumbura city showing the study sites

II.2 Fruit collection and incubation process

Ripe fruits (of brown or violet brown colour) were harvested or collected on the ground and stored immediately in black bags. The number of collected fruits at each sampling day depended on available ripe fruits, but overall 40 fruits were collected per site at the end of the sampling period. After sampling, fruits were put in boxes to avoid shocks during transportation. The samples were taken to incubation facility of the OBPE (Office Burundais pour la Protection de l'Environnement) and were processed according to the protocol of Ekesi and Billah (2007). In the incubation facility, fruits were counted, washed and weighed. Fruit samples were then stored in ventilated rectangular plastic boxes containing sand of 21.5 cm x 15 cm x 16.5 cm or in boxes with circular base of 13 cm x 8 cm. During incubation, mold that appeared on the fruits was removed with a small wooden spatula to facilitate the larvae release and emergence of flies. Fruit sample boxes were monitored on a daily basis for the emergence of adults. Daily monitoring and room cleaning were performed to prevent the predation from ants. The incubated fruits were discarded after their complete decomposition.

II.3 Data analysis

II.3.1 Infestation rate

The infestation rate is obtained using the formula from De Souza et al. (2016) and Vayssières et al. (2009) where the Infestation Rate (IR) is the ratio between the total number of pupae per sample and the weight of the incubated fruits. Since the study did not take pupae into account due to the lack of suitable devices to keep them in normal development conditions (temperature and pressure), the IR was obtained using the ratio between the number of flies that emerged and the weight of the incubated fruits for each site .
IR=Number of emerged flies/weight of the incubated fruits.

II.3.2 Index of Bray-Curtis

The Bray-Curtis Similarity Index was used to make a Hierarchical Habitat Grouping (UPGMA).

Index of Bray-Curtis : $BCd_{ij} = \frac{\sum_{k=1}^{n} |Xik - Xjk|}{\sum_{k=1}^{n} (Xik + Xjk)}$

Where Xik: species abundance k for line i, Xjk: species abundance k for line j, n: total number of variables (species) in the matrix.
This index is the quantitative equivalent of the similarity index of Sorensen. The hierarchical grouping was done by applying the "UPGMA (Unweighted Peer Group Method with Arithmetic Mean)" using Cluster Analysis option of the MVSP 3.2 (Multi Variate Statistical Package) (Kovach, 1997) software to generate dendrogram. This method hierarchically groups the different habitats according to their similarity.

III. RESULTS

III.1 Abundance

A total of 360 fruits of *Terminalia catappa* L. were collected and 2681 individuals of *Bactrocera dorsalis* (Hendel) emerged from them. As per site, 633 individuals that is 23.61% emerged from the fruits collected at Q. Industriel. In Kinindo and Kiriri, we got respectively 576 and 558 individuals that is 21.48% and 20.81% respectively of the emerged individuals. Fruits collected at Rohero and Mutakura sites provided 297 and 247 flies, meaning 11.08% and 9.21% of all individuals (Table 2). Low numbers of individuals emerged from fruits collected in Mutanga and Kanyosha with 180 and 110 individuals or 6.71% and 4.10% respectively. The lowest numbers were observed in Ngagara and Kibenga sites with 57 and 23 individuals, that is 2.13% and 0.86% of the emerged individuals (fig. 2).

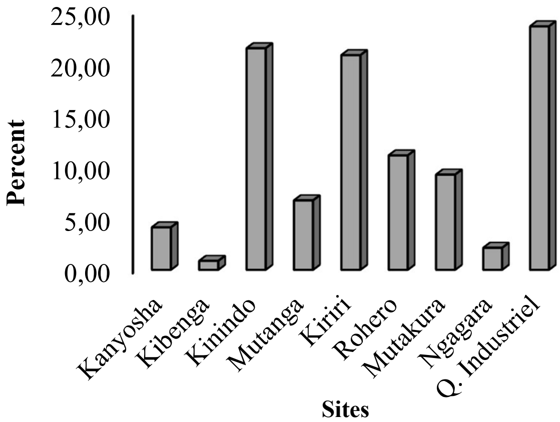

Figure 2: Relative abundance of captured flies per site

III.2 Infestation rate

Taking into account the emergence of *B. dorsalis* (2681 individuals) in relation to weight (16.65kg), the general infestation rate is 161.02 flies per kg. The highest infestation rate was recorded at Q. Industriel with 301.43 flies per kg followed by Kiriri, Kinindo and Mutanga sites with respectively 279.00 flies per kg, 274.29 flies per kg and 225.00 flies per kg. For Rohero and Mutakura sites the infestation rates were 165.00 and 141.14 flies per kg respectively. The lowest infestation rates were observed at Kanyosha, Ngagara and Kibenga sites with 57.89 flies per kg, 20.36 flies per kg and 16.43 flies per kg (Table 2).

Table 2 : Results on collected fruits and infesting flies

Communes	Sites	Collected fruits	Fruits weight (Kg)	Emerged flies	%	Infestation rate (flies/kg)
Muha	Kanyosha	40	1.9	110	4.10	57.89
	Kibenga	40	1.4	23	0.86	16.43
	Kinindo	40	2.1	576	21.48	274.29
	Subtotal	*120*	*5.4*	*709*	*26.45*	*131.30*
Mukaza	Mutanga	40	0.8	180	6.71	225.00
	Kiriri	40	2.0	558	20.81	279.00
	Rohero	40	1.8	297	11.08	165.00
	Subtotal	*120*	*4.6*	*1035*	*38.60*	*225.00*
Ntahangwa	Mutakura	40	1.75	247	9.21	141.14
	Ngagara	40	2.8	57	2.13	20.36
	Q. Industriel	40	2.1	633	23.61	301.43
	Subtotal	*120*	*6.65*	*937*	*34.95*	*140.90*
Total		**360**	**16.65**	**2681**	100.00	**161.02**

III.3 Index of Bray-Curtis

The dendrogram shows clear clustering with the first group composed of Kinindo, Kiriri, Q. Industrial and Mutanga sites (fig. 3). The highest rates of infestation have been observed at these sites. The second group is composed of Mutakura and Rohero sites making the group which is closer to the first one. These sites have average infestation rates. On the other hand, Ngagara, Kibenga and Kanyosha sites form the last group with strong similarity observed between Ngagara and Kibenga. The last two sites have the lowest infestation rates.

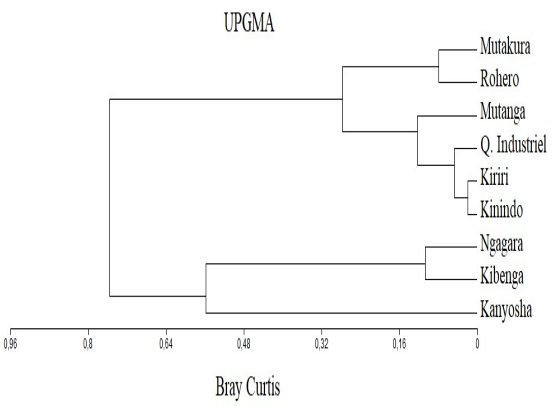

Figure 3: Dendrogram

IV. DISCUSSION

In this study, two species of fruit flies, *Bactrocera dorsalis* and *Ceratitis cosyra,* emerged from the collected fruits of *T. catappa.* These species have been found infesting the same host species fruits in studies conducted in other regions. José et al. (2013) found *C. cosyra* infesting *T. catappa* in Cabo Delgado, northern Mozambique. In Thailand, Somta et al. (2010) found that *Terminalia catappa* was used as a host by four species of *Bactrocera* including *B. dorsalis*, *B. correcta*, *B. latifrons*, and *B. cucurbiteae* with a significant dominance of *B. dorsalis* with 94.9% of the catches.

Although the tropical almond or *T. catappa* is infested by many species of fruit flies (Diptera: Tephritidae) (Rwomushana et al., 2008a), there seem to be a dominant emergence of *B. dorsalis*. This would be due to the fact that tropical almond is among the preferred wild hosts of *B. dorsalis*. In fact, in their study in Kenya, Rwomushana et al. (2008) found that *T. catappa* was the most heavily infested among the wild host plants by *B. dorsalis*. In addition, Siderhurst and Jang (2006) reported that ripe fruits of tropical almond attract females of *B. dorsalis.* The presence of these fruits on the trees during the dry season provides oviposition sites for females and maintains high population densities of *B. dorsalis*. These wild plants ensure basic conditions for breeding such as spawning and nutrient source for larvae, for *B. dorsalis* during the off-season period when host plants do not bear fruits.

The number of emerged fruit flies individuals observed differed in different sites. This could be explained by the ability of *B. dorsalis* to use many alternative host plants. In fact, Mwatawala et al. (2009) found that *B. dorsalis* was predominant but was using a much larger range of available alternative host plants in their study area. Another factor increasing its abundance is that *B. dorsalis* displaces other fruit flies species. Indeed, *B. dorsalis* has displaced *C. cosyra* on mango by its aggressive behaviour between adult flies and competition on food resources in studies conducted in Kenya (Rwomushana et al., 2009; Ekesi et al., 2009). A similar behaviour was observed in the Hawaiian Islands, in 1945, where *B. dorsalis* has largely displaced *Ceratitis capitata* in the coastal areas where it was previously established (Duyck et al., 2004). Also on the Thailand Peninsula, *B. dorsalis* has been observed displacing other species of *Bactrocera* genus (Danjuma, 2018). It has been said that *Bactrocera* spp. could use resources better than pre-established species, probably by denying them access to food or target sites (Duyck et al., 2004). In Kenya, Ekesi et al. (2006, 2009) found that *C. cosyra* was abundant on the mango before the arrival of *B. dorsalis* while Salum et al. (2013), reported that *B. dorsalis* reproduces more quickly than *C. cosyra.* Thus, the arrival of *B. dorsalis* in a given area leads to a decrease in populations of pre-established species. In fact, we have observed some individuals of *C. cosyra* during the emerged flies' collection; showing that this populations of this species would have been dominated by *B. dorsalis*.

Despite the variation between sites, the infestation rate showed that fruits had strong infestation from *B. dorsalis*. Other studies have found similar infestation rates ranging from 123.1 to 652.8 individuals per kg of fruits (Rwomushana et al. 2008a, Thomson and Evans, 2006 and José et al. 2013). This variation would be due to the availability and abundance of host plants in different sites as these two factors have direct influence on the abundance of fruit flies populations. For example, Mwatawala et al. (2006) in their study conducted in Morogoro, found that the abundance of *B. dorsalis* was correlated with the fruiting season of mango and guava. In addition, the abundance of a species of fruit flies in a given locality is linked to the presence of preferred host plants (Hafsi et al. 2016). Thus, the presence of mango trees in a site contribute to the increase in populations of *B. dorsalis*. According to Rattanapun et al. (2009), Ekesi and Billah (2007) and Mwatawala et al. (2006), mango is the preferred host plant for *Bactrocera dorsalis* and Chen & Ye (2007) indicate that the availability of host plants is one of the factors influencing the distribution and density of the population of Tephritidae in general.

Q. Industrial, Kiriri, Kinindo and Mutanga sites which have the highest infestation rates show the strongest similarity. These sites are located in residential neighbourhoods with low population and house density. In these areas, there are large plots and few houses with a high density of planted fruit trees including mango. In these neighbourhoods, a high number of ripe fruits are not harvested and therefore fall on the ground. Thus, these fruits ensure reproduction and development of *B. dorsalis*. This could explain the high density of fruit flies that emerged from the fruits collected in these neighbourhoods. Secondly, there is similarity between Mutakura and Rohero sites. Rohero is near downtown Bujumbura and has a low density of houses with planted trees but the area is mostly used for offices and business with a large number of trees planted along roadsides. Like in Mutakura which is a high populated neighbourhood with less fruit trees, fruits especially mangoes are harvested most of the time before maturity by children or some house workers to be sold or for consumption. Thus, the populations of *B. dorsalis* do not have the opportunity to multiply at this site. On the other hand, Kanyosha, Ngagara and Kibenga sites are among the most populated neighbourhoods in Bujumbura city with few fruit trees. Kibenga site is located in a new neighbourhood with a dominance of ornamental plants while Ngagara and Kanyosha are old neighbourhoods.

This study shows that *T. catappa* Linn contributes significantly to the survival of populations of *B. dorsalis* in Bujumbura city as the latter uses its fruits as hosts especially in the dry season. In addition, the presence of preferred hosts in an area increases the abundance of the fruit flies *B. dorsalis* in tropical almond fruits. Thus, *T. catappa* can be considered as an alternative host plant for *B. dorsalis* used in the absence of its preferred host plants. Programmes aiming at eradicating fruit flies as pests should take *T. catappa* into account as a potential host significantly contributing to the survival and development of *B. dorsalis*.

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