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ASSESSMENT OF INVASIVE FRUIT FLY FRUIT INFESTATION AND DAMAGE IN CABO DELGADO PROVINCE, NORTHERN MOZAMBIQUE

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ABSTRACT

Fruit flies are among the most important pests of fruits and vegetables in the world. The invasive fruit fly *Bactrocera invadens* (Diptera: Tephritidae) was first detected in Africa in 2003 in Kenya. In Mozambique, it was first recorded in 2007 in Niassa Province. Direct damage due to *B. invadens* attack in African countries varies between 30-80%, but in Mozambique such information is lacking. This study aimed at assessing fruit damage and *B. invadens* infestation levels in different fruits in Mozambique. Four fruit fly species emerged from the collected fruits: *Bactrocera invadens*, *Ceratitis rosa*, *Ceratitis cosyra* and *Ceratitis capitata*. *Bactrocera invadens* was the most abundant species (97%), followed by *C. rosa* (1.8%), *C. cosyra* (1.1%) and *C. capitata* (0.1%). The highest damage was observed in guava (92.5% of fruits) followed by tropical almond (67.3%) and mango (56.5%). Mean number of pupae/fruit and per kg was also higher in guava with 10.10±0.57 and 217.33±3.93, respectively. Tropical almond had the highest number of *B. invadens*/fruit (6.63±1.35) and per kg (157.24±7.35). The severity of damage was high in all economically important hosts.

Key Words: *Bactrocera invadens*, guava, mango, sugar apple

RÉSUMÉ

Les mouches des fruits sont parmi les peste les plus importantes des fruits et legumes à travers le monde. La mouche invasive *Bactrocera invadens* (Diptera: Tephritidae) de fruits était détectée en Afrique en 2003 au Kenya. Au Mozambique, elle y avait été trouvée pour la première fois en 2007 dans la Province de Niassa. Le dégat direct dû à l'attaque du *B. invadens* dans des pays africains varie entre 30-80%, mais au Mozambique une telle information est manquante. Cette étude a évalué le niveau de dégat et l'infestation de différents fruits au Mozambique. Quatre espèces des mouches de fruits issues de fruits collectés: *Bactrocera invadens, Ceratitis rosa, Ceratitis cosyra* et *Ceratitis capitata*. *Bactrocera invadens* était l'espèce la plus abondante (97%), suivie de by *C. rosa* (1.8%), *C. cosyra* (1.1%) et *C. capitata* (0.1%). Le dégat le plus élevé était observé dans guava (92.5% des fruits) suivi par "tropical almond" (67.3%) et mangue (56.5%). Le nombre moyen de nimphe par fruit et par kg était aussi plus élevé dans guava avec 10.10±0.57 et 217.33±3.93, respectivement. Le "Tropical almond" avait le nombre le plus élevé de *B. invadens* par fruit (6.63±1.35) et par kg (157.24±7.35). La sévérité du dégat était élevée élevée dans tous les hôtes économiquement importants.

Mots Clés: *Bactrocera invadens*, guava, mangue, pomme cannelle

INTRODUCTION

Flies (Diptera: Tephritidae) are considered the most destructive insect pests of fruit and vegetables in the world (Vayssiéres *et al.*, 2008a; Ekesi *et al.*, 2009). The invasive fruit fly, *Bactrocera invadens* (Diptera: Tephritidae) was first detected in Africa in 2003 in Kenya (Lux *et al.*, 2003), and was subsequently detected in other African countries (Ekesi *et al.*, 2006; 2009).

Without control, direct damage has been reported from 30 to 80% depending on the fruit, variety, location and fruit season (Ekesi, unpublished data; Mwatawala *et al*., 2006a). Studies conducted in Tanzania, where *B. invadens* was detected in 2003, reported losses ranging from 20 to 61.7%; while in Ghana and Benin losses were estimated between 60 and 85% (Ekesi *et al*., 2006; Mwatawala *et al*., 2006a; Vayssiéres *et al*., 2008b; 2009a). In addition to direct losses, indirect losses due to quarantine restrictions imposed by importing countries have been enormous (Ekesi, unpublished data).

In Mozambique, *B. invadens* was first detected in 2007 in Cuamba district, Niassa province (Correia *et al*., 2008). Due to its detection, quarantine measures were imposed in Mozambique by importing countries of fruit and vegetables produced leading to loss of international markets. The temporary closure of South African market for three weeks in October 2008 resulted in the loss of about 2.5 million U.S. dollars (Cugala, 2011).

Currently, the invasive fruit fly, *B. invadens*, is well established and widespread in the Northern region of Mozambique where it occurs at high population density (Cugala *et al.*, 2011). However, since its first detection in the Northern region, there has been no assessment of its levels of infestation and fruit damage. Therefore, the present study was conducted to assess the levels of *B. invadens* fruit damage and infestation.

MATERIALS AND METHODS

The present study was carried out between January and March 2012 in Cabo Delgado province, north of Mozambique. This is a region characterised by a tropical weather with an annual average temperature between 22º à 34ºC. The cooler weather is between June and August, and peak summer months are December and January. Fruit crops are widely grown in the study area, being the most important mango, guava, tomatoes, banana and cashew among others.

Samples of ripe fruit of mango (*Mangifera indica* L.), guava (*Psidium guajava* L.), tropical almond (*Terminalia catappa* L.), sugar apple (*Anonna squamosa* L.) and pomegranate (*Punica granatum*) were collected weekly in Pemba (Niuje, 13º07.662' S; 040º26.145' E and 18 masl, Koma-koma, 13º05.426' S; 040º26.404' E and 28 masl) and Chiure (Mahipa, 13º36.097' S; 039º50.352' E and 246 masl), where *B. invadens* is widespread and well established (Cugala *et al*., 2011).

Niuje and Koma-koma are well organised fruit production areas and Mahipa is a major mango and cashew production area in Cabo Delgado Province. The choice of these host species was due to their abundance, availability during the study period and their being hosts of *B. invadens* (Ekesi and Billah, 2007).

For each host species, 5 trees were selected and from each tree, 5-10 fruits, preferably mature, were collected. For tropical almond, 30 fruits were collected in the soil due to the tree height. The fruits were taken to the laboratory in Pemba and checked for infestation symptoms. A fruit was considered damaged when a fly ovipuncture was visible. Since in guava, tropical almond and sugar apple it was difficult to observe the oviposition puncture, after a week of fruit rearing, fruits were opened slightly to check the presence of larvae. Following this procedure, a fruit was considered damaged when at least one fruit fly larva was observed inside the fruit according to Vayssiéres *et al*. (2009b).

Thereafter, the fruits were weighed, counted and placed in plastic containers with a net lid and sterilised sand at the bottom, and incubated for about 6 weeks. While mangoes were placed individually into the containers, other fruit species were placed in groups of 5-10 depending on the fruit and container size.

The fruits in the containers were checked once a week for puparia and adults flies. Puparia were sieved from the sand, counted, weighed, placed in Petri-dishes with moistened filter paper, and transferred to a cage for adult emergence (Ekesi and Billah, 2007). Emerged adults were provided with honey into the roof of the cage and water (cotton wool soaked with water) on the floor of the cage for feeding. Emerged adults were left in the cage for 3-5 days for growth and full development of morphological characteristics.

The adults of fruit flies that emerged from various fruits were counted, sexed and preserved in 70% alcohol for later identification. The samples were identified at the Laboratory of Entomology, Faculty of Agronomy and Forestry Engineering, Eduardo Mondlane University in Maputo. The abundance of each fruit fly species was estimated as the proportion of the total adult of each fruit fly species and the total adult collected of all fruit fly species. Percent damage was determined as ratio of number of infested fruits per total of collected fruits; while the infestation indices were expressed as mean number of pupae and *B. invadens* adults per fruit and per weight of collected fruits according to procedures described by Vayssiéres *et al*. (2009b).

Data were subjected to ANOVA using the generalised linear model (PROC GLM, SAS Institute). The data were transformed using the procedure square root " (x +0.5) and means were separated by "Student Newman Keuls" multiple test when ANOVA was significant at P <0.05.

A total of almost 60 kg of fruits from different hosts were collected: 37.8 kg mangoes, 12 kg of guavas, 4.6 kg of tropical almond, 3.5 kg of sugar apple and 1.2 kg of pomegranate. The majority of the fruit trees were local varieties.

RESULTS

Fruit flies species and their abundance. A total of 3,368 adult fruit flies emerged from 3962 pupae collected from all the 5 fruit hosts' species, corresponding to an average mean of 85% of adult emergence. Four fruit fly species were recovered from the fruits collected *Bactrocera invadens*, *Ceratitis rosa*, *Ceratitis cosyra* and *Ceratitis capitata*. *Bactrocera invadens* was the most abundant species and accounted for 96.9% of total emerged adults and *C. capitata* had the lowest proportion of emerged adults (0.12%) (Fig. 1). Three of the observed species emerged from guava, 2 from mango and sugar apple and 1 from tropical almond and pomegranate (Table 1). Only *B. invadens* emerged from all observed hosts fruits, indicating its polyphagous nature.

After guava fruits, tropical almond fruits contributed 26.6% of emerged adults, and all of them were *B. invadens* (Fig. 2). On the other hand, it was observed that in tropical almonds, pupae emerged more frequently and with lower weight and size compared with the pupae obtained from other hosts (Table 3). However, emerged adults showed no difference in terms of size and flight ability with the adults emerged from other hosts.

Damage and infestation indices. The level of fruit fly damaged fruits ranged from 36.7 to 92.5%. The highest percentage of fruit damage was observed on guava (92.49 ± 0.21), followed by tropical almond (67.32±2.71) and 56.50±0.12% on mango (Table 3).

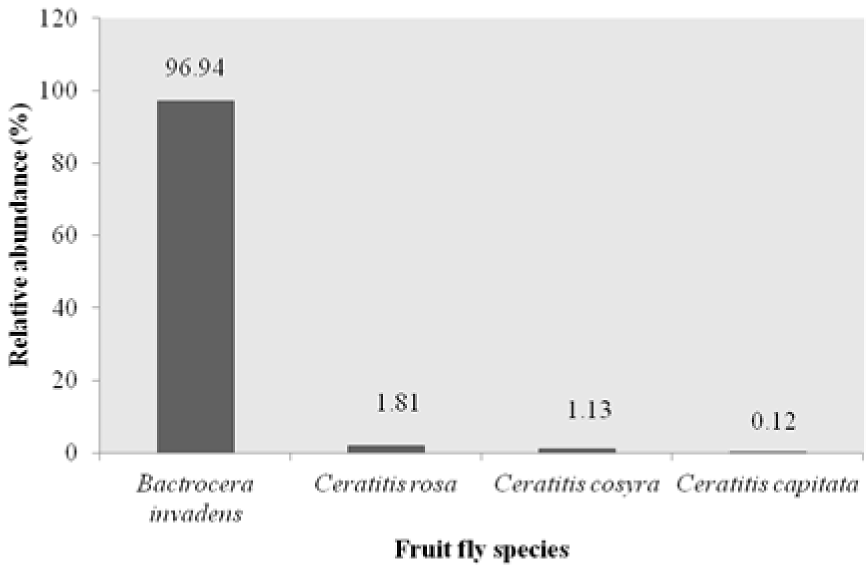

Figure I. Relative abundance of the fruit flies recovered from the host fruits in northern Mozambique.

TABLE 1. Fruit flies host range in northern Mozambique

Fruit fly species	Observed host range	Reference
Bactrocera invadens	Guava, mango, tropical almond, sugar apple and pomegranate*	EPPO (2012), CABI (2012), Ekesi and Billah (2007), De Meyer *et al.* (2012)
Ceratitis rosa	Guava and sugar apple	EPPO (2012), CABI (2012), Ekesi and Billah (2007)
Ceratitis cosyra	Mango	EPPO (2012), Steck (2012), CABI (2012), Ekesi and Billah (2007)
Ceratitis capitata	Guava	EPPO (2012), CABI (2012), Ekesi and Billah (2007), Thomas *et al.* (2010)

* This is the first time that pomegranate is reported as a *B. invadens* host fruit

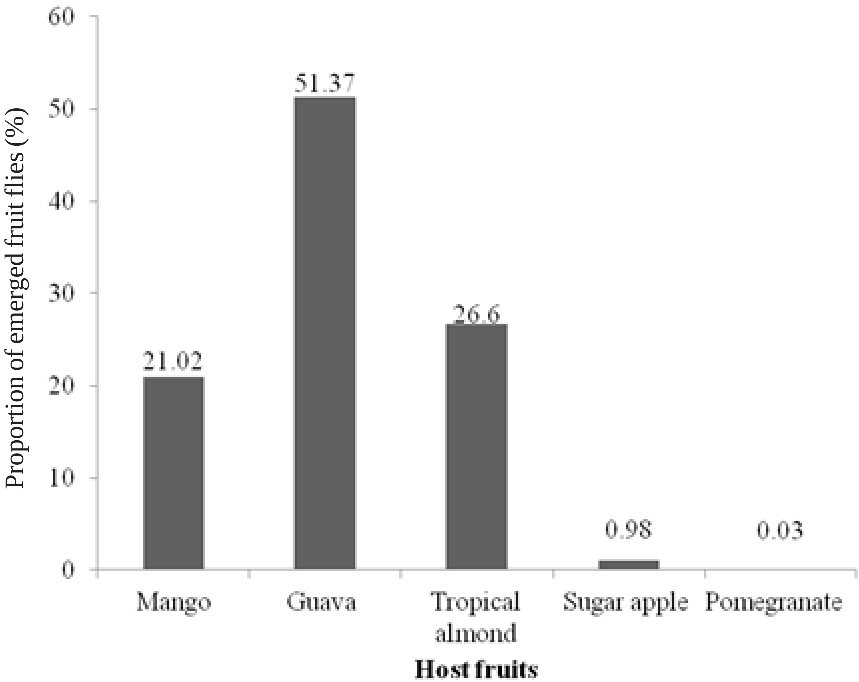

Figure 2. Contribution of each host fruit on the total number of emerged fruit flies in northern Mozambique.

Significantly more pupae per fruit emerged from guava (10.10 ± 0.57), mango (8.91 ± 0.35) and tropical almond (7.46±1.34) compared to other fruits. The highest number of pupae per kg was also significant in the same fruits, with 217.33 ± 3.93, 175.60±7.2 and 29.03±0.44, respectively on guava, tropical almond and mango. The number of pupae per kg was higher in the hosts with highest percentage of damage: guava and tropical almond (Table 3).

The mean number of *B. invadens* per fruit were not statistically different among the hosts. The number of *B. invadens*/kg reported on mango was about 8 times lower than the rate found on guavas and tropical almonds (Table 3).

DISCUSSION

Fruit flies species and their abundance. In three of the 5 evaluated hosts were observed to have

TABLE 2. Fruit flies abundance per host fruit in northern Mozambique

Fruit fly species	Number of fruit flies species per Host				
	Mango	Guava	Tropical almond	Sugar apple	Pomegranate
Bactrocera invadens	670	1667	896	31	1
Ceratitis rosa	0	59	0	2	0
Ceratitis cosyra	38	0	0	0	0
Ceratitis capitata	0	4	0	0	0

TABLE 3. Fruits collected percentage fruit fly damage and infestation indices (pupae and number of *B. invadens* per fruit and kg) in 5 studied hosts

Host	Number of fruits	Damage (%)	Pupae $fruit^{-1}$	Pupae kg^{-1}	*B. invadens* $fruit^{-1}$	*B. invadens* kg^{-1}	Average weight of 1 pupae (mg)
Mango	119	56.50±0.12b	8.91±0.35a	29.03±0.44b	5.47±0.28	17.26±0.36b	10b
Guava	237	92.49±0.21a	10.10±0.57a	217.33±3.93a	6.29±0.55	141.62±0.63a	10b
Tropical almond	107	67.32±2.71b	7.46±1.34a	175.60±7.2a	6.63±1.35	157.24±7.35a	6.99b
Sugar apple	28	36.67±4.06c	0.9±0.38b	8.25±1.67c	0.85±0.36	7.87±1.63c	15a
Pomegranate	15	6.67d	0.07c	0.84d	0.07	0.84d	10b
SNK (5%)	*	*	*	*	NS	*	*

SNK = Student Newman Keuls multiple test. Means followed by the same letter in the same column are not significantly different (SNK, P<0.05)

simultaneous occurrence of *B. invadens* with other *Ceratitis* species. As shown in Table 1, *B. invadens* shared mango only with *C. cosyra*, guava with *C. rosa* and *C. capitata* and sugar apple with *C. rosa*. *Bactrocera invadens* was the only species that occurred in all studied fruit hosts. When multiple infestations were observed, *B. invadens* emerged in high numbers dominating native fruit flies species (Table 2). This reveals its greater competitive ability and poliphagy.

Currently, *B. invadens* is considered the major pest of fruit and vegetables in Africa because of its polyphagous nature, prevalence and predominance in all attacked hosts, its rapid spread in Africa, invasiveness and destructive nature (Drew *et al.*, 2005). This was confirmed by Mwatawala *et al.* (2006b), who stated that *B. invadens* is a species of great economic significance in Africa, where the increasing number of infested fruits indicates its destructive potential.

This study confirms that the invasive fruit fly, is well established in the study area where it occurs at high densities and is becoming the most abundant species over the native fruit flies species in attacked fruits. The same phenomenon was reported in Tanzania by Mwatawala *et al.* (2009a), where they observed the displacement of *Ceratitis* species by the invasive fly. Comparing *B. invadens* with *C. cosyra* and *C. capitata*, they found that *B. invadens* population was higher in many host species, and they concluded that *B. invadens* dominated the native *Ceratitis* species both in terms of infestation as well as in terms of abundance. Later on, Mwatawala *et al*. (2009b) stated that the invasive fruit fly was not only an important pest, but also had an ecological impact within the native fruit flies species.

Moreover, Ekesi *et al.* (2009) observed in Nguruman-Kenya that 4 years after *B. invadens* invasion, it displaced *C. cosyra* and became the most predominant fruit fly in mango orchards: 88% of fruit flies adults emerged from reared mangoes and 98% of trapped fruit flies were *B. invadens*. The same authors indicated two possible displacement mechanisms, namely (i) larvae competition for the same food resource in the same fruit; and (ii) adult aggressive behaviour that do not leave females of other fruit flies species lay eggs in the same fruits. Duyck *et al.* (2007) observed in Reunion islands that *B. invadens* has k-oriented profile selected to dominate r-selected species such as *Ceratitis* spp.

In the study, the low numbers of *Ceratitis* adults shows that its presence seems to be limited in Cabo Delgado, although pre-invasion data indicated that *Ceratitis* and *Dacus* species were the most abundant and more economically important fruit fly species in the country (Maússe and Bandeira, 2007). So, there are evidences to believe that *B. invadens* is gradually displacing the native *Ceratitis* fruit flies species in the study area. This will produce a negative impact in horti/ fruticulture sector in the country and in the presence of native species.

In Tanzania, the Relative Abundance Index (RAI) of *B. invadens* to *C. rosa*, *C. cosyra* and *C. capitata* in 19 evaluated hosts was high (more than 0.5) and in some hosts (*Citrus sinensis*, *Spondias cytherea* e *Terminalia catappa*) it reached 1, meaning that only *B. invadens* was found (Mwatawala *et al.*, 2009a). In fact, in the study area from tropical almond only emerged *B. invadens* meaning that it completely displaced other fruit flies in this host.

Damage and infestation indices. Damage levels varied depending on the host; guava had the highest level of fruit fly damage (92.49 ± 0.21) due to higher availability in the field and oviposition by fruit flies. The present results agree with studies in other African countries which indicate that the *B. invadens* primary or preferred hosts may vary according to the region, type and host availability (Vayssiéres *et al.*, 2008b). Tropical almond, guava and mango were the most preferred and damaged host fruits, and they have already been cited as fruit flies most infested hosts (Mwatawala *et al.*, 2006a; De Meyer *et al.*, 2007; Ndiaye *et al.*, 2008; Rwomushana *et al.*, 2008; Vayssiéres *et al.*, 2009b).

Damage assessment done by Mwatawala *et al.* (2006a) in Tanzania revealed highest percentage of damage on mangoes (61.7%), followed by guava (37.5%) and soursop (20%). In Kenya, Ekesi *et al.* (2006) and Rwomushana *et al.* (2008), reported 58.3, 32.9, 27 and 31.4% of damaged fruits in mangoes, guava, tropical almond and sugar apple, respectively. Both studies showed mango as the most infested fruit because the sampling time covered the entire mango season (fruiting and ripening). This study covered the ripening period of late maturation mango varieties and the ripening period of guava and tropical almond. So, in the field, ripe guava and tropical almond were more available than mango, sugar apple and pomegranate.

Bactrocera invadens was the most abundant species reaching an infestation index of 157.24 and 141.6 adults kg^{-1} on tropical almond and guava, respectively (Table 3). In Tanzania and Kenya, Mwatawala *et al.* (2006a; 2009b) and Rwomushana *et al.* (2008) reported infestation index by *B. invadens* above 100 adults kg^{-1} in the hosts with highest number of damaged fruits (mango and tropical almond). In Tanzania, it was reported 175.8 *B. invadens* kg^{-1} of mango, while in Kenya it was 104.3 *B. invadens* kg^{-1} of mango and 123 *B. invadens* kg^{-1} of tropical almond.

Studies conducted in West and Central Africa by Vayssiéres *et al.* (2005), in Kenya by Rwomushana *et al.* (2008) and in Tanzania by Mwatawala *et al.* (2006a or b) indicated guava as a good host for fruit flies, especially *B. invadens.* This was also observed in the study area where guava was one of the hosts with the highest *B. invadens* infestation index.

Considering that only *B. invadens* emerges from tropical almond and in high numbers, this host may be considered an important reservoir of *B. invadens* at the sampling site. This feature was also mentioned by Rwomushana *et al.* (2008) in Kenya, adding to the fact that it produces fruits almost all over the year.

As evidenced by the low damage and infestation indices, sugar apple and pomegranate are less important in *B. invadens* population dynamics. The same was mentioned by Ekesi and

Billah (2007). Therefore, the knowledge of host plant's role in *B. invadens* population dynamics becomes important in development and implementation of *B. invadens* integrated management programmes.

The severity of infestation was high in all economically important hosts. The occurrence of *B. invadens* at high population densities in the study sites is associated with the highest level of damage observed, and this could lead to high economic losses in fruit production, affecting not only the commercial sector, but also the sources of livelihood, income and food security to the household sector in the country.

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