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

Ndayizeye Lievin[1+]
Sibomana Claver[2]

[1]*Office Burundais pour la Protection de l'Environnement, Direction de l'Environnement et des Changements Climatiques, B.P. 2757 Bujumbura, Burundi.*
Email: ndayizeyelievin@yahoo.com
[2]*Center for Research in Natural Science and Environment, Faculty of Sciences, University of Burundi, Bujumbura, Burundi.*
Email: claver.sibomana@ub.edu.bi

(+ Corresponding author)

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ABSTRACT

The research aimed at showing the contribution of *Terminalia catappa* to the survival of *B. dorsalis*. Through fruit incubation, the study was done in Bujumbura city from June to September 2017. Individuals were collected from fruits infested by flies. Fruits were collected in neighborhoods according to the population and fruit trees density. Results show that *T. catappa* was infested by two species *B. dorsalis* and *C. cosyra* with very low numbers. *B. dorsalis* was abundant in the neighborhoods with low population density and high number of fruit trees. The latter 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 host especially in the dry season. *T. catappa* can be considered an alternative host plant for *B. dorsalis* used in the absence of its preferred host plants. Practical implications of this research is the use of orchard sanitation for eradicating *B. dorsalis*.

Contribution/Originality: This study shows that Terminalia catappa is an alternative host of B. dorsalis, hence significantly contributing to its development and survival in the absence the main hosts. The importance of considering alternative hosts in fruit fly management programs is highlighted.

1. INTRODUCTION

Fruit flies are among the most damaging pests of fruits and vegetables in the world [1-3]. Among them, the oriental fruit fly *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) is a polyphagous pest species first identified in Africa in 2003 [4]. Nevertheless, this species shows preference for ripe mango (*Mangifera indica*) [5]. It is an invasive species considered a fruit pest attacking a wide range of host plants causing huge damage to both local and export production [6-10]. In Burundi, *B. dorsalis* was first detected in Kigwena, south-western Burundi in 2009 and is abundant in the western part of Burundi in Imbo region along the shore of Lake Tanganyika and Rusizi river [11].

The Western Burundi is 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 fruits and vegetables 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 fruit 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 Southeast Asia [12]. These trees are widely cultivated in tropical and subtropical coastal areas and used by local communities for several household uses. The tree is planted for shade and ornamental purposes in urban environments [13-15]. *Terminalia catappa* is generally known as a host for some fruit fly species within *Bactrocera* genus [16, 17].

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. Despite their attractive color and smell, they are not consumed by local population, except for some children from poor families. During the rainy season (September to May), some trees can be seen with sparse amounts of ripe fruit. In Burundi, the dry season is considered an off-season period for most fruit crops. Due to its preference for warm climate regions, *Terminalia catappa* is largely distributed in western Burundi, especially in the city of Bujumbura, where it is often planted along avenues, in public and home gardens for shade and ornamental purposes. In addition, the flesh of the fruit is often fibrous and not tasty despite the pleasant smell [18] 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. Therefore, the survival of *B. dorsalis* would be compromised if there are no alternative host plants during this season. Given that its fruition occurs during the dry season in the city of Bujumbura, *T. catappa* is a potential host that would be essential for the survival of *B. dorsalis* during this season. In most cases, ripe fruits are often observed remaining on the tree or decomposing on the ground. However, to our knowledge, no study has evaluated to what 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.

2. MATERIALS AND METHODS

2.1. 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 neighborhood taking into account the presence of other trees and potential fruit fly host, especially mango trees (Table 1). The 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 (Figure 1).

2.2. Fruit Collection and Incubation Process

Ripe fruits (of brown or violet brown color) were harvested or collected on the ground and stored immediately in black bags. The number of fruits collected on each sampling day depended on the availability of 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 the incubation facility of the OBPE (Office Burundais pour la Protection de l'Environnement) and processed according to the protocol of Ekesi and Billah [3]. 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 a 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 daily for the emergence of adults. Daily monitoring and room cleaning were performed to prevent predation by ants. The incubated fruits were discarded after their complete decomposition.

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.)

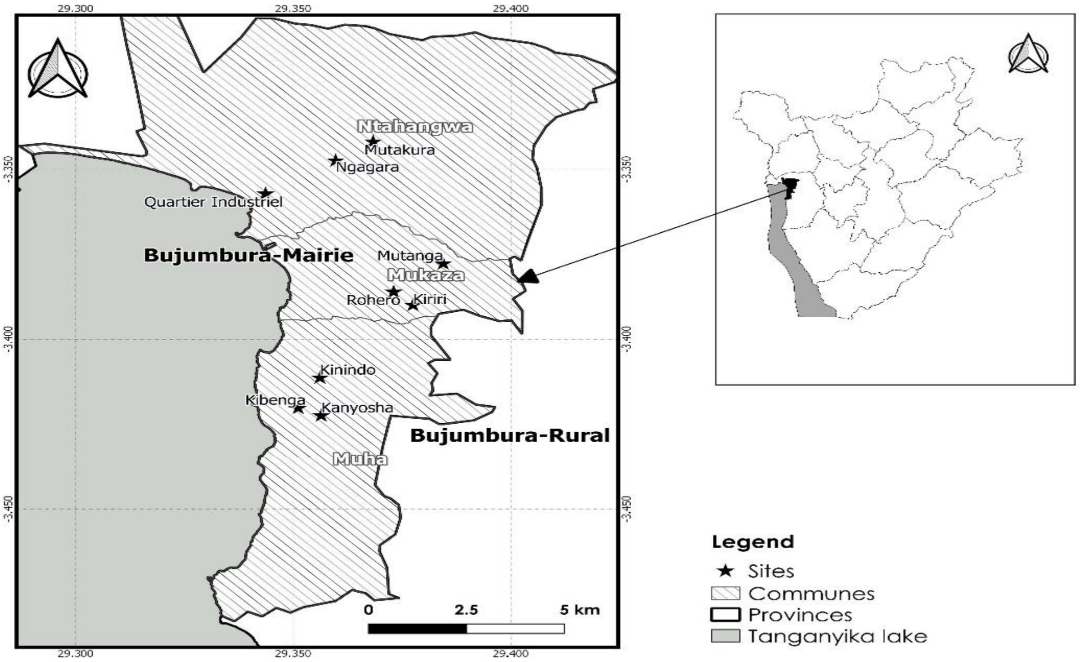

Figure 1. Map of Bujumbura city showing the study sites.

3. DATA ANALYSIS

3.1. Infestation Rate

The infestation rate is obtained using the formula from De Souza, et al. [19] and Vayssières, et al. [20] 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/weights of the incubated fruits.

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) [21] software to generate dendrogram. This method hierarchically groups the different habitats according to their similarity.

4. RESULTS

4.1. 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 or 23.61%, emerged from 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 (Figure 2).

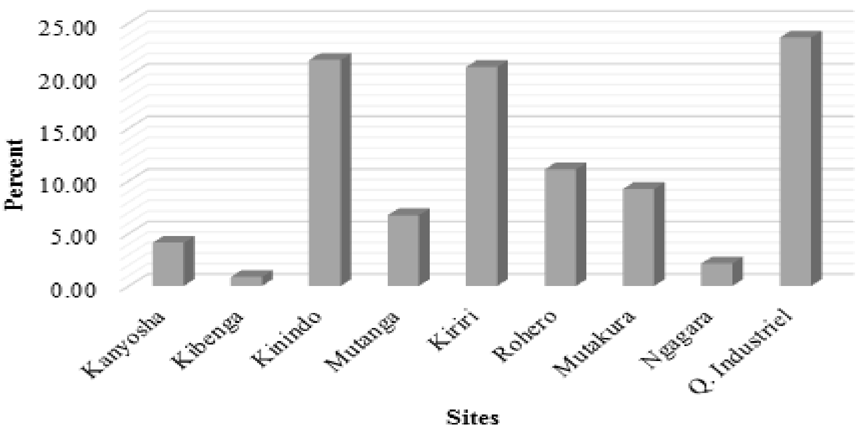

Figure 2. Relative abundance of captured flies per site.

4.2. Infestation Rate

Taking into account the emergence of *B. dorsalis* (2681 individuals) from 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	9	360	16.65	2681	100.00	161.02

4.3. Index of Bray-Curtis

The dendrogram shows clear clustering with the first group composed of Kinindo, Kiriri, Q. Industriel and Mutanga sites (Figure 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 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.

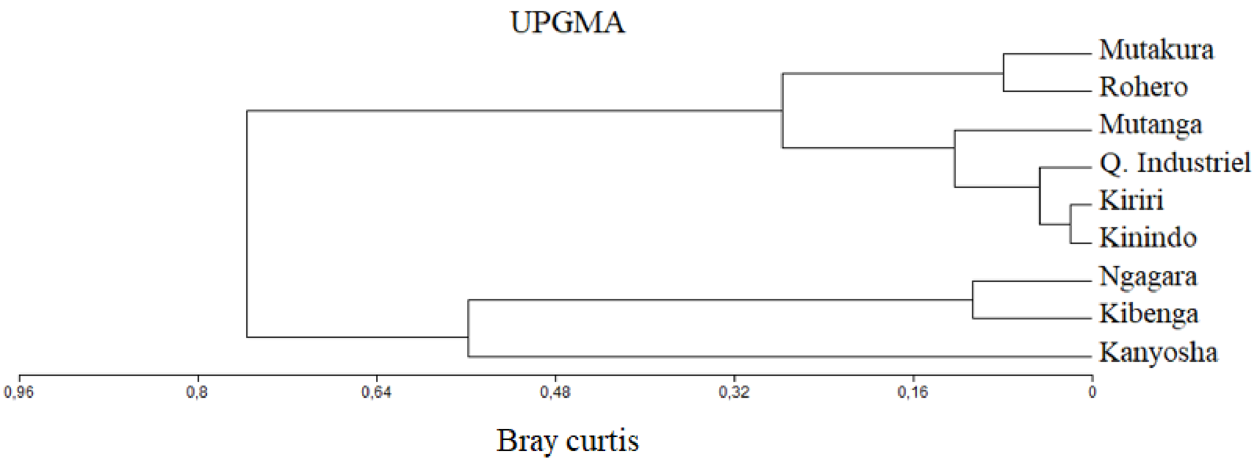

Figure 3. Dendrogram.

5. DISCUSSION

In this study, two species of fruit flies, *Bactrocera dorsalis* and *Ceratitis cosyra*, emerged from the collected fruits of *T. catappa*. Only two individuals of *C. cosyra* were captured but were not considered given that it wasn't the aim of the study. These species have been found infesting the same host plant in studies conducted in other regions. José, et al. [22] found *C. cosyra* infesting *T. catappa* in Cabo Delgado, northern Mozambique. In Thailand, Somta, et al.

[23] 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) [10], there seems to be a dominant emergence of *B. dorsalis*. This would be because tropical almond is among the preferred wild hosts of *B. dorsalis*. In fact, in their study in Kenya, Rwomushana, et al. [10] found that *T. catappa* was the most heavily infested among the wild host plants by *B. dorsalis*. In addition, Siderhurst and Jang [24] 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 individuals differed in all sites. This could be explained by the ability of *B. dorsalis* to use many alternative host plants. Mwatawala, et al. [25] 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 fly species. Indeed, *B. dorsalis* has displaced *C. cosyra* on mango because of its aggressive behavior between adult flies and competition for food resources in studies conducted in Kenya [26, 27]. A similar behavior was observed in the Hawaiian Islands in 1945, where *B. dorsalis* largely displaced *Ceratitis capitata* in the coastal areas where it was previously established [27]. Also on the Thailand Peninsula, *B. dorsalis* has been observed displacing other species of *Bactrocera* genus [28]. 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. [27]. In Kenya, Ekesi, et al. [7] and Duyck, et al. [27] found that *C. cosyra* was abundant on the mango before the arrival of *B. dorsalis* while Salum, et al. [29], 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 the populations of pre-established species. We have observed some individuals of *C. cosyra* during study, showing that the populations of this species would have been dominated by *B. dorsalis*.

Despite the variation between sites, the infestation rate showed that fruits had a strong infestation from *B. dorsalis*. Other studies have found similar infestation rates ranging from 123.1 to 652.8 individuals per kg of fruits [10, 22, 30]. This variation would be due to the availability and abundance of host plants at different sites, as these two factors have a direct influence on the abundance of fruit flies populations. For example, Mwatawala, et al. [8] found in their study conducted in Morogoro 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 [31]. Thus, the presence of mango trees on a site contributes to the increase in populations of *B. dorsalis*. According to Ekesi and Billah [3]; Rattanapun, et al. [5] and Mwatawala, et al. [8], mango is the preferred host plant for *Bactrocera dorsalis* and Chen and Ye [32] 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. Industriel, Kiriri, Kinindo and Mutanga sites which have the highest infestation rates, show the strongest similarity. These sites are located in residential neighborhoods with low population and house density. In these areas, there are large plots and a few houses with a high density of planted fruit trees, including mango. In these neighborhoods, a high number of ripe fruits are not harvested and therefore fall to the ground. Thus, these fruits ensure the reproduction and development of *B. dorsalis*. This could explain the high density of fruit flies that emerged from the fruits collected in these neighborhoods. Secondly, there is a 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 businesses, with a large number of trees planted along roadsides. Mutakura which is a highly populated neighbourhood with fewer fruit trees, mangoes are harvested most of the time before maturity by children or some houseworkers 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 neighborhoods in Bujumbura city with few fruit trees. Kibenga is located in a new neighbourhood with a dominance of ornamental plants, while Ngagara and Kanyosha are old neighborhoods.

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 an alternative host plant for *B. dorsalis* in the absence of its preferred host plants. Programs 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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REFERENCES

[1] I. M. White and M. M. Elsonharris, "Fruit flies of economic significance: Their identification and bionomics," *Environmental Entomology*, vol. 22, pp. 1408-1408, 1992. https://doi.org/10.1093/ee/22.6.1408a

[2] IAEA, "Trapping guidelines ofr area-wide fruit fly programmes." Vienna, Austria: FAO/IAEA, 2003, p. 47.

[3] S. Ekesi and M. K. Billah, *A field guide to the management of economically important tephritid fruit flies in Africa*. Nairobi, Kenya: ICIPE Science, 2007.

[4] S. A. Lux, R. S. Copeland, I. M. White, A. Manrakhan, and M. K. Billah, "A new invasive fruit fly species from the Bactrocera dorsalis (Hendel) group detected in East Africa," *International Journal of Tropical Insect Science*, vol. 23, no. 4, pp. 355-361, 2003. https://doi.org/10.1017/s174275840001242x

[5] W. Rattanapun, W. Amornsak, and A. R. Clarke, "Bactrocera dorsalis preference for and performance on two mango varieties at three stages of ripeness," *Entomologia Experimentalis et Applicata*, vol. 131, no. 3, pp. 243-253, 2009. https://doi.org/10.1111/j.1570-7458.2009.00850.x

[6] J. Vayssières, G. Goergen, O. Lokossou, P. Dossa, and C. Akponon, "A new bactrocera species in Benin among mango fruit fly (Diptera: Tephritidae) species," *Fruits*, vol. 60, pp. 371–377, 2005.

[7] S. Ekesi, P. Nderitu, and I. Rwomushana, "Field infestation, life history and demographic parameters of the fruit fly Bactrocera invadens (Diptera: Tephritidae) in Africa," *Bulletin of Entomological Research*, vol. 96, no. 4, pp. 379-386, 2006.

[8] M. Mwatawala, M. De Meyer, R. H. Makundi, and A. Maerere, "Seasonality and host utilization of the invasive fruit fly, Bactrocera invadens (Dipt., Tephritidae) in central Tanzania," *Journal of Applied Entomology*, vol. 130, no. 9-10, pp. 530-537, 2006. https://doi.org/10.1111/j.1439-0418.2006.01099.x

[9] G. Goergen, J.-F. Vayssières, D. Gnanvossou, and M. Tindo, "Bactrocera invadens (Diptera: Tephritidae), a new invasive fruit fly pest for the Afrotropical region: host plant range and distribution in West and Central Africa," *Environmental Entomology*, vol. 40, no. 4, pp. 844-854, 2011. https://doi.org/10.1603/en11017

[10] I. Rwomushana, S. Ekesi, I. Gordon, and C. K. Ogol, "Host plants and host plant preference studies for Bactrocera invadens (Diptera: Tephritidae) in Kenya, a new invasive fruit fly species in Africa," *Annals of the Entomological Society of America*, vol. 101, no. 2, pp. 331-340, 2008. https://doi.org/10.1603/0013-8746(2008)101[331:hpahpp]2.0.co;2

[11] L. Ndayizeye, B. Nzigidahera, and C. D. Theron, "Effect of parapheromones on the capture of fruit flies (Diptera, Tephritidae) in Burundi," *Journal of Agricultural Science and Technology A*, vol. 7, no. 6, pp. 413-425, 2017. https://doi.org/10.17265/2161-6256/2017.06.007

[12] A. C. Smith, "Studies of pacific island plants, XXIV. The genus Terminalia (Combretaceae) in Fiji, Samoa, and Tonga," *Brittonia*, vol. 23, pp. 394-412, 1971. https://doi.org/10.2307/2805706

[13] P.-S. Chen, J.-H. Li, T.-Y. Liu, and T.-C. Lin, "Folk medicine Terminalia catappa and its major tannin component, punicalagin, are effective against bleomycin-induced genotoxicity in Chinese hamster ovary cells," *Cancer Letters*, vol. 152, no. 2, pp. 115-122, 2000. https://doi.org/10.1016/s0304-3835(99)00395-x

[14] D. F. Hayward, "The phenology and economic potential of Terminalia catappa L. in south-central Ghana," *Vegetatio*, vol. 90, no. 2, pp. 125-131, 1990. https://doi.org/10.1007/bf00033022

[15] S. Kinoshita, Y. Inoue, S. Nakama, T. Ichiba, and Y. Aniya, "Antioxidant and hepatoprotective actions of medicinal herb, Terminalia catappa L. from Okinawa Island and its tannin corilagin," *Phytomedicine*, vol. 14, no. 11, pp. 755-762, 2007. https://doi.org/10.1016/j.phymed.2006.12.012

[16] K. Tsuruta *et al.*, "A preliminary notes on the host plants of fruit flies of the tribe Dacini (Diptera: Tephritidae) in Sri Lanka”," *Isaiah*, vol. 37, pp. 149-160, 1997.

[17] A. R. Clarke *et al.*, "Invasive phytophagous pests arising through a recent tropical evolutionary radiation: The Bactrocera dorsalis complex of fruit flies," *Annual Review of Entomology*, vol. 50, pp. 293-319, 2005.

[18] T. Heinsleigh and B. Holaway, *Agroforestry species for the Philippines*. Metro Manila Philippines: US Peace Corps, AJA Printers, 1988.

[19] E. O. De Souza, M. Florence, A. H. Bokonon-Ganta, and V. Micheline, "Infestation naturelle de Murraya paniculata L. Jack,(Rutaceae) par les mouches Tephritidae nuisibles aux fruits dans la commune de Porto-Novo (Sud-Est Bénin)," *Journal of Applied Biosciences*, vol. 105, pp. 10111-10119, 2016.

[20] J. F. Vayssières, A. Sinzogan, and A. Adandonon, *Range of cultivated and wild host plants for the main species of fruit flies in Benin". Technical Sheet 8*. Montpellier, France; IITA Cotonou Benin: CIRAD, Fruit Production UPR, 2009.

[21] W. Kovach, *“MSVP-multi-variate statistical package data analysis”*. Pentraeth, Anglesey: Kovach Computing Services; 85 Nant-y-Felin, 1997.

[22] L. José, D. Cugala, and L. Santos, "Assessment of invasive fruit fly fruit infestation and damage in Cabo Delgado Province, Northern Mozambique," *African Crop Science Journal*, vol. 21, no. 1, pp. 21-28, 2013.

[23] C. Somta, A. Winotai, and P. Ooi, "Fruit flies reared from Terminalia catappa in Thailand," *Journal of Asia-Pacific Entomology*, vol. 13, no. 1, pp. 27-30, 2010. https://doi.org/10.1016/j.aspen.2009.09.003

[24] M. S. Siderhurst and E. B. Jang, "Female-biased attraction of oriental fruit fly, Bactrocera dorsalis (Hendel), to a blend of host fruit volatiles from Terminalia catappa L," *Journal of Chemical Ecology*, vol. 32, pp. 2513-2524, 2006. https://doi.org/10.1007/s10886-006-9160-6

[25] M. Mwatawala, M. De Meyer, R. H. Makundi, and A. Maerere, "Host range and distribution of fruit-infesting pestiferous fruit flies (Diptera, Tephritidae) in selected areas of Central Tanzania," *Bulletin of Entomological Research*, vol. 99, no. 6, pp. 629-641, 2009. https://doi.org/10.1017/s0007485309006695

[26] I. Rwomushana, S. Ekesi, C. K. Ogol, and I. Gordon, "Mechanisms contributing to the competitive success of the invasive fruit fly Bactrocera invadens over the indigenous mango fruit fly, Ceratitis cosyra: the role of temperature and resource pre-emption," *Entomologia Experimentalis et Applicata*, vol. 133, no. 1, pp. 27-37, 2009. https://doi.org/10.1111/j.1570-7458.2009.00897.x

[27] P. F. Duyck, P. David, and S. Quilici, "A review of relationships between interspecific competition and invasions in fruit flies (Diptera: Tephritidae)," *Ecological Entomology*, vol. 29, no. 5, pp. 511-520, 2004. https://doi.org/10.1111/j.0307-6946.2004.00638.x

[28] Danjuma, "Population dynamics and displacement capacity of nine bactrocera spp. (Diptera: Tephritidae) in Fruit Orchards of the Peninsular Thailand," *Kaduna Journal of Agriculture and Natural Resources*, vol. 3, no. 1, pp. 63-83, 2018.

[29] J. Salum, M. Mwatawala, P. Kusolwa, and M. Meyer, "Demographic parameters of the two main fruit fly (D iptera: Tephritidae) species attacking mango in C entral T anzania," *Journal of Applied Entomology*, vol. 138, no. 6, pp. 441-448, 2014.

[30] L. A. J. Thomson and B. Evans, *Terminalia catappa (tropical almond). Species profiles for Pacific Island Agroforestry*. Holualoa, HI: Permanent Agriculture Resources (PAR), 2006.

[31] A. Hafsi *et al.*, "Host plant range of a fruit fly community (Diptera: Tephritidae): does fruit composition influence larval performance?," *BMC Ecology*, vol. 16, no. 1, pp. 1-12, 2016. https://doi.org/10.1186/s12898-016-0094-8

[32] P. Chen and H. Ye, "Population dynamics of Bactrocera dorsalis (Diptera: Tephritidae) and analysis of factors influencing populations in Baoshanba, Yunnan, China," *Entomological Science*, vol. 10, no. 2, pp. 141-147, 2007. https://doi.org/10.1111/j.1479-8298.2007.00208.x