Relative numbers of fruit fly species in avocado orchards

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ABSTRACT

Several fruit fly species (Diptera: Tephritidae) are known to attack different types of commercially grown fruit. The economic impact includes direct yield losses and increased production cost. Furthermore, fruit flies often have significant quarantine implications. The avocado is known to be a poor host for the development of fruit flies. However, fruit flies can develop in the fruit under certain conditions. Various fruit fly species are associated with the production of avocado in South Africa. Among these is the Natal fruit fly, *Ceratitis rosa sensu lato* Karsch. Recent studies indicated that the Natal fruit fly comprises a complex of two species and a new species, *Ceratitis quilicii* De Meyer, Mwatawala and Virgilio, was described and is commonly referred to as the Cape fruit fly.

Fruit flies were monitored in four avocado orchards in the Tzaneen area since January 2017. Monitoring was done in two 'Fuerte' orchards, a 'Pinkerton' orchard and a 'Hass' orchard. Three different monitoring systems were used in each orchard in order to trap different fruit fly species of economic significance. Fruit were inspected for the presence of fruit fly lesions. Fruit were also sampled to determine if any fruit fly larvae were present inside the fruit. The data gathered are important in the development of threshold levels. The information can also be used in the development of a systems approach to access new markets. In addition to the abovementioned, fruit flies were also monitored at Nelspruit, Burgershall and Deerpark to determine the absence or presence of the Natal fruit fly and the Cape fruit fly, based on the identification of males.

High Oriental fruit fly numbers were present in yellow bucket traps with Invader-Lure™ in the avocado orchards in the Tzaneen area. The Cape fruit fly exceeded 1 fruit fly/trap/day in bucket traps with BioLure® UNIPAK®. The Natal fruit fly was absent or present in low numbers in the Tzaneen area. In Sensus traps with Questlure, all fruit fly species remained below 1 fruit fly/trap/day. Less than 1% of fruit had fruit fly lesions. No larvae were present in 600 sampled fruit. At Nelspruit, the Natal fruit fly was the abundant species while low numbers of the Cape fruit fly were detected. In orchards at Burgershall, high numbers of Cape fruit fly were present and no Natal fruit fly was trapped. At Deerpark, both species were found abundantly.

The different fruit fly species should be kept below 1 fruit fly/trap/day in traps with food bait lures. There was a difference in the ration of Cape and Natal fruit flies present in the different areas. Therefore, pest free areas can be established (in accordance with IPPC ISPM 26) and/or areas of low pest prevalence (in accordance with IPPC ISPM 30).

INTRODUCTION

Fruit flies are known as important pests for the production of fruit and vegetables. Females lay eggs in fruit and the developing larvae cause decay. Fruit flies are regarded as a major phytosanitary threat when host commodities are exported to countries where the flies are absent and can possibly become established. In South Africa, various fruit fly species are important for the production of subtropical crops. The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), the Marula fruit fly, *Ceratitis cosyra* (Walker), and the Natal fruit fly, *Ceratitis rosa sensu lato* Karsch, are important indigenous species. Recent studies indicated that the Natal fruit fly comprises a complex of two species and a new species, *Ceratitis quilicii* De Meyer, Mwatawala and Virgilio, was described and is commonly referred to as the Cape fruit fly (De Meyer *et al*., 2015, 2016). Oriental fruit fly, *Bactrocera dorsalis* (Hendel), is an invasive species which was detected in South Africa during 2010. Currently, the pest is present in avocado production areas in Limpopo, Mpumalanga and KwaZulu-Natal.

The avocado is known to be a poor host for the development of fruit flies. Natural infestations are usually rare and often associated with defective fruit. The avocado is a climacteric fruit that ripens after harvest. Increase in infestation is correlated with decrease in fruit firmness (Follett, 2009). The thick

exocarp of some cultivars can also be a barrier for egg laying (De Graaf, 2009). Callus tissue formation around eggs deposited in the pulp has been reported (Armstrong *et al*., 1983; Liquido *et al*., 1995; Aluja *et al*., 2004). De Graaf (2009) conducted research on the susceptibility of 'Hass' avocados to the Mediterranean fruit fly, the Marula fruit fly and the Natal fruit fly (as previously described) in South Africa. 'Hass' was found to be a conditional non-host for the Mediterranean fruit fly, and a potential host for the Marula fruit fly and Natal fruit fly. No successful reproduction took place when exposing the Marula fruit fly and Natal fruit fly to 'Hass' avocado while attached to the tree and not followed by harvest. Ware *et al*. (2016) working in Kenya and Tanzania, exposed the cultivars 'Hass', 'Pinkerton' and 'Fuerte' to the Oriental fruit fly. Development took place in punctured fruit but not in uncompromised fruit. In the field studies, only fruit damaged by false codling moth, *Thaumatotibia leucotreta* (Meyrick), (Lepidoptera: Tortricidae) were found to harbour Oriental fruit fly.

Monitoring for pests is a fundamental step in integrated pest management (IPM) programmes. Monitoring is a tool in decision-making, indicating whether intervention is required. Monitoring also enables one to compare data from one season to the next and to make more informed decisions. Therefore, it is very important to keep records of monitoring data. Pest monitoring is also important for compliance to GLOBAL GAP standards.

The objectives of the study were to determine:

1. the relative numbers of the different fruit fly species present in avocado orchards;
2. the presence of the Natal fruit fly and the Cape fruit fly;
3. the infestation levels by fruit sampling; and
4. establish the relationship between fruit fly numbers trapped and damage levels in avocado orchards.

MATERIALS AND METHODS

Fruit flies were monitored in avocado orchards in the vicinity of Tzaneen (-23.824342, 30.158212, Elevation above sea level: 719 m) (Greater Tzaneen Local Municipality, Mopani District Municipality, Limpopo Province). Monitoring was done on two farms. On farm No. 1, monitoring was conducted in a 'Fuerte' (No. 1) and a 'Pinkerton' orchard while on farm No. 2 monitoring was done in a 'Fuerte' (No. 2) and a 'Hass' orchard. This study commenced during January 2016. The results of the first year were reported by Grové (2017). Therefore, in this paper the results for 2017 are given.

The three monitoring systems used were:

1. Sensus trap (River BioScience [Pty] Ltd, Port Elizabeth, South Africa) with Questlure (River BioScience [Pty] Ltd). Questlure contains protein hydrolysate. This system is used for the monitoring of females and males of *Ceratitis* spp. Questlure is a food bait and does not attract fruit flies from a long distance.
2. Chempac yellow bucket trap (Chempac [Pty] Ltd, Suider Paarl, South Africa) with Invader-Lure™ (River BioScience [Pty] Ltd). Invader-Lure™ is an attractant for the monitoring of the Oriental fruit fly males and the active ingredient is methyl eugenol. Invader-Lure™ is a male lure and known to attract males from a long distance.
3. Chempac yellow bucket trap with BioLure® UNIPAK® (Chempac [Pty] Ltd). BioLure® UNIPAK® is a food bait that consists of three components, i.e. ammonium acetate, trimethylamine hydrochloride and 1,4-diaminobutane (putrescine). Both males and females of the four important *Ceratitis* spp. and the Oriental fruit fly are attracted to the lure. The lure is a food bait and does not attract fruit flies from far away.

The traps were placed in a diagonal line in the orchards. The bucket trap with BioLure® UNIPAK® was placed in the centre of the orchard while the other two traps were deployed near the edges of the orchards. Spacing between the traps was approximately 50 m. Traps were placed 1.5 m above the ground. A block of Vapona agricultural insecticide strip (Acorn Products [Pty] Ltd, Strubens Valley, South Africa) with the active ingredient dichlorvos was used as a killing agent. The Vapona and the lures were replaced every six weeks. Traps were serviced fortnightly to monthly. Fruit flies were identified to species level, and the sex of each recorded except in the case of the females of the Cape fruit fly and the Natal fruit fly. Females of the two species cannot be distinguished based on morphological characteristics. Population densities were expressed as the number of fruit flies/trap/day.

Hundred fruit per orchard were visually inspected for the presence of fruit fly lesions on a fortnightly to monthly basis. The lesion caused by the female's ovipositor develops in a typical star-shaped crack. Fruit with suspected lesions were taken to the laboratory. Lesions were cut and inspected with a stereo microscope for the presence of fruit fly eggs.

Hundred fruit were sampled once or twice in each orchard. One sample each was taken from the two 'Fuerte' orchards ('Fuerte' No. 1 – 5 January 2017 and 'Fuerte' No. 2 – 4 April 2017). Two samples each were taken from the cultivars 'Pinkerton' (5 January 2017 and 4 April 2017) and 'Hass' (4 April 2017 and 14 July 2017). Sampled fruit were left in the laboratory and inspected when soft for the presence of fruit fly larvae.

In addition to the abovementioned, Natal fruit fly and Cape fruit fly were monitored to determine the distribution of the two species, as the Cape fruit fly is a newly described species. Monitoring was done at the ARC-TSC experimental farms at Burgershall (-25.111866, 31.086583, Elevation above sea level: 757 m) and Nelspruit (-25.451496, 30.969084, Elevation above sea level: 670 m). Both farms are situated in the City of Mbombela Local Municipality, Ehlanzeni District Municipality, Mpumalanga Province. At Burgershall fruit flies were monitored in a 'Hass', a 'Lamb Hass' and a 'Pinkerton' orchard.

The following two monitoring systems were used in each orchard:

1. Chempac bucket traps with BioLure® UNIPAK®; and
2. Sensus traps with Capilure (River BioScience [Pty] Ltd). Capilure contains trimedlure and is known to attract males of the Mediterranean fruit fly, the Cape fruit fly and the Natal fruit fly. At Nelspruit monitoring was done in an avocado orchard consisting of different cultivars. Three traps of each of the two abovementioned trap and lure combinations were used. Traps were placed out during April 2017, and traps were serviced on a monthly basis. Lures and Vapona blocks were changed as prescribed. Population densities were expressed as the number of fruit flies/trap/day.

Monitoring was also conducted on a commercial farm in the Deerpark area close to Tzaneen (-23.718579, 30.280699, Elevation above sea level: 620 m) (Greater Tzaneen Local Municipality, Mopani District Municipality, Limpopo Province). Fruit flies were monitored in guava orchards next to 'Fuerte' orchards with four of each of the following: Chempac bucket trap with BioLure® UNIPAK® and Sensus trap with Capilure. Monitoring was conducted from April to August 2017 and traps were serviced fortnightly. Lures and Vapona blocks were replaced as prescribed. Population densities were expressed as the number of fruit flies/trap/day.

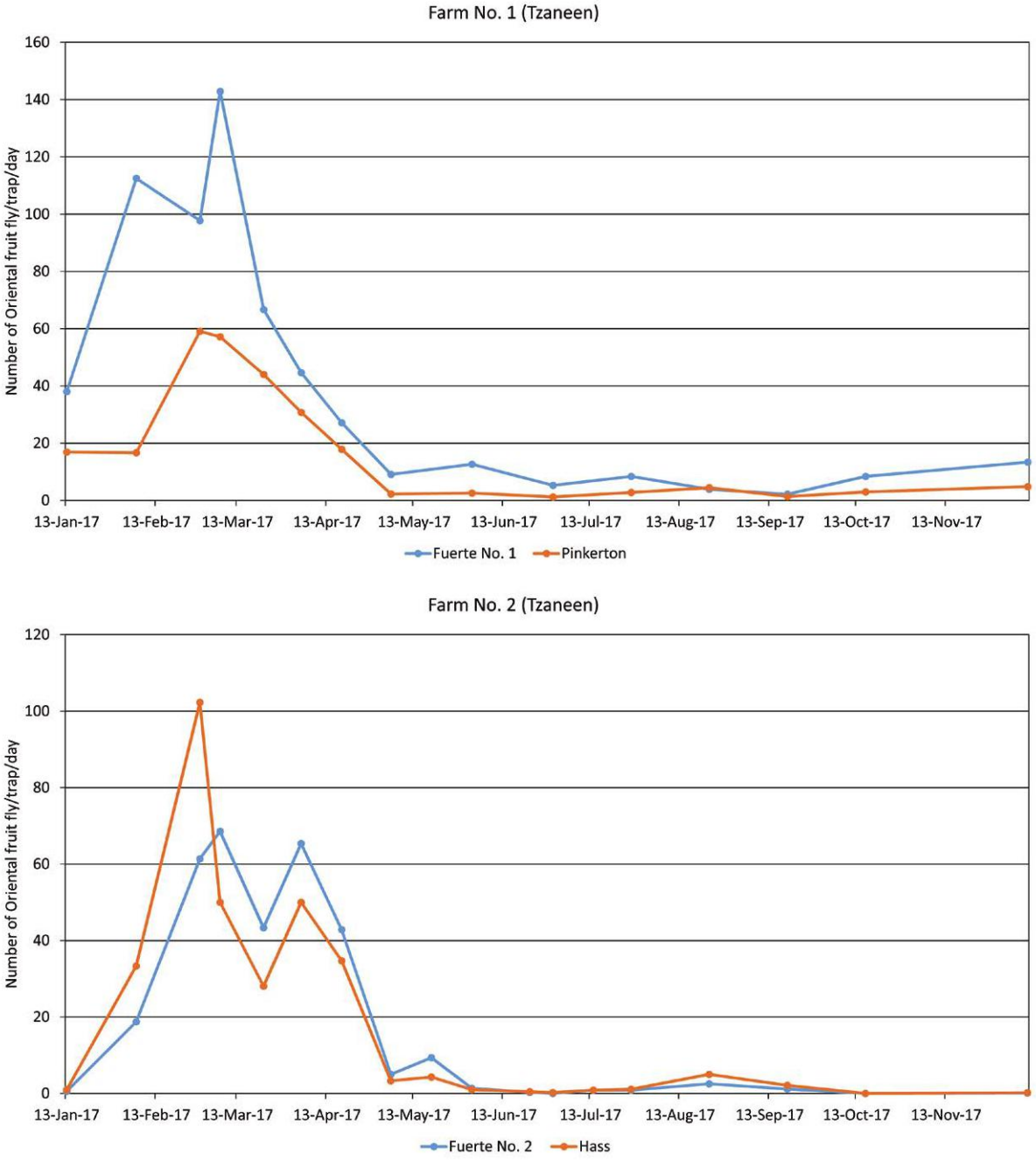

Figure 1: The number of Oriental fruit fly in yellow bucket traps with Invader-Lure™ trapped on two farms in the Tzaneen area.

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RESULTS

The cumulative number of the economically important species trapped is given in Table 1. Low fruit fly numbers were trapped with Sensus traps with Questlure. High numbers of the Oriental fruit fly were trapped with Invader-Lure™. The Oriental fruit fly was the abundant species trapped with BioLure® UNIPAK® on farm No. 1 while the Cape fruit fly was the abundant species trapped on farm No. 2. Only the Cape fruit fly males were trapped on farm No. 2 while on the other farm, both males of Cape fruit fly and Natal fruit fly were present. In Sensus traps with Questlure, all fruit fly species remained below 1 fruit fly/trap/day. The number of Oriental fruit flies trapped is given in Figure 1. In the 'Fuerte' No. 1 and the 'Hass' orchards, the Oriental fruit fly reached >100 fruit flies/trap/day. Peak numbers of Oriental fruit fly were present during February and March. In bucket traps with BioLure® UNIPAK®, all species were below 1 fruit fly/trap/day, except for the Cape fruit fly in the 'Hass' and the 'Fuerte' No. 2 orchards (Fig. 2). The percentage of fruit with fruit fly lesions is given in Table 2. In most instances no lesions were found on the fruit and 2% was the highest level found. A total of 600 fruit were sampled and no live larvae were found in any fruit.

Only Cape fruit fly and no Natal fruit fly were trapped in avocado orchards at Burgershall (Fig. 3). The Natal fruit fly was the abundant species at the Nelspruit experimental farm and low numbers of Cape fruit fly were present (Fig. 4). At Deerpark, both species were found abundantly (Fig. 5).

DISCUSSION

In Sensus traps with Questlure, low numbers of the different fruit fly species were trapped. All species remained below 1 fruit fly/trap/day. High numbers of Oriental fruit fly were trapped in all the orchards with Invader-Lure™ and peak numbers were present during February and March. Invader-Lure™ is a male lure and is known to attract Oriental fruit fly from a far distance. Although high numbers were trapped, a low percentage of fruit with lesions was found and no live larvae were found in the fruit. This supports the observation by Ware *et al*. (2016) that Oriental fruit fly did not lay eggs in uncompromised fruit. In Hawaii, a systems approach was developed to reduce the risk of Oriental fruit fly infestation in 'Sharwil' avocados exported to the United States (Follett and Vargas, 2010). Traps with protein are used for monitoring Oriental fruit fly as opposed to methyl eugenol. The food bait traps gave a better indication of population levels within orchards in Hawaii (Klungness *et al*., 2009). In traps baited with BioLure® UNIPAK®, the Cape fruit fly exceeded 1 fruit fly/trap/day in two orchards. Although high numbers were trapped, a very low percentage of fruit with lesions was found in these orchards. Marula fruit fly and Natal fruit fly (as previously described) are known to be able to lay eggs inside avocado fruit. The avocado is known to be a poor host for the development of fruit flies, and these studies support the observation.

Differences were found in the distribution of the Cape fruit fly and the Natal fruit fly. Natal fruit fly was absent in certain areas. From the data it seemed that the Cape fruit fly dominated at higher altitudes. A study in Tanzania showed that the Natal fruit fly was predominant at lower altitudes, while the Cape fruit fly was predominant at higher altitudes (Mwatawala *et al.*, 2015). Further studies are needed to confirm the consistency of the observed distribution patterns. Therefore, there is the potential to establish

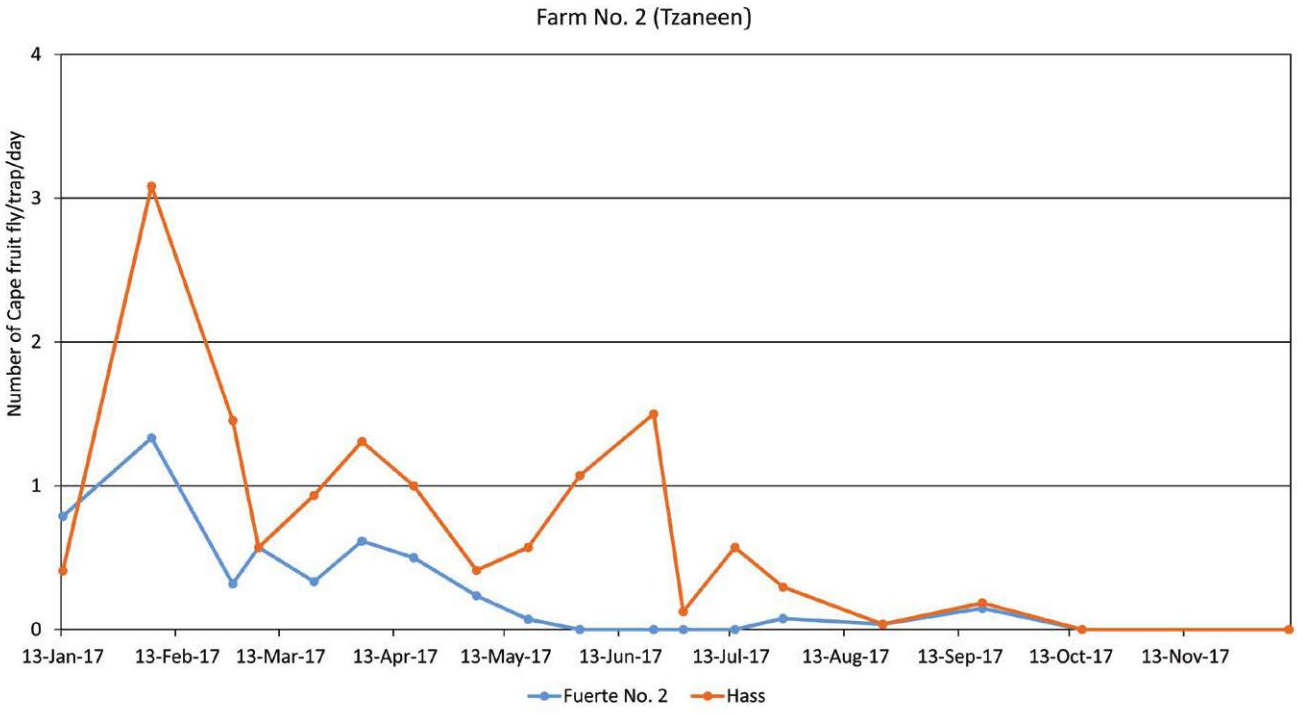

Figure 2: The number of Cape fruit fly in bucket traps with BioLure® UNIPAK® on farm No. 2 in the Tzaneen area.

Table 1: Cumulative number of economically important fruit fly species trapped with three monitoring systems from January 2017 to December 2017.

Orchard	Cumulative number trapped with Sensus trap and Questlure			
	Mediterranean fruit fly	Marula fruit fly	Cape fruit fly & Natal fruit fly	Oriental fruit fly
'Hass'	0	1	41	1
'Fuerte' No. 1	3	5	0	2
'Fuerte' No. 2	2	11	11	6
'Pinkerton'	0	0	3	3
Orchard	**Cumulative number trapped with bucket trap and Invader-Lure**			
	Oriental fruit fly			
'Hass'	5 413			
'Fuerte' No. 1	12 534			
'Fuerte' No. 2	4 790			
'Pinkerton'	5 347			
Orchard	**Cumulative number trapped with bucket trap and Biolure Fruit Fly**			
	Mediterranean fruit fly	Marula fruit fly	Cape fruit fly & Natal fruit fly	Oriental fruit fly
'Hass'	1	0	267	28
'Fuerte' No. 1	11	8	5	34
'Fuerte' No. 2	4	4	130	20
'Pinkerton'	10	7	18	53

Table 2: Number of fruit with fruit fly lesions. Hundred fruit were inspected in each orchard from January until harvest on the dates given.

Date	'Hass'	'Fuerte' No. 1	'Fuerte' No. 2	'Pinkerton'
5 Jan 17	0	1	-	0
13 Jan 17	0	1	0	0
6 Feb 17	0	0	0	0
28 Feb 17	0	0	0	0
7 Mar 17	0	1	0	0
22 Mar 17	0	-	0	0
4 April 17	0	-	0	-
18 April 17	0	-	0	-
5 May 17	0	-	-	-
19 May 17	0	-	-	-
2 Jun 17	0	-	-	-
22 Jun 17	0	-	-	-
30 Jun 17	0	-	-	-
14 Jul 17	0			
27 Jul 17	2			
Total number of fruit inspected	1 500	500	700	600
Total number of fruit with lesions	2	3	0	0

pest-free areas (in accordance with IPPC ISPM 26) and/or areas of low pest prevalence (in accordance with IPPC ISPM 30).

Based on this season's results as well as the previous season, producers are advised to use traps for monitoring fruit flies as well as fruit inspections to determine the presence of fruit fly lesions. Trapping is an indirect method of sampling. Fruit fly host plants near avocado orchards may influence trap catches. Producers are also advised to keep good records of fruit fly numbers trapped. These records can be used as a reference to compare seasons. Fruit flies can be suppressed in avocado orchards by using the bait application technique. Because high numbers of the Oriental fruit fly are trapped in avocado orchards, producers are advised to use the male annihilation technique for the Oriental fruit fly, as well as the bait application technique. Although not all species can lay eggs inside the avocado and due to the fact that avocado is not a good host for the development of fruit flies, it is still important to monitor fruit fly species and inspect fruit for lesions. Therefore, producers can make informed decisions on the management of fruit flies in avocado orchards. Fruit flies can cause lesions and eggs can be laid in fruit with surface lesions or defects. Therefore, there is some risk involved when exporting avocado fruit – although the risk is negligible (De Graaf, 2009;

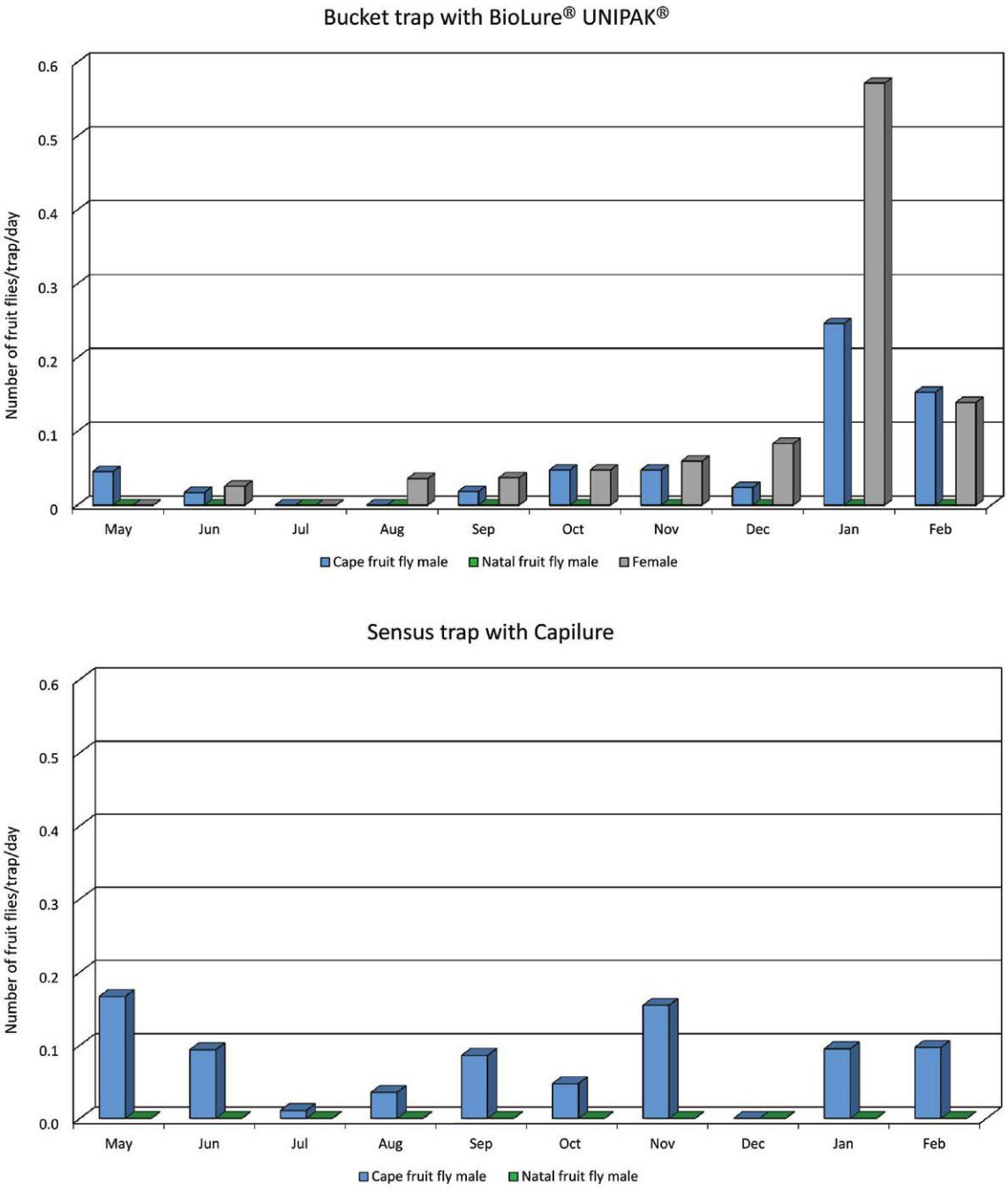

Figure 3: The number of Cape fruit fly and Natal fruit fly trapped in avocado orchards on the ARC-TSC Burgershall experimental farm. Females of the two species cannot be distinguished based on morphological characteristics.

Ware *et al*., 2016). As a guideline, producers must keep the different fruit fly species below 1 fruit fly/trap/day in the food bait lures.

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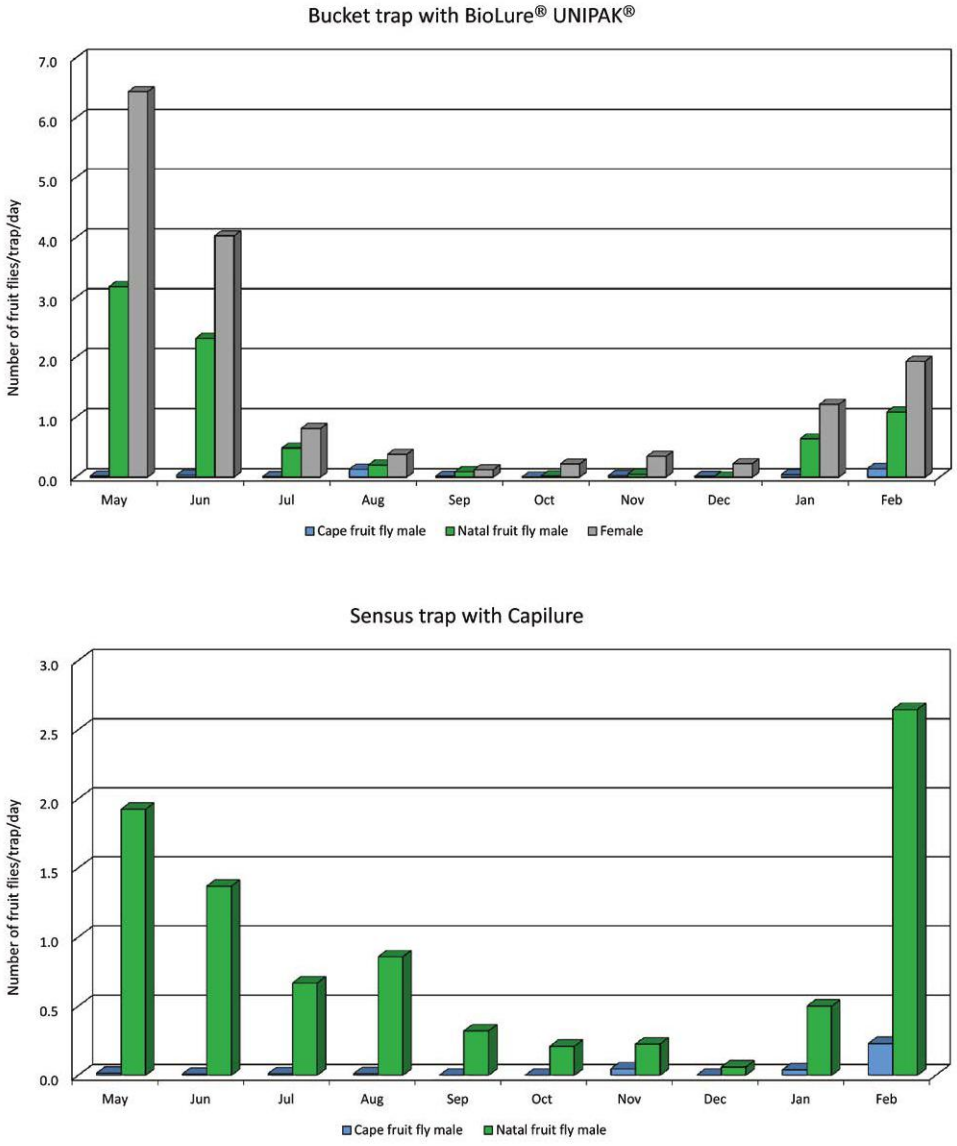

Figure 4: The number of Cape fruit fly and Natal fruit fly trapped in an avocado orchard on the ARC-TSC Nelspruit experimental farm. Females of the two species cannot be distinguished based on morphological characteristics.

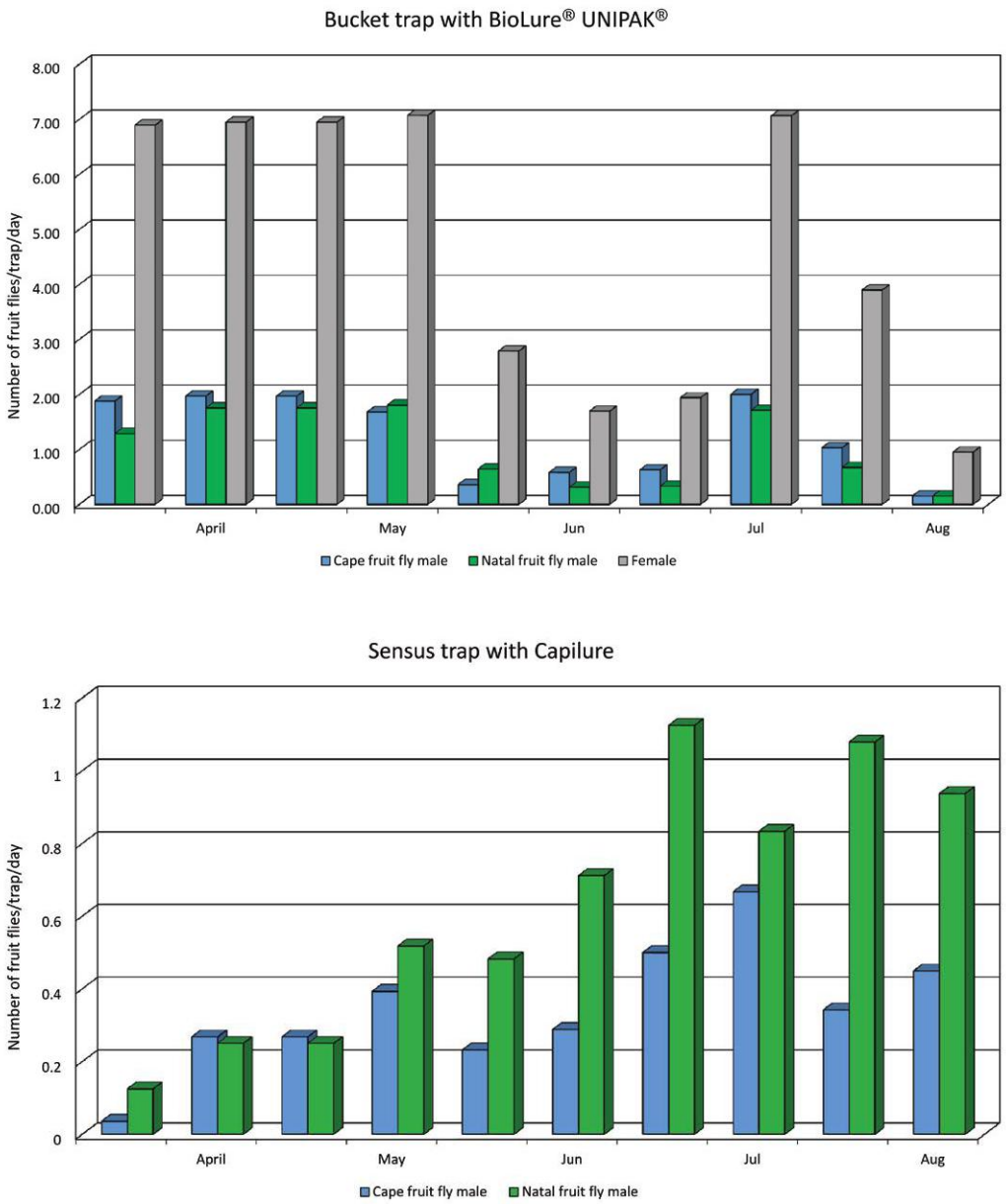

Figure 5: The number of Cape fruit fly and Natal fruit fly trapped in guava orchards next to 'Fuerte' orchards in the Deerpark area. Females of the two species cannot be distinguished based on morphological characteristics.

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