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ORIGINAL RESEARCH ARTICLE

Current distribution of *Bactrocera latifrons* Hendel in the different agro-ecological zones of Burundi

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Abstract

Bactrocera latifrons Hendel is a species of Asian origin. It is a major destructive pest of fruits and vegetables of the family of Solanaceae and, to a lesser extent, Cucurbitaceae. It was detected for the first time in Burundi in 2016, in the province of Kirundo in the north of the country. Since this detection, a study using fruit rearing methodology was conducted in five agro-ecological zones of Burundi from July 2016 to April 2017 to determine the distribution of *B. latifrons*, and to analyze the infestation rate on African eggplant *(Solanum aethiopicum)*. The results of this study revealed that *B. latifrons* has invaded all the agro-ecological zones of Burundi, and could invade neighboring countries.

Keywords Incubation · Invasive species · Host plant · *Solanum aethiopicum* · Infestation rate

Introduction

Tephritid fruit flies (Diptera), particularly species belonging to the genera *Anastrepha*, *Bactrocera*, *Ceratitis*, *Dacus*, *Rhagoletis* and *Zeugodacus*, are among the most important pests for the horticultural industry in tropical, subtropical, and temperate regions (Hendrichs et al. 2015). Fruit flies cause direct economic loss through feeding damage from larvae, and exposing fruit to secondary infestation (Kachigamba et al. 2012). The presence of tephritid fruit flies in a country also leads to economic loss through costly and potentially damaging quarantine measures for local and international markets. The control of established tephritid fruit flies in a country is very costly (Cugala et al. 2011; Carey et al. 2017). For example, Dowell and Wange (1986) stated that establishment of major fruit fly threats to the Californian fruit industry would cause crop losses of US $910 M yearly, and an eradication program would cost US $290 M. The introduction of papaya fruit fly (*Bactrocera papayae* Drew and Hancock) to Australia in 1995, led to a major blockade of papaya exports from northern Queensland and major losses to local growers between 1995 and 1998. Commercial trade was only restored (Cantrell et al. 2002) through an eradication program that cost US $32.5 M.

Sub-Saharan Africa is home to 915 fruit fly species from 148 genera, with 299 species developing in wild and/or cultivated hosts (Ekesi 2010). Tephritid fruit flies from the genera *Ceratitis*, *Dacus* and *Bactrocera* constitute one of the major threats to horticultural production in East, Central and West Africa, causing substantial loss to produce (Gupaul et al. 2000; Mwatawala et al. 2005; Van Melle et al. 2007; Zacharopoulou et al. 2017). Apart from the native species populating Africa, exotic species of the genera *Bactrocera* Macquart (*B. dorsalis* and *B. latifrons*) and *Zeugodacus (Z. cucurbitae*), known to be pests of fruit and vegetables, have invaded most of the countries in sub-Saharan Africa (Clarke et al. 2005; Ekesi and Billah 2007). *B. dorsalis*, originating from the Indian subcontinent, was first detected in Africa in 2003, *Z. cucurbitae*, originating from Asia, was detected in Gambia (West Africa) in 1999, with long established adventive populations in Hawaii, Réunion, and eastern Africa (Drew et al. 2005; Vayssières et al. 2007; De Meyer et al. 2007). Finally, *B. latifrons* Hendel (Solanum fly), is an invasive species of Asian origin (Carroll et al. 2002). This fly originates from South and Southeast Asia (White and Elson-Harris 1994), including Malaysia, Thailand, Taiwan, India and South China.

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B. latifrons has been recorded infesting fruits from the family Solanaceae and Cucurbitaceae in Tanzania, Thailand, Malaysia and Hawaï (Allwood et al. 1999; Peck and McQuate 2004; Mziray et al. 2010a, b; Wingsanoi and Siri 2012). In Asia, *B. latifrons* has been reported to use hosts such as e.g. guava (*Psidium guajava*), pomegranate (*Punica granatum*) and citrus fruits (*Citrus aurantifolia*) (Allwood et al. 1999). This species is among the 10 taxa regularly intercepted during import controls in Europe (Balmès et al. 2010; Steffen et al. 2015). The introduction of *B. latifrons* into Hawaii in 1983 affected wild and cultivated solanaceous crops. However, it has been observed to maintain relatively low population densities, perhaps because its wild hosts are usually sparsely distributed (making studies of wild populations difficult), and the crop species it attacks have only limited areas of production (Peck and McQuate 2004). Despite being a host specialist, the solanum fruit fly is a pest of quarantine importance and has the potential to permanently establish itself and compete and/or coexist with other native and previously introduced tephritid fruit fly species (Liquido et al. 1994; Mziray et al. 2010a, b).

In Africa *B. latifrons* has been recorded for the first time on African eggplants *Solanum aethiopicum* both in Tanzania, in 2006, and in Kenya near the border with Tanzania in 2007 (Mwatawala et al. 2007; De Meyer et al. 2013; EPPO 2014; Ekesi, unpublished records). In 2016, *B. latifrons* was reared from *S. aethiopicum* harvested in Kirundo in northern Burundi. *B. latifrons* is the third exotic species detected in Burundi, since the detection of *B. dorsalis* and *Zeugodacus cucurbitae* in 2009 (Ndayizeye et al. 2017). The spread and detection of this pest throughout the African continent is slower than *B. dorsalis*, and this may be due to the limited distribution of available hosts forcing this species to rely on human facilitated movement. New detections of this species have not been reported since 2007 (Ekesi et al. 2016).

The detection of *B. latifrons* in Burundi constitutes a great danger to fruit and vegetable production as this adds to the damage caused to mangoes, oranges, mandarins, avocado, guava, currently being infested by *B. dorsalis* (Ndayizeye, unpublished data). Eggplant is grown throughout the year in different agro-ecological zones of Burundi and so may provide a continuous host for *B. latifrons* (Bart et al. 2001; Floresta Burundi 2012). Eggplant is an economically important crop as it forms part of the staple diet in Burundi, and is transported and sold throughout the country. The damage of crops will affect the supply of produce to markets. Eggplant is not subjected to pesticide treatment in Burundi and in this publication we assess the distribution and the infestation rates of *Bactrocera latifrons* on eggplant throughout the various agro-ecological zones in Burundi.

Materials and methods

Field sites

This research was conducted from July 2016 to April 2017 at the Biodiversity Research Center within Burundi Environment Protection Authority. The work was carried out in five agro-ecological zones, namely the Imbo Plain, the western slope of the Congo-Nile Ridge, the Congo-Nile Ridge, the Central Plateaus and the Northeast Depressions (Fig. 1). Eggplant samples were collected from 19 selected sites throughout the country covering all agro-ecological zones. Imbo Plain had three sites (Bugarama, Mutimbuzi and Kinama) located at an altitude ranging from 800 to 1100 masl (meters above sea level) with an annual average temperature of 23 °C–28 °C. The western slope of the Ridge Congo-Nile consisted of five sites (Bubanza, Mabayi, Mubimbi, Nyabiraba, Vyanda) with an altitude of 1000–1700 masl, and the average annual temperature ranging from 18°-28 °C. The Ridge Congo Nile consisted of a single site (Bururi) at an altitude of 1700–2500 masl and an average annual temperature of 14 °C–15 °C. The Central Plateaus consisted of six sites (Cankuzo, Giheta, Gihogazi, Kayokwe, Mbuye, Ngozi, Ruyigi) at an altitude between 1350 and 2000 masl and an average annual temperature of 17 °C–20 °C. Finally, the Northeast depressions consisted of three sites (Bukemba, Kayogoro, Kirundo) with an altitude between 1100 and 1400 masl with an annual average temperature of 20 °C–23 °C. The number of sites per agro-ecological zone was dictated both by the availability of eggplants and access to cultivated fields.

Fruit collection and incubation

Mature eggplants (yellowish or reddish) were harvested or collected from the ground (fallen eggplants) and placed in black plastic bags. The samples were then transported to the Biodiversity Research Center laboratory for incubation, following the method outlined by Copeland et al. (2002). For all sites, the number of sampled fruits differed due to the availability of eggplants in the field and the size of eggplants. The variation in the size of the eggplant observed is due to natural variation caused by ecological conditions. In the laboratory, fruits were counted, washed and weighed (using an electrical balance type Kitchen Scale, 5 kg). Fruits were placed in ventilated rectangular plastic boxes of 21.5 cm × 15 cm × 16.5 cm or circular base boxes of 13 cm × 8 cm containing fine sifted sand. Samples were checked daily for adult emergence. Emerged adults were captured and placed in labeled vials containing 70% alcohol. Measures were taken to prevent predation of fruit samples by ants.

Identification of specimens

Preserved specimens were first identified using a LEICA EZ4HD stereomicroscope using the published

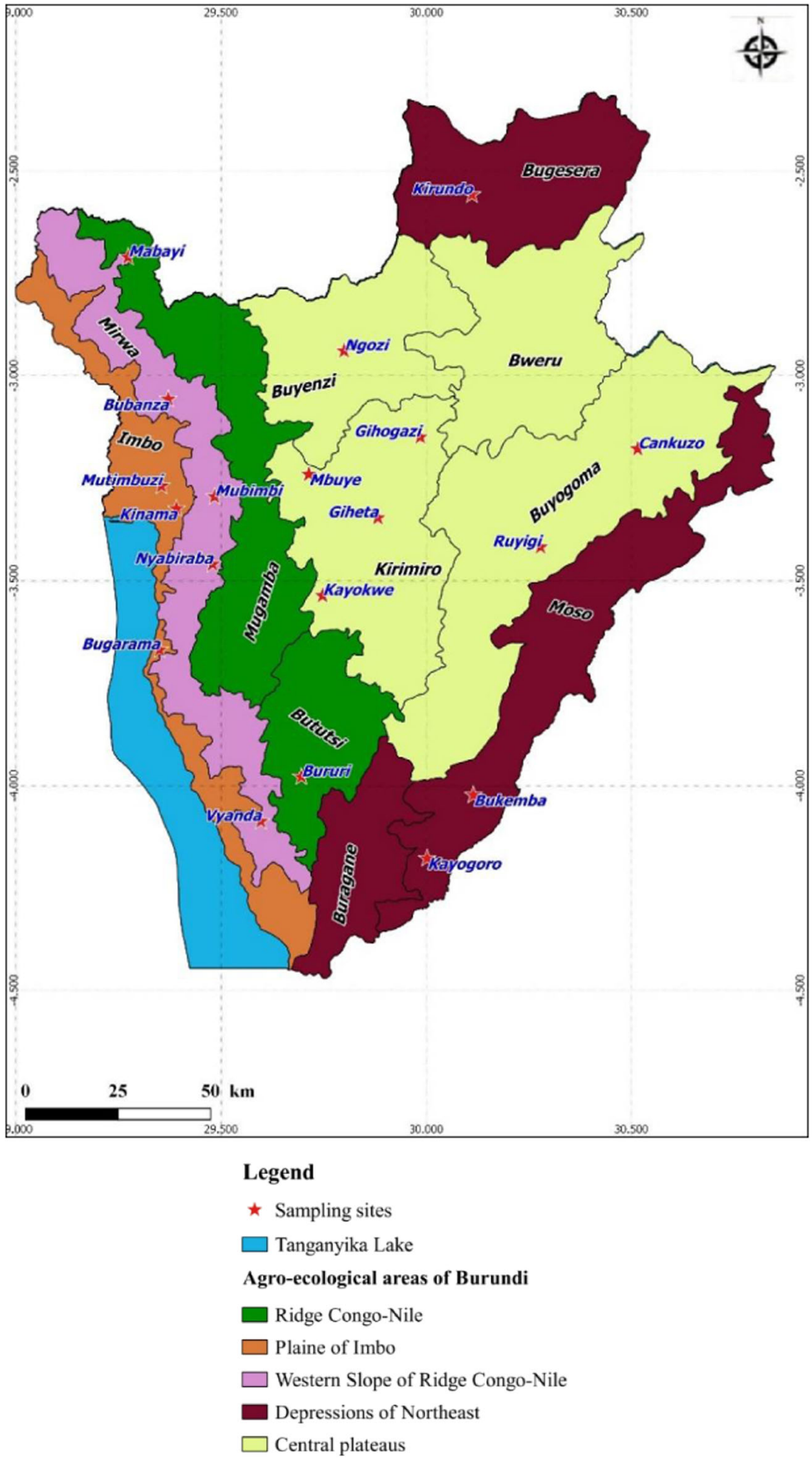

Fig. 1 Map of the different agro-ecological zones of Burundi

identification key for African fruit flies (Ekesi and Billah 2007). Confirmatory identification was done by Dr. Marc De Meyer of Entomology Section, Department of Biology, Royal Museum of Central Africa, Tervuren, Belgium.

Results

In the course of this research, 580 individuals of *Bactrocera latifrons* emerged from 2156 fruits weighing 33.5 kg collected in the five agro-ecological zones of Burundi (Table 1). *Musca* *domestica* and *Drosophilla melanogaster* were also identified as they emerged from sample fruit but were not included in further analyses as they were not targets of this study. These species occur naturally throughout the study area and opportunistically lay eggs in damaged and rotting fruit. Their yield may be due to previous infestation by fruit flies which facilitate the laying of eggs.

Within each agro-ecological zone, there was a difference in yields (number of fruit flies that emerged from reared fruit) at each site. High yield was observed in the Plain of Imbo with 92 individuals from 300 fruit, whereas low yield was recorded at the Ridge Congo-Nile with 41 individuals from 184 fruit. Also, some differences in yields were observed between sites within each zone. In addition, high yields were recorded at Bugarama site with 72 individuals from 56 fruit, followed by Mbuye site with 38 individuals from 35 fruit. Low yield was observed at Ngozi site with 2 individuals from 94 fruit.

Quantitative analysis both at the level of agro-ecological zones and the level of the sites showed different yields in relation to the weight of the incubated fruits. Indeed, quantitative analysis was based on the number of individuals yielded compared to the total weight (kg) of incubated fruits per site. Also, the infestation rate varied from 15.13 flies/kg to 27.33 flies/kg between agro-ecological zones, whereas it varied from 1.67 flies/kg to 76.00 flies/kg between sites. For all study sites, there was an infestation rate of 17.31 flies/kg.

Discussion

This research shows that *B. latifrons* was present in all the agro-ecological zones sampled in Burundi. No other Tephritid species were observed to emerge from the sampled fruit. Similar results were recorded by Harris et al. (2001) and Mwatawala et al. (2007). *B. latifrons* is utilizing eggplant as a host throughout its distribution in Burundi.

B. latifrons has a high intrinsic rate of increase and the ability to proliferate rapidly in newly invaded areas. With this species present in the north and west of Burundi, bordering regions with Rwanda and Democratic Republic of Congo, and the lack of strict phytosanitary measures at the borders and the illegal trade in fruit, there is a great possibility that these countries are also host to this invasive species. However, no published records of *B. latifrons* have been found in these areas to

Table 1 Emergence of fruit flies and the level of infestation by agro-ecological zone

Agro-ecological zones	Sampling sites	Number of fruits	Weight in kg	Number of emerged flies	Number of flies per kg
Imbo Plain	Bugarama	56	1.1	72	65.45
	Kinama	160	2.5	11	4.40
	Mutimbuzi	84	1.3	9	6.92
Subtotal	3	300	4.9	92	18.78
Western Slope of Congo-Nile Ridge	Bubanza	80	1.5	7	4.67
	Mabayi	66	1.5	15	10.00
	Mubimbi	122	1.9	10	5.26
	Nyabiraba	159	2.5	15	6.00
	Vyanda	193	2.8	116	41.43
Subtotal	5	620	10.2	163	15.98
Congo-Nile Ridge	Bururi	184	1.5	41	27.33
Subtotal	1	184	1.5	41	27.33
Central Plateaus	Cankuzo	41	0.8	14	17.50
	Giheta	195	3	13	4.33
	Gihogazi	60	0.8	17	34.00
	Kayokwe	143	2.1	69	32.86
	Mbuye	35	0.5	38	76.00
	Ngozi	94	1.2	2	1.67
	Ruyigi	74	1.2	16	13.33
Subtotal	7	642	9.3	169	18.17
Northeast Depressions	Bukemba	164	3	18	6.00
	Kayogoro	120	3	92	30.67
	Kirundo	126	1.6	5	3.13
Subtotal	3	410	7.6	115	15.13
Total	19	2156	33.5	580	17.31

date. Given that Rwanda borders Uganda, this species could invade Uganda through human facilitated movement as fruit flies may be transported across borders without being detected. Studies have also shown that fruit flies are able to fly great distances and thereby invade new areas (Fletcher 1987). *B. latifrons* could, in the near future, invade the entire sub-Saharan Africa as witnessed for *B. dorsalis*, which is currently causing heavy losses in produce in sub-Saharan Africa.

Regarding the infestation rate, eggplants from all five agro-ecological zones are infested by *B. latifrons*. This polyphagous pest species has been recorded to infest 59 species of plants divided in 14 families (Liquido et al. 1994; Mziray et al. 2010a, b). In addition Mziray et al. (2010a, b) reported that certain host plants of *B. latifrons* are utilized by other fly species such as *B. dorsalis*, *Zeugodacus cucurbitae*, *Ceratitis capitata*, *Dacus bivittatus*, *Dacus punctatifrons*, *Dacus ciliatus* and *Dacus vertebratus*, all of which are present in Burundi except last two (Ndayizeye et al. 2017).

The infestation rates varied both at zones and sites level. Considering zones, close infestation rates were observed between the Imbo Plain and the Central Plateaus (18.78 flies/kg and 18.17 flies/kg), and between the western slope of the Ridge Congo-Nile and Northeast depressions (15.98 flies/kg and 15.13 flies/kg). This could be due to the diversity, availability, and abundance of host plants. According to Hanson (1983), host plants maintain fruit fly populations. In these zones, eggplants are cultivated intensively to supply for local markets. However, some fruits are left in the field to produce seeds needed for the next season, and then contribute to the survival of *B. latifrons*. Mziray et al. (2010a, b) reported that *S. aethiopicum* mature red fruits are attacked by *B. latifrons* in detriment of non-mature eggplants. Mature, unripe fruits constitute the products that are harvested for consumption. In addition, Mwatawala et al. (2010) confirmed that *S. aethiopicum* was a very suitable host for *B. latifrons* during their sampling in Morogoro, Tanzania. Also, Liquido et al. (1994) found that the solanum fruit fly outcompetes *B. dorsalis*, *Z. cucurbitae* and *C. capitata* in its solanaceous hosts. Although having high infestation rate (27.33 flies/kg), the Ridge Congo-Nile cannot be subject of comparison since it has a single site.

At the sites level, the differences in infestation rates were observed at Bugarama, Kinama and Mutimbuzi sites, where eggplant is cultivated mainly for trade purposes. The availability of other host plants could explain this observation. Other solanaceous crops (e.g. tomato) are cultivated in Bugarama site, while Kinama and Mutimbuzi sites are surrounded by cereal crops. Apart from mature eggplants, other solanaceous and cucurbitaceous crops ensure the survival of this solanum fruit fly (Vargas and Nishida 1985; Kumar and Agarwal 2003; Ishida et al. 2005; Mziray et al. 2010a, b). Low infestations rates were found at Kirundo and Bukemba sites, contrary to Kayogoro site. For Kirundo and Bukemba sites eggplant is cultivated for farmer self-sufficiency. Thus, fruits are harvested as soon as they are mature, escaping from attacks of *B. latifrons*. Contrary to Kayogoro site, eggplants are produced both for consumption and trade purposes, and can spend more time in the field because they are harvested gradually according to market needs. Infestation rates between sites have also varied according to the maturity status of sampled fruits. Infestation rates were low in Giheta, Ngozi and Mubimbi sites. Fruits collected at these sites were yellowish, some of which had greenish patches. This result confirms the observations of Mziray et al. (2010a, b) indicating that *B. latifrons* attack mature ripe eggplant.

Studies show that *B. latifrons* has a preference for mature red eggplant, and the fact that eggplant are harvested at mature green stage might eliminate the need for quarantine restrictions. However, further research is required to determine the non-host status of mature green fruit. More research is also needed to determine the full host range and seasonal abundance of this species in Burundi.

Conclusion

Bactrocera latifrons is present throughout Burundi in *Solanum aethiopicum*. It displays a rapid progression given that it invaded the entire country within 1 year of first detection, with potential to invade neighboring countries. Other studies are necessary to understand the ecological parameters for this species and thus propose an effective control program for this pest.

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