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Fruit fly infestation in mango: A threat to the Horticultural sector in Uganda

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Abstract

Fruit flies (Diptera: Tephtritidae) are one of the most important insect pests to fruits worldwide. In Uganda, fruit flies have inflicted considerable yield losses especially in mangos (*Mangifera indica* L.), However, there has been no recent assessment of the associated economic damage impact despite the outcries from the farming communities. The objective of this study was to assess fruit fly prevalence and infestation in mango and other hosts, to guide the development and improvement of fruit fly control measures in the mango industry in Uganda. A survey was conducted in the major mango producing areas of the country. Four fruit fly (Diptera: Tephritidae) species were recovered from various field-collected fruits; namely *Bactrocera invadens*, *Ceratitis cosyra*, *Ceratitis rosa* and *Ceratitis capitata*. *Bactrocera invadens* was the most prevalent species (98%), while *C. capitata* was the populous. A total of 73% of the mango fruit samples collected from seven agro-ecological zones was found infested with fruit fly larvae. Fruit samples from West Nile had the highest infestation (83%), followed by Northern Moist, Lake Victoria Crescent, and Western Medium High Farmland, with 78, 75 and 73% fruit fly infestation, respectively. It was common to experience 100% fruit losses across the agro-ecological zones in the absence of control measures. The situation was increasingly severest with exotic commercial varieties. Besides mangoes, over 15 other cultivated and wild fruits acted as alternative hosts to the fruit flies.

Key words: *Bactrocera invadens*, Diptera, *Mangifera indica*

Introduction

Fruit flies (Diptera:Tephtritidae) are recognised worldwide as the most important insect pests to fruits, especially mangos (Drew *et al*., 2005; Vayssieres *et al*., 2008; Ekesi *et al.,* 2009). Female fruit flies lay eggs under the skin of the fruit, which hatch into larvae that feed in the decaying flesh of the crop. Infested fruits quickly rot and become inedible or drop on the ground, thus causing direct loss to the farmer. Besides the direct damage to the fruit, indirect loss is associated with quarantine restrictions that are imposed by fruits and vegetable importing countries. Trade of several horticultural produce between Africa and

the developed countries has been severely hampered by the quarantine restrictions imposed on African countries where *B. invadens* has been reported (APHIS-USDA, 2009). *Bactrocera invadens* is responsible for causing extensive economic loss since its first detection in the African continent in 2003 (Drew *et al*., 2005; Vayssieres *et al.,* 2005; Mwatawala *et al.,* 2006a; Ekesi *et al.,* 2006; Ekesi *et al.,* 2009; Rwomushana *et al.,* 2008; Goergen *et al*., 2011). Without control, direct damage has been reported from 30 to 100% depending on the fruit maturity stage, variety, location and season (Mwatawala *et al.,* 2006a; De Meyer *et al.,* 2007; Vayssieres *et al.,* 2008; 2009).

Despite the economic importance of fruit flies in domestic food security and export market, there has been no assessment on the fruit fly infestation, the associated economic damage impact and required control on the fruit and vegetable sub-sector in Uganda. This study was thus conducted to assess fruit fly prevalence and infestation level in mango and other hosts so as to guide the fruit fly control measures in the country.

Materials and methods

Fruit fly prevalence and infestation

This study was carried out during March and August 2010 in 11 Agro-ecological zones of Uganda (Wortmann and Eledu, 1999, Table 1). A rapid rural appraisal was conducted along four routes, namely (i) Kampala-Jinja-Mbale-Soroti-Lira,

Table 1. Agro-ecological zones and districts evaluated for fruit fly prevalence in Uganda

[a]Agro-ecological zones	Districts surveyed
Lake Victoria Crescent Moist Farmlands (LVCMF)	Wakiso, Mpigi, Luwero, Mityana, Masaka, Jinja, Iganga, Mayuge, Busia
Central Wooded Savana (CWS)	Nakasongola, Masindi
Southern and Eastern Lake Kyoga Basin (SELKB)	Bugiri, Namutumba, Palisa, Budaka, Kalilo, Kumi, Bukadea
Western Medium-High Farmlands (WMHF)	Ntungamo, Kasese, Kabarole
Southern Grass Farmlands (SGF)	Lyantonde, Mbarara
Western Mid Altitude Farmlands and Semiliki flats (WMAFSF)	Bundibugyo, Kyenjonjo, Mubende, Masindi
Nothern Moist Farmlands (NMF)	Soroti, Kaberamaido, Dokolo, Apac, Lira, Oyam, Amuria, Gulu
Northwestern Farmland-Wooded Savana (NWFWS)	Nebbi, Masindi, Arua
West Nile Farmlands (WNF)	Zombo, Maracha-Terogo, Arua
South Western Highlands (SWH)	Kabale, Kisolo
Mt Elgon Farmlands (MEF)	Mbale, Tororo, Sironko

[a]Source: Wortmann and Eledu (1999)

Gulu, (ii) Kampala-Mityana-Mubende-Kabalore-Kasese; (iii) Kampala-Masaka-Mbarara-Kabale, and (iv) Kampala-Masindi-Nebbi-Arua. With participation of local government agriculture extension, the fruit fly research team set up traps with Methyl eugenol (ME) at distances of 15-20 km on each route to determine presence or absence *B.invadens* in the area. The ME traps were used for quick detection of the genus *Bactrocera.* The traps were suspended in mango trees and observed for fruit flies capture within 5-10 minutes after setting the trap. Records of the precise location using Geographic Positioning System (GPS) were documented for each site where ME traps detected fruit flies.

At each stop, the survey team engaged in discussions with individuals or community farmer groups located at that site, to gather information on the perceptions of fruit fly pest problem in the area. The team also made deliberate visits to individual farmers in the area who were reportedly growing exotic mangoes as a commercial enterprise. With the guidance of the agricultural extension at the site, focused groups (5-15 people) were interviewed by the research team, using a check list of pre-tested questions. Farmers were asked to describe the mango production constraints they faced to ascertain whether they knew the fruit fly and how serious the problem was in that area, how long they had experienced the problem, the associated damage and losses attributed to the fruit fly and what measures the individual farmer or as community had collectively taken to manage the fruit fly problem. A total of 186 respondents (125 males and 61 females) were interviewed from seven districts including Luwero (47.3%), Nakaseke (6.5%) and Wakiso (2.2%) in the central part of Uganda (Lake Victoria Crescents), Iganga (27.4%), Kibiku (0.5%) and Budaka (1.1%) in the eastern region of the country and Kasese(12.4%) in the Western Moist farm lands).

Fruit fly infestation in mangoes and other hosts

To assess fruit fly infestation during the survey samples of mature and ripe fruits of mango and other cultivated or wild fruits were randomly picked to check whether they were infested with fruit fly larvae. The choice of the fruit hosts picked was based on its availability at the site during the survey period and between 5 and 10 fruits of different varieties were picked for evaluation. More samples were picked during the mango fruiting season in 2011 and 2012. Fruits were collected in 7 agro-ecological zones (Table 1).

In the field, fruit fly infestation was assessed by cutting through two or three randomly selected mature fruits to check the presence of larvae. A fruit was considered damaged when at least one fruit fly larvae was observed inside the fruit (Vayssieres *et al.,* 2009). Collected fruits were washed using non-caustic liquid dish washing soap and weighed. Each was placed in plastic container (approximately 2-3 litre capacity) with sterilised moist sand covered, with a net and incubated for for 2–6 weeks until fruit fly larvae emerged and pupated. Big mangoes (700 - 1500 g) were placed individually in the containers, while smaller fruits (50 - 300 g) were placed in groups of 3-5 to allow ample space for incubation and emerging larvae. The fruits in the containers were checked twice a week for pupae. The emerged pupae were kept in separate plastic vials, containing moist stand and covered with moist cotton wool and observed for emergency of fruit flies.

The emerging fruit flies were counted and preserved in 70% alcohol for later identification. The samples were identified at the fruit fly laboratory at the National Agricultural Research Laboratories and sample specimens were sent to Nature History Museum, Belgium for confirmation.

Percentage fruit fly damage in the fruits was determined as ratio of number of infested fruits per total of collected fruits. The percentage of fruits infested was calculated based on the fraction of fruit samples that showed positive occurrence of fruit fly larvae or pupae in the fruit per agro-ecological zone. The infestation indices were expressed as mean number of pupae per kilogramme of collected fruits (Cowley *et al.,* 2002). Fruit fly species abundance was computed by counting the number of fruit flies species emerging per fruit type. Descriptive statistics for the abundance and infestation rates across AEZs and fruit type were computed. Fruit fly infestation data was subjected to ANOVA using XLSTAT version 2010 statistical programme (Addinsoft, 2010) for analysis in differences in infestation across the agro-ecological zones.

Results

Fruit fly prevalence and infestation

Bactrocera invadens was detected across sites that were at altitude 611 meters above sea level (masl) in Pakwachi to 1628 masl in Kabale (Fig. 1). A few *Ceratitis* and *Dacus* species were detected in Kabale, Ntungamo, Wakiso, Luwero, Kamuli, Iganga, Budaka, Soroti and West Nile.

Fruits samples that were infested ranged from 33 to 83%, with individual Agro Ecological Zones having various levels of infestation (Fig. 2). The highest frequency of of fruit fly infestation (83%) was recorded in the West Nile Farmlands (WNF), followed by Northern Moist farmlands (NMF) (78%), and the North Western Farmland wooded savanna (NWFWS) with the lowest infestation level. The trend for infestation load (number of pupae kg^{-1} of fruit) also varied. Lake Victoria Crescent Moist Farmland (LVCMF) had the highest fruit fly infestation per kilogramme, followed by Northern Moist farmland (NMF), was and lastly Western Medium High farmland (WMHF) (Fig. 3).

Mango and other fruit fly hosts

On the spot, almost all fruits sampled in the field picked under the trees were infected with fruit fly larvae (Table 2). During seasonal monitoring fruit fly larvae were observed in some of the mature fruit samples in the field, but on incubating the fruits under laboratory conditions, no pupae were recovered.

Overall, 12,055 samples from 9 fruit hosts were incubated in this study; of which 9,100 were mangoes, 1455 were citrus, 460 were of apples, 419 were guavas, 157 were avocados, 123 peers, 21 anonna; while the rest were from vegetables and wild fruits. Out of these samples 33,953 adult flies emerged with five fruit fly species recorded *Bactrocera invadens* was the most abundant species, accounting for 97% from all fruits, and 98% from mangoes. Six of the nine fruits were co-infected by *B. invadens* with other *Ceratitis* spp. *Bactrocera invadens* shared mango fruits with *C. cosyra*, *C. rosa*, *C. anonae,* but not *C. capitata*. In guava, *B. invadens* shared fruits with *C. cosyra*, *C. anonae* and *C. capitata;* while in avocado and pawpaw *B. invadens* shared the host with *C.*

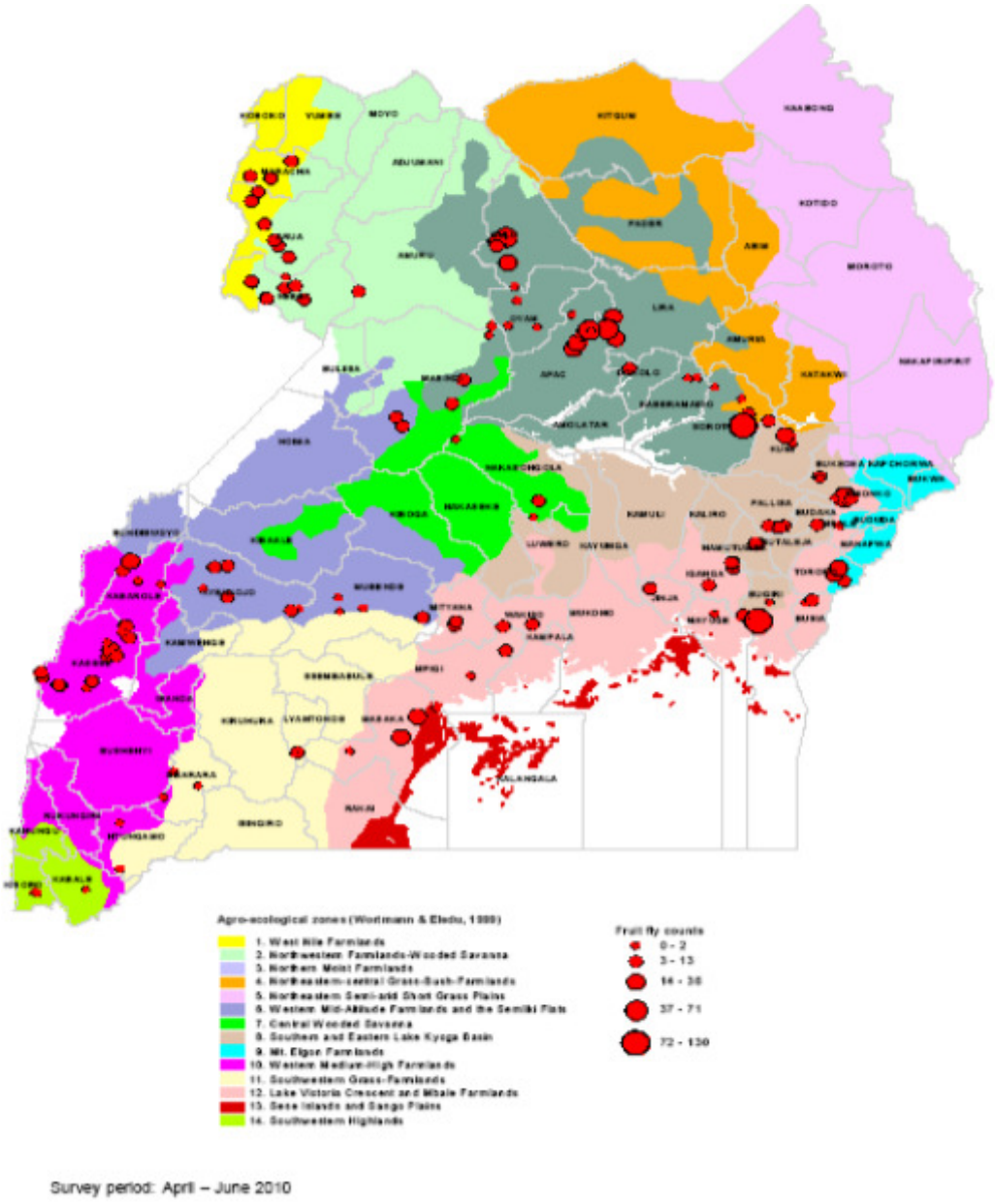
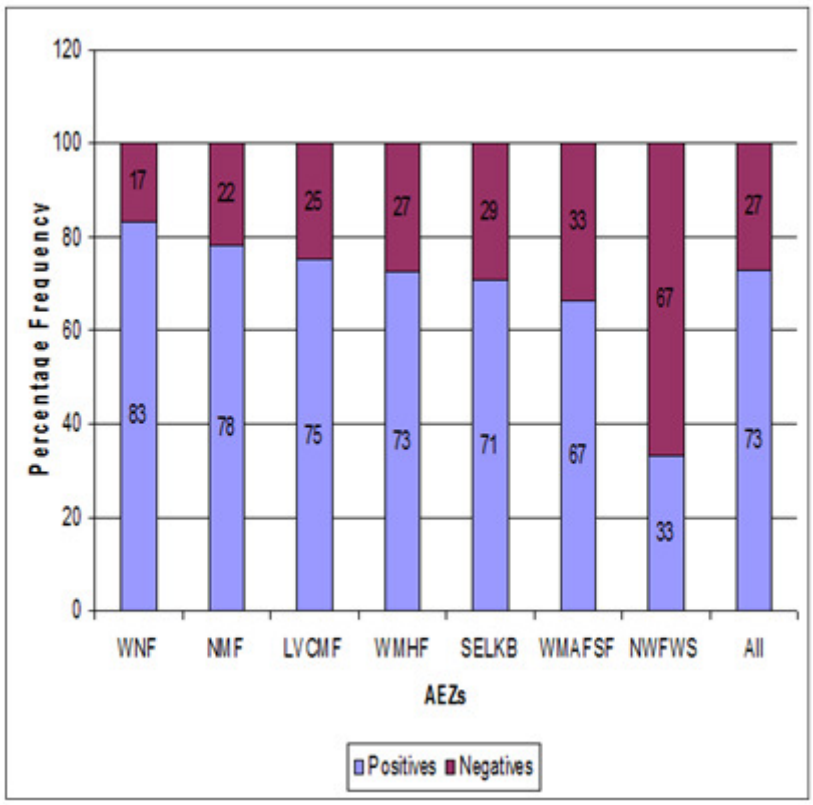


Figure 1. Occurance of *Bactrocera invadens* in various agro-ecological zones of Uganda.

anonae. In *annona* spp., *B. invadens* co-infected with *C. cosyra;* while in *Solanacae* spp. *B. invadens* shared with *C. capitata*. *Ceratitis anonae* occurred in very low numbers from avocado, guava and pawpaw. *Ceratitis capitata* and *Ceratitis anonnae* had the lowest proportion of emerged adults (Table 3).

Based on fruit fly infestation indexes, the exotic and local mango varieties were highly infested by the fly (Table 4). Infestation ranged from 5-175 pupae kg^{-1}



WNF = West Nile Farmlands, NMF = Northern Moist Farmlands, LVCMF = Lake Victoria Crescent Moist Farmlands, WMHF = Western Medium-High Farmlands, SELKB = Southern and Eastern Lake Kyoga Basin, WMAFSF = Western Mid Altitude Farmlands and Semiliki Flats, NWFWS = Northwestern Farmlands-Wooded Savannah

Figure 2. Percentage of fruit fly infestation in fruit samples collected from diffrerent agro-ecological zones in Uganda.

of fruit and 33-399 pupae kg^{-1} of fruits picked from the ground (Table 4). Varieties such as Kachi, Kanabalemu, Kawomera, Kayaga, Kayembelunywa, Suu and Zebidayo that were collected at premature stage did not show pupae emergency. Varieties such as Pinero, Koona, Kenstone, Kasaka, Asante, Bagampade, Galubindi, Kifuta, Irwin and Kawanda were obtained in very low numbers and exhibited low pupae infestation. Varieties such as Apple, Boribo, Bire, Kate, Gelen, Kakoola, Florigon, Aliphonso showed relatively high infestation with fruits collected from the trees and on the ground. The local fibrous Kagwogwa mango that is perceived to be highly resistant to fruit fly attack was observed with high infestation index of 80-129 pupae kg^{-1} of fruits (Table 4).

Community perception on the fruit fly infestation

In all agro-ecological zones respondents reported fruit flies as the most destructive pest in mangoes and could cause losses ranging 50-85% of fruits due to rotting (Fig. 2). Most farmers attributed the loss

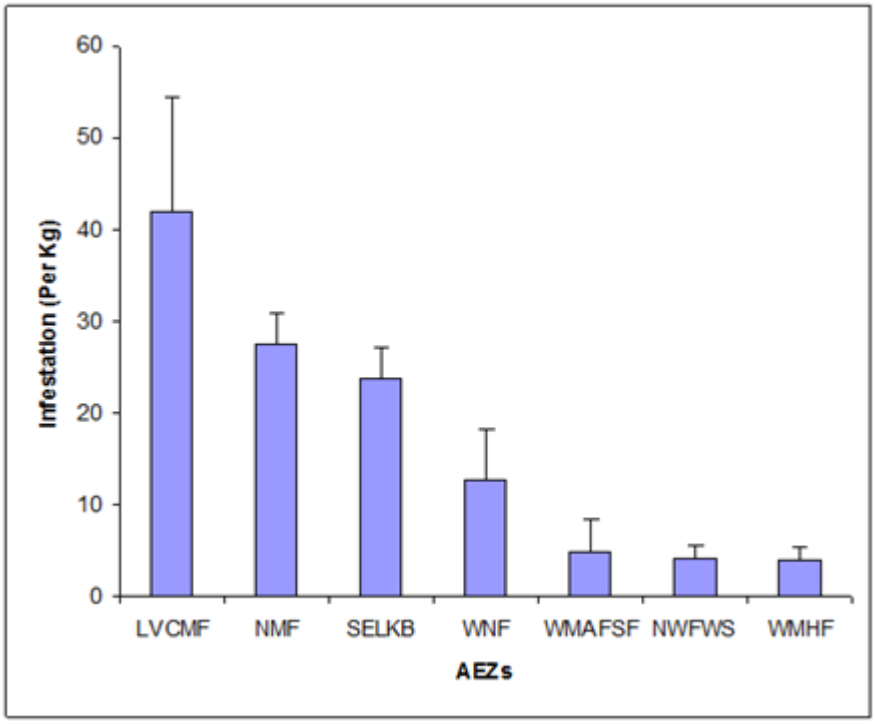


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Figure 3. Variation in infestation per kilogramme of mango fruit collected from different agro-ecological zones.

on their farms to fruit fly maggots that they observed in the fallen fruits. Most mango farmers reported the rotting problem to have started around 2004-2005 and since then the problem has worsened. Generally, local mango varieties were perceived to be resistant and/or less susceptible; while the exotic varieties were very susceptible to fly infestation. Although 65% of the commercial farmers (Fig. 5) attempted to control the fruit flies by applying insecticides, high economic losses were still observed. In Maracha and Kasese, farmers used a local botanical concoction to control fruit flies. Farmers reported that without interventions, one can loose up 100% of the fruits due to fruit fly infestation. In Kamuli, Palisa, Soroti, Lira and Arua exotic mango orchards were almost abandoned due to huge losses caused by fruit fly and other mango diseases. The situation appeared to have been less at high altitudes above 1600 masl. and very few counts of *B. invadens* were detected in these highland zones. Most mango trees could not bear fruits, but showed high vegetative growth. A few fruits emerged reportedly took 6 to 9 months to mature compared to the lower altitude zones where fruits matured within 3-4 months.

Table 2. Fruits found infested with fruit fly maggots under field conditions in Uganda

Fruit common name	Botanical name	Positive infestation in the field	Positive infestation from laboratory reared fruits
Mango	*Mangifera indica*	Yes	Yes
Citrus	*Citrus* spp	Yes	Yes
Guava	*Psidium guajava*	Yes	Yes
Avocado	*Persea americana*	Yes	Low
Apples		Yes	None
Water melon	*Citrullus lanatus*		
Pears		Yes	Yes
Solanacea spp		Yes	Yes
Banana		Yes	No
Cherimoya	*Annona cherimola*		
Sugar apple	*Annona squamosa*	Yes	Yes
Pawpaw	*Carica papaya*	Yes	Yes
Coffee		Yes	Yes
Pepper	*Capsicum annum*	Yes	Yes
White star apple	*Chrysophyllum albidum*	Yes	Yes
Water melon	*Cucumis melo*	Yes	Yes
Quince	*Cydonia oblonga*	Yes	Yes
Ficus	*Ficus* spp	Yes	Yes
Gloriosa	*Gloriosa* spp	Yes	Yes
Tomato	*Lycopersicon esculentum*	Yes	Yes
Melothria	*Melothria* spp	Yes	Yes
Bitter gourd	*Momordica charantia*	Yes	Yes
Grand wounian	*Myrianthus arboreus*	Yes	Yes
Peach	*Prunus persica*	Yes	Yes
Tropical almond	*Terminallia catappa*	Yes	Yes

Table 3. Relative abundance of the different fruit fly species emerging from the mango and other hosts in Uganda

Fruit fly species	Percentage relative abundance in 9 hosts	Percentage relative abundance in mangoes
Bactrocera invadens	97.2	98.1
Ceratitis cosyra	2.6	1.75
Ceratitis rosa	0.13	0.13
Ceratitis anonae	0.05	0.02
Ceratitis capitata	0.005	0

Table 4. Mean number of pupae recovered from grafted exotic and un-grafted local mangoes picked from the field

Mango cultivar	Type	Mean number of pupae kg^{-1} of fruits from the tree	Mean number of pupae kg^{-1} of fruits from the ground	Average weight of the mature ripe fruit (g)
Glen	Grafted exotic	175.4±55.8	75.3±21.8	206.8±35.6
Kate	Grafted exotic	123.7±27.0	151.7±23.1	199.4±11.7
Florigon	Grafted exotic	92.2±10.5	195.5±26.6	159.8±12.0
Dodo	Grafted exotic	90.2±15.3	95.9±21.4	348.9±46.1
Bire	Grafted exotic	82.6±9.7	131.4±13.4	265.4±8.2
Boribo	Grafted exotic	82.0±43.6	357.6±119.1	439.1±98.8
Kagogwa	Un-grafted local	80.5±8.1	129.1±22.5	94.2±5.8
Apple mango	Grafted exotic	64.7±11.4	33.3±7.9	414.3±17.5
Aliphonso	Grafted exotic	63.2±11.3	294.24±13.0	50.0±17.0
Kakoola	Un-grafted local	59.7±11.3	114.9±20.0	121.4±16.7
Kibirizi	Un-grafted local	57.6±14.7	273.2±70.3	224.5±10.6
Local	Un-grafted local	48.1±9.8	30.9±5.1	252.7±34.6
Zillette	Grafted exotic	46.3±20.3	43.7±2.2	512.2±56.3
Keit	Grafted exotic	34.0±7.1	33.9±7.5	557.1±32.0
Palvin	Grafted exotic	30.6±10.5	61.9±21.6	325.4±36.1
Kent	Grafted exotic	30.3±7.7	298.3±187.1	468.4±26.3
Tommy	Grafted exotic	28.8±3.4	81.9±25.2	320.9±20.7
Palmer	Grafted exotic	21.5±7.3	-	652.6±92.6
Bagada	Grafted exotic	8.1±0.2	8.7±3.9	372.5±10.5
Sejembe	Un-grafted local	5.9±1.5	-	299.0±20.9
Exotic mango	Grafted exotic	-	399.5±100.9	100.0±0.0

Discussion

There is clear evidence that fruit fly damage is a threat to the mango industry in Uganda (Figs. 2, 3 and 4). *Bactrocera*, *Ceratitis, Dacus* and *Trirhithrum* species were recorded in the different localities in Uganda with *Bactrocera invadens* being most prevalent in mangoes. *Bactrocera invadens* prevalence in the study regions relates to surveillance findings by Nemeye (2005). This study confirms that *Bactrocera invadens* an invasive fruit fly originally from Asia and a widely known pest of fruits and vegetables because of its polyphagous and destructive nature (Drew *et al.,* 2005; Vayssieres *et al.,* 2005; Ekesi *et al.,* 2006; Rwomushana *et al.,* 2008; Goergen *et al.,* 2011) is well established in Uganda. This study revealed that *B. invadens* was the most abundant species over the native fruit fly species, which were more prevalent a decade ago (Nakasinga, 2002). In Tanzania, Mwatawala *et al.* (2009) found that *B. invadens* population was higher than *C. cosyra* and *C. capitata* in many host species and concluded that *B. invadens* dominated the native *Ceratitis* species both in infestation and in abundance. It was also found that the invasive fruit fly, in addition to being an important pest, also had an ecological impact within the fruit fly species. In

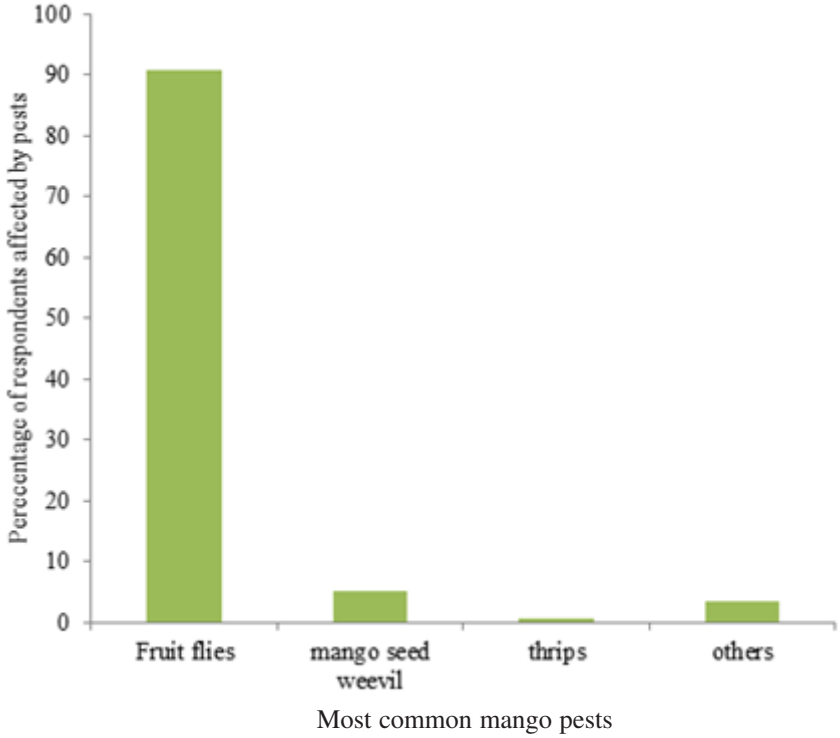

Figure 4. Pest problems reported by mango producing farmers in Uganda.

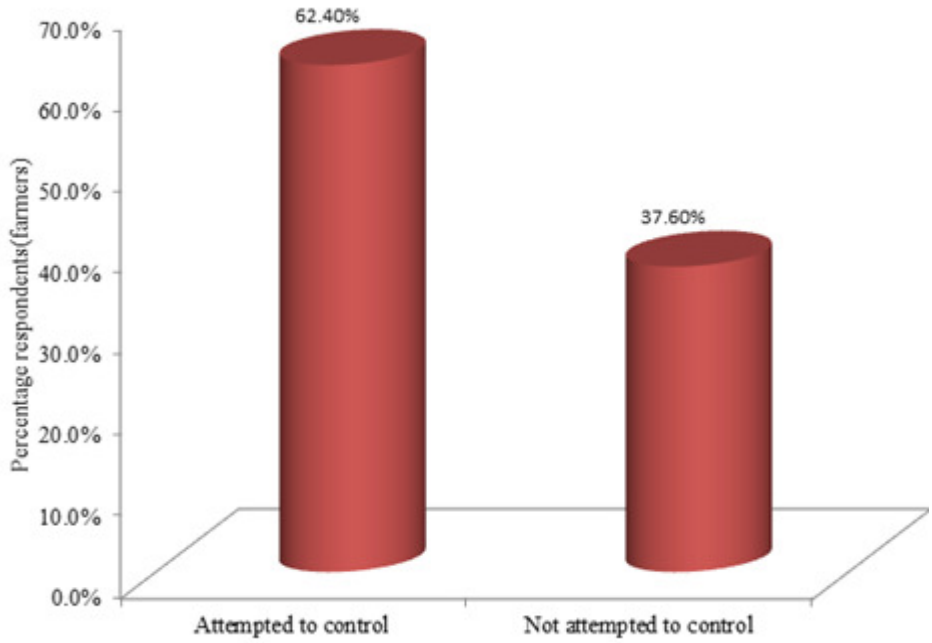

Figure 5. Farmers who attempted to control fruit flies in commercial mango orchards in Uganda.

Kenya, Ekesi *et al.* (2009) found that after 4 years of *B. invadens* invasion, it displaced *C. cosyra* and became the most predominant fruit fly in mango orchards, with 88% of fruit flies adults that emerged from reared mango fruits and 98% of trapped fruit flies recorded as *B. invadens*. From these studies, the authors indicate two possible displacement mechanisms; either there was larva competition for the same food resource in the same fruit or adult aggressive behaviour that allowed females of *B. invadens* to lay eggs in the same fruit that had been utilised by other fruit fly species. It has been observed that *B. invadens* had a K-oriented profile that dominated the R-selected profile species such as *Ceratitis* spp. (Duyck *et al.,* 2007).

The high fruit fly infestation observed in different agro-ecological zones led to high economic losses in fruit production reported by the mango farming communities. The variation in fruit fly infestation among the different agro-ecological zones, confirm previous studies which indicated that *B. invadens* infestation may vary according to the region, host type and host availability (Vayssieres *et al*., 2008). In Kenya, adult fruit fly infestation in mango was higher at lower elevation locations (39.2 to 103.3 flies per kg fruit) than with 0-29.4 flies per kg fruit in high elevation areas (Rwomushana *et al.,* 2008).

The high *B. invadens* infestation in mango recorded in this study relates to earlier findings in Kenya, where higher infestations of 58.35% were observed compared with guava, sugar apple and tropical almond (Ekesi *et al.,* 2006; De Meyer *et al.,* 2007; Rwomushana *et al.,* 2008). In related studies in Tanzania, Mwatawala *et al. (*2006a) showed highest percentage damage in mangoes (61.7%) compared with other fruits. Mango is known to be the preferred host for *B. invadens* and this was aggravated by the fact that the sampling was done at ripening stage, thus making mangoes more vulnerable to fruit fly attack. Our observation of the premature fruits infested with fruit fly larvae relates with similar studies in Guinea where young fruits (less than 10 weeks old) where observed with high fruit fly infestation (Vayssieres *et al.,* 2010). These observations imply that early implementation of control practices before the mango season picks up is worthwhile. On the other hand, the collection and destruction of fallen fruits under the mango tree needs to be given sufficient attention.

The differences in fruit fly infestation observed in the different agro-ecological zones and in various local and exotic commercial mango varieties (Fig. 3 and Table 4) could be due to several physical, biochemical and ecological factors. Specific physical features of the fruit could be related to peel thickness, fibre content and fruit colour, which would also depend on the ripening stage (pre-mature or mature fruits), and ripening date (early maturing cultivars, seasonal cultivars, late maturing cultivars). Thus, yellow cultivars with thin peels such as Apple and Bire are more infected than green cultivars with thicker peels found in many local varieties.

In this study over 15 host plants were found infested with fruit flies relating to Kenya studies where Rwomushana *et al.* (2008) recorded 14 plant species while in Tanzania Mwatawala *et al.* (2006a and b) recorded 15 plant species. In this study, even when multiple fruit fly infestation occurred; *B. invadens* emerged in higher numbers, dominating the native fruit flies (Table 3). This result confirms the greater competitive ability and phytophagous habits of *B. invadens* (White and Elson-

Harris, 1992). The observed levels of infestation in citrus agree with earlier findings by Vayssierres *et al*. (2005), who reported high *B. invadens* infestation in similarly acidic hosts. They suggested that *B. invadens* might be adapted to a range of fruit characteristics. This study has further demonstrated that *B. invadens* uses cultivated and wild host plants, and this will have implications on the management practices targeting the fruit fly pests. The guava (*Psidium guajava*) is a primary host for *B. invadens*, while *Annona* spp. and *Citrus* spp. are secondary hosts; and they will allow fruit fly population proliferation and trigger quick infestation in mango before the pick of the mango season.

The growing of mangoes with other cultivated crops or near wild plants is a common practice in many farming communities in Uganda; and will have implication on the control measures being developed. The fruit fly control programme should take into consideration the large host range of these fruit flies and optimise the ecological mechanisms that these hosts would offer in pulling or repelling the fruit flies that would be attracted to the mango trees.

Assessment made by the ICIPE-led African Fruit Fly Programme revealed that, out of 1.9 million tonnes of mangoes produced in Africa annually, about 40% is wasted due to fruit flies' damage (Ekesi *et al.,* 2005). Such losses reduce the profits of the fruit growers and traders, and contribute to high cost of fruits on the local urban markets. This loss is not only affecting the mango sector but also the sources of livelihood, income and food security of horticultural farmers. The results from this study have projected the magnitude of the fruit fly problem and the prevalent losses suffered by the mango fruit sector. The fruit fly losses threaten the country's potential income and employment opportunities that would be derived through locally produced fruits and vegetables. The fruit fly has jeopardised the local market of some varieties such as Bire yet fresh fruit export have been greatly affected by quarantine restrictions imposed by importing countries due to the threat posed by *B. invadens.* The losses highlighted in this study should be used to raise awareness about the dangers of the fruit fly to the horticulture industry both at local and international markets. There is also need to assess the economic losses caused by the fruit flies in other economically important horticultural fruits and vegetables in Uganda. Future studies should aim at developing effective management strategies that should include baiting techniques, use of biological control, sound orchard sanitation, and post-harvest treatments for quarantine sensitive markets. There is also need to build capacity of farmers and the extension on crop husbandry/management, post-harvest handling, processing and marketing of the fruits as a key to the development of the Uganda Mango industry.

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