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Original article

Species composition and abundance of fruit flies (Diptera: Tephritidae) in subtropical fruit orchards in the Mbombela Local Municipality, South Africa

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Summary

Introduction – **Fruit flies (Diptera: Tephritidae) are of economic importance for subtropical fruit production. In the tribe Dacini, *Bactrocera*, *Ceratitis*, *Dacus* and *Trirhithrum* are among the important pest genera occurring naturally in Africa. However, three Asian *Bactrocera* species were introduced to Africa. The first detection of the Oriental fruit fly, *Bactrocera dorsalis*, in South Africa was in 2010 in the Limpopo province. In this study, fruit flies were trapped in subtropical fruit orchards in the Mbombela Local Municipality, Mpumalanga province.** *Materials and methods* – **Fruit flies were trapped in four orchards from March 2011 to March 2015. In each of the orchards, three yellow bucket traps were used with the following lures: BioLure® Fruit Fly (contains ammonium acetate, trimethylamine hydrochloride and putrescine), Chempac ME Lure/Invader-Lure™ (contains methyl eugenol) and Pumpkin Fruit Fly Pherolure™ (contains cue lure).** *Results and discussion* – **In traps with BioLure® Fruit Fly, two *Bactrocera* species, two *Capparimyia*, ten *Ceratitis* species, five *Dacus* species and one *Trirhithrum* species were trapped. In traps with methyl eugenol, *B. dorsalis*, *C. rosa s.l.* and *Perilampsis curta* Munro were trapped. *Bactrocera dorsalis* was detected during April 2012, and this was the first detection of the species in the area. Although the population level was low at the beginning, it increased and *B. dorsalis* became the dominant species in methyl eugenol baited traps. Six *Dacus* species were trapped with cue lure.** *Conclusion* – **The presence of *B. dorsalis* in subtropical production areas necessitates in-depth studies to determine the impact of the pest. Thereby, actions for pest management can be defined and undertaken.**

Keywords
South Africa, subtropical fruit species, pest control, *Bactrocera* spp., *Capparimyia* spp., *Ceratitis* spp., *Dacus* spp., *Trirhithrum* spp., Tephritidae

Significance of this study

What is already known on this subject?
- Some fruit flies (Diptera: Tephritidae) are of economic significance for subtropical fruit production in South Africa.
- Fruit fly females lay eggs in the fruit, and developing larvae cause fruit decay.
- Fruit flies are also a major constraint in fresh commodity trade due to quarantine measures.

What are the new findings?
- Fruit fly species present in subtropical fruit orchards in the Mbombela Local Municipality were identified.
- The invasive Oriental fruit fly, *Bactrocera dorsalis* (Hendel) was detected and monitored.
- Although the population level was low at first, it rapidly increased and *B. dorsalis* became the dominant species in methyl eugenol baited traps.

What is the expected impact on horticulture?
- Due to the presence of *B. dorsalis* in South Africa, in-depth studies are needed to determine the impact of the pest on subtropical fruit crops, and the most efficient measures of control.

Introduction

Horticulture is very important for human wellbeing in Africa. From an economic viewpoint, fruit flies belonging to the family Tephritidae (Diptera) are one of the most important families for the horticultural sector in Africa (Ekesi *et al.*, 2016). Fruit fly females lay eggs in the fruit, and developing larvae cause fruit decay. Fruit flies are also a major constraint to trade in fresh commodities. Some fruit fly species have become pests outside their native range. In Africa, there are about 400 frugivorous species of which more than 50 are of economic importance. There are seven genera of main economic relevance in Africa: *Bactrocera* Macquart, *Capparimyia* Bezzi, *Ceratitis* MacLeay, *Dacus* Fabricius, *Neoceratitis* Hendel, *Trirhithrum* Bezzi, and *Zeugodacus* Coquillett (Virgilio, 2016).

In South Africa, 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 pests of importance for subtropical fruit production (Prinsloo and Uys, 2015). Studies indicated that *C. rosa s.l.* consisted of a complex of two genotypes, and the two types should be considered as two different species (De Meyer *et al.*, 2015). De Meyer *et al.* (2016) described the one type as a new species, *Ceratitis quilicii* De Meyer, Mwatawala and Virgilio. Various species belonging to the genus *Dacus* are of economic importance for the cultivation of Cucurbitaceae in South Africa, *i.e.*, the greater pumpkin fly, *Dacus bivittatus* (Bigot), the lesser pumpkin fly, *Dacus ciliatus* Loew, *Dacus*

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frontalis Becker, *Dacus punctatifrons* Karsch, and the jointed pumpkin fly, *Dacus vertebratus* Bezzi (White, 2006; Visser, 2015).

Three Asian *Bactrocera* species were introduced to Africa, *i.e.*, the Oriental fruit fly, *Bactrocera dorsalis* (Hendel), the Solanum fruit fly, *Bactrocera latifrons* (Hendel) and the peach fruit fly, *Bactrocera zonata* (Saunders) (De Meyer and Ekesi, 2016). Another introduced species of Asian origin on the African continent is the melon fruit fly, *Zeugodacus cucurbitae* (Coquillett), which is especially a pest of cultivated Cucurbitaceae. Of the introduced species, *B. dorsalis* is currently the most widespread in Africa and poses an enormous threat to horticulture, because it is a highly polyphagous species attacking many cultivated crops (De Meyer and Ekesi, 2016). *B. dorsalis* was first found on the African continent in Kenya in 2003. Since its arrival in Africa, it has rapidly spread throughout the continent. In many African countries, *B. dorsalis* is currently the dominant fruit fly species attacking subtropical fruit and high damage levels were reported (De Meyer and Ekesi, 2016).

The detection of *B. dorsalis* in countries close to South Africa led to the development of an action plan and the formation of a *B. dorsalis* steering committee comprising of the Department of Agriculture, Forestry and Fisheries (DAFF) and the various fruit industries (Manrakhan *et al.*, 2015). A surveillance network was initiated for early detection of *B. dorsalis*. The first detection in South Africa was during 2010, in the northern parts of the country. Although eradication attempts were initially successful, the pest was declared present but subjected to official control in the Vhembe District Municipality in the Limpopo province in 2013 (Manrakhan *et al.*, 2015). During 2015, *B. dorsalis* was declared present but subjected to official control in certain district municipalities of Limpopo, Mpumalanga, North West, Gauteng and KwaZulu-Natal (IPPC, 2015). By 2018, *B. dorsalis* was declared present in Limpopo, Mpumalanga, North West, Gauteng, and in certain district municipalities of KwaZulu-Natal. *Bactrocera dorsalis* was successfully eradicated in the Eastern and Northern Cape provinces while in the Overberg District Municipality (Western Cape province), *B. dorsalis* was under eradication at the time when the paper was composed (IPPC, 2018).

This study reports on the trapping of fruit flies over a 4-year period in the Mbombela Local Municipality, Mpumalanga province. The aims of the study were: (i) to identify the fruit fly fauna present; (ii) to determine the presence or absence of alien invasive fruit fly species; and (iii) to obtain information on population dynamics of the important species.

Materials and methods

Study area

Trapping was carried at the Burgershall experimental farm (Latitude -25.10934, Longitude 31.08376, altitude 745 m) of the Agricultural Research Council - Tropical and Subtropical Crops (ARC-TSC) near Hazyview. The farm is situated in the Mbombela Local Municipality, Ehlanzeni District Municipality, Mpumalanga province, South Africa. The Köppen-Geiger climate classification is Cwa (Kottek *et al.*, 2006). Cwa is a monsoon-influenced humid subtropical climate, temperate with dry winters and warm summers. The area has a Savannah habitat. Agriculture is an important economic sector and various subtropical crops are cultivated which include avocado (*Persea americana* Mill.), banana (*Musa* spp.), citrus (*Citrus* spp.), guava (*Psidium guajava* L.), litchi (*Litchi chinensis* Sonn.), macadamia (*Macadamia* spp.) and mango (*Mangifera indica* L.). Vegetables are also produced on a commercial scale. Many households in the district have fruit trees as well as vegetables in their home gardens. On the Burgershall experimental farm, avocado, banana, coffee (*Coffea* spp.), litchi, macadamia and papaya (*Carica papaya* L.) are cultivated.

Trapping of fruit flies

Traps were placed out during March 2011. At that stage, *B. dorsalis* was only detected in the most northern part of the Limpopo province adjacent to Zimbabwe and near the Groblersbrug border post adjacent to Botswana. Trapping continued until March 2015. Traps were placed in a 'Pinkerton' avocado orchard, a 'Hass' avocado orchard, a litchi orchard consisting of different cultivars, and a variety orchard. The latter consisted of a variety of subtropical and indigenous fruit trees. Both avocado and litchi fruit are known to be poor hosts for the development of fruit flies (Grové and De Beer, 2013, 2014). In each orchard, three yellow bucket traps (Chempac (Pty) Ltd., Suider Paarl, South Africa) were used with the following lures: Chempac ME Lure (Chempac (Pty) Ltd.) or Invader-Lure™ (River Bioscience (Pty) Ltd., Port Elizabeth, South Africa), BioLure® Fruit Fly (Chempac (Pty) Ltd.) and Pumpkin Fruit Fly Pherolure® (Insect Science (Pty) Ltd., Tzaneen, South Africa). Therefore, there was only one replicate of the three trap and lure combinations in each orchard. Chempac ME lure contains methyl eugenol at 4 g lure^{-1}. Chempac ME Lure was used in the first year of the study, and afterwards Invader-Lure™. Invader-Lure™ is a wood-fibre block impregnated with methyl eugenol at 15 g block^{-1}. Methyl eugenol can be chemically described as 4-allyl-1,2-dimethoxybenzene and is a naturally occurring substance found in several plant species (Tan and Nishida, 2012). Methyl eugenol was used to attract species of *Ceratitis* subgenus *Pardalaspis* and the invasive species *B. dorsalis* and *B. zonata*. Pumpkin Fruit Fly Pherolure® contains cue lure at 2 mL dispenser^{-1}. Cue lure can be chemically described as 4-(p-acetoxyphenyl)-2-butanone, and was used to attract *Dacus* spp. and the invasive *Z. cucurbitae* (White, 2006). *Bactrocera latifrons* is not attracted to methyl eugenol or cue lure. Both methyl eugenol and cue lure are olfactory attractants and can be categorised as male lures which are species-specific and are usually preferred in detection programmes. Many fruit flies require sugar and protein when adults in order to survive and reproduce. The attraction of fruit flies to protein have been exploited in the development of food odour attractions for monitoring (Manrakhan, 2016). Food odour attractants are not species specific and generally female biased. Biolure® Fruit Fly is a food odour attractant that consists of three components, *i.e.*, ammonium acetate at 211 g kg^{-1}, trimethylamine hydrochloride at 91 g kg^{-1} and 1,4-diaminobutane (Putrescine) at 3 g kg^{-1}. Both males and females of various fruit fly genera are attracted to Biolure® Fruit Fly and a number of non-target insects can also be attracted (Joubert *et al.*, 2015; Manrakhan *et al.*, 2017). A block that contains dichlorvos at 195 g kg^{-1} (Vapona agricultural insecticide strips) (Acorn Products (Pty) Ltd., Strubens Valley, South Africa) was placed in each trap as a killing agent. Lures and blocks were replaced every 4–6 weeks. Traps were hung at a height of approximately 1.5–2.0 m. Only one trap was placed per tree and traps were placed 50 m apart in each orchard. Traps were serviced approximately every 4 weeks. Collected fruit flies were counted and identified in the laboratory.

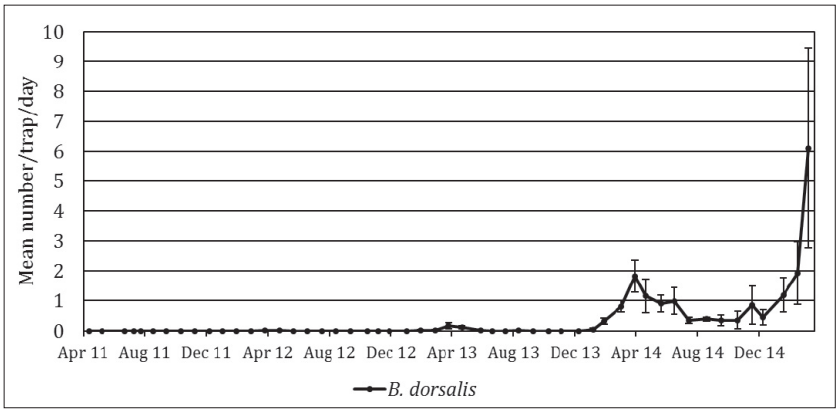

Figure 1. The seasonal fluctuations in trap catches (means ± standard errors) of *Bactrocera dorsalis* in yellow bucket traps baited with methyl eugenol at the Burgershall experimental farm, Mpumalanga province, South Africa.

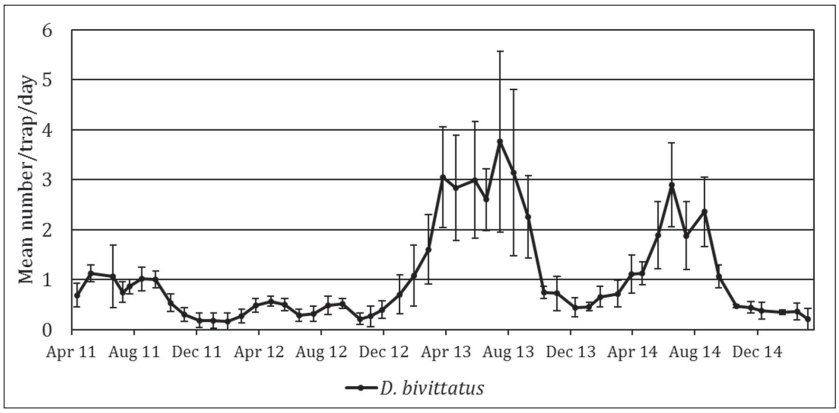

Figure 2. The seasonal fluctuations in trap catches (means ± standard errors) of *D. bivittatus* in yellow bucket traps baited with cue lure at the Burgershall experimental farm, Mpumalanga province.

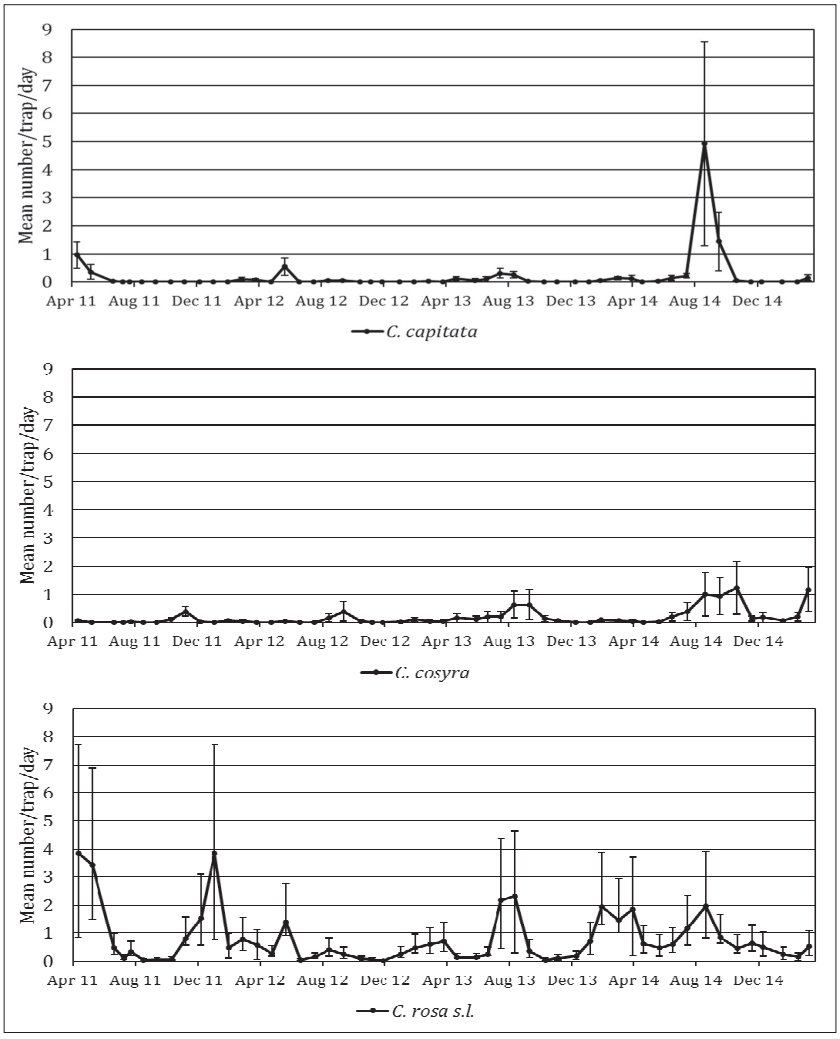

Figure 3. The seasonal fluctuations in trap catches (means ± standard errors) of *Ceratitis capitata*, *C. cosyra* and *C. rosa s.l.* in yellow bucket traps baited with ammonium acetate, trimethylamine hydrochloride and putrescine at the Burgershall experimental farm, Mpumalanga province, South Africa.

The species richness was calculated for each orchard as the number of species trapped with the three trapping systems. The number of fruit flies trap^{-1} day^{-1} was calculated for the important pest species. The average number trap^{-1} day^{-1} (± SE) for important pest species was determined for the catches in the four orchards (Figures 1–3).

Fruit fly identification

All the fly species were identified by using keys (De Meyer, 1998, 2000, 2009; White *et al.*, 2003; De Meyer and Freidberg, 2005, 2006; White, 2006; Virgilio *et al.*, 2014). Specimens were sent to Dr. M. de Meyer (Royal Museum for Central Africa, Tervuren, Belgium) for confirmation of identification. No distinction was made between *C. rosa sensu stricto* and *C. quilicii* because, at that stage, it was still considered as one species.

Results and discussion

Inventory of Tephritidae species trapped

A total of 16,625 tephritid specimens were trapped in the four orchards (Table 1). The fruit flies trapped represented 23 species. There was a large representation of the genus *Ceratitis* and ten species were trapped. The highest number of fruit flies were trapped in the 'Hass' orchard and the lowest number in the 'Pinkerton' orchard (Table 1). The species richness was the highest in the 'Hass' orchard. The high number of fruit flies and species trapped in the 'Hass' orchard is probably due to the surrounding host plants. In the traps baited with methyl eugenol, a total of 2,099 specimens were trapped. Three species were trapped: *B. dorsalis*, *C. rosa s.l.* and *Perilampsis curta* Munro. Both *B. dorsalis* and *C. rosa s.l.* are species of economic significance for the subtropical fruit industry (Prinsloo and Uys, 2016). *Perilampsis*

Table 1. Fruit fly species trapped at the ARC-TSC Burgershall experimental farm from March 2011 to March 2015.

Species	Hass	Litchi	Pinkerton	Variety	Total	Females	Males	Percentage
Traps with methyl eugenol								
Bactrocera dorsalis (Hendel)	339	238	217	1,147	1,941	5	1,936	92.47
Ceratitis rosa s.l. Karsch	50	1	6	47	104	64	40	4.95
Perilampsis curta Munro	13	2	8	31	54	0	54	2.57
Total	402	241	231	1,225	2,099	69	2,030	
Traps with cue lure								
Dacus bivittatus (Bigot)	1,551	772	1,629	2,017	5,969	69	5,900	90.16
Dacus durbanensis Munro	11	5	6	2	24	0	24	0.37
Dacus eclipsis (Bezzi)	55	67	65	52	239	0	239	3.65
Dacus punctatifrons Karsch	41	29	39	73	182	1	181	2.77
Dacus venetatus Munro	66	38	44	50	198	1	197	3.01
Dacus vertebratus Bezzi	0	1	2	0	3	0	3	0.05
Total	1,724	912	1,785	2,194	6,615	71	6,544	
Traps with three-component lure								
Bactrocera amplexa (Munro)	5	1	1	6	13	10	3	0.16
Bactrocera dorsalis (Hendel)	8	1	10	4	23	10	13	0.29
Capparimyia bipustulata (Bezzi)	0	0	1	0	1	1	0	0.01
Capparimyia melanaspis (Bezzi)	2	0	0	0	2	2	0	0.03
Ceratitis capitata (Wiedemann)	406	725	158	973	2,262	1,328	934	28.59
Ceratitis connexa (Bezzi)	0	1	0	0	1	1	0	0.01
Ceratitis cosyra (Walker)	763	65	232	23	1,083	641	442	13.69
Ceratitis discussa Munro	53	10	34	11	108	42	66	1.37
Ceratitis pedestris (Bezzi)	16	2	4	4	26	16	10	0.33
Ceratitis podocarpi (Bezzi)	2	0	0	13	15	11	4	0.19
Ceratitis quinaria (Bezzi)	0	0	0	3	3	2	1	0.04
Ceratitis rosa s.l. Karsch	1,783	1,160	701	463	4,107	2,185	1,922	51.92
Ceratitis rubivora Coquillett	1	0	0	0	1	0	1	0.01
Ceratitis venusta (Munro)	4	0	0	1	5	4	1	0.06
Dacus bivittatus (Bigot)	27	3	17	6	53	30	23	0.67
Dacus ciliatus Loew	14	3	0	8	25	13	12	0.32
Dacus eclipsis (Bezzi)	1	0	0	1	2	0	2	0.03
Dacus punctatifrons Karsch	0	0	1	0	1	0	1	0.01
Dacus vertebratus Bezzi	1	0	0	1	2	0	2	0.03
Perilampsis curta Munro	1	0	1	0	1	1	0	0.01
Trirhithrum occipitalis Bezzi	159	2	16	0	177	105	72	2.24
Total	3,246	1,973	1,175	1,517	7,911	4,402	3,509	
Species richness	20	17	16	18	23			

Table 2. Fruit fly species trapped with methyl eugenol at the ARC-TSC Burgershall experimental farm from March 2011 to March 2015.

Seasons	*Bactrocera dorsalis* (Hendel)			*Ceratitis rosa s.l.* Karsch			*Perilampsis curta* Munro		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
2011/12	0	0	0	40	30	70	0	9	9
2012/13	0	7	7	3	2	5	0	18	18
2013/14	1	178	179	5	2	7	0	18	18
2014/15	4	1,751	1,755	16	6	22	0	9	9

is a small Afrotropical genus not considered of economic importance, with hosts in the Loranthaceae family (De Meyer, 2009). More *B. dorsalis* males were trapped in comparison to the females, while more females of *C. rosa s.l.* were trapped. The reason why more females were trapped is not clear. Only males of *P. curta* were trapped. During the 2011/12 season, *C. rosa s.l.* was the most abundant species while in 2012/13, *P. curta* dominated (Table 2). *B. dorsalis* was trapped for the first time in the variety orchard on the farm in April 2012. This was also the first detection of the species in the Mpumalanga province. The detection was reported to the National Plant Protection Organization (Department of Agriculture, Forestry and Fisheries). A delimiting survey was carried out, a quarantine area was set up and the movement of host material from the area was regulated. Eradication measures were implemented. After the detection, no captures were made until February 2013. From January 2014, *B. dorsalis* was continuously trapped. By then, *B. dorsalis* was also reported elsewhere in the Ehlanzeni District Municipality (Manrakhan *et al.*, 2015). *B. dorsalis* was declared present but subjected to official control in the Ehlanzeni District Municipality by early 2015 (IPPC, 2015). There was a rapid increase in the number of *B. dorsalis* trapped from 2012/13 to 2013/14 and from 2013/14 onwards, and *B. dorsalis* became the dominant species trapped with methyl eugenol. Since the first detection of the invasive species, its numbers rapidly increased, which could be attributed to the wide host range of the species and its competitive dominance over other fruit fly species like *C. cosyra* and the absence of natural enemies (Ekesi *et al.*, 2009; Rwomushana *et al.*, 2009; Salum *et al.*, 2013). *Bactrocera dorsalis* represented 92.47% of the fruit flies trapped with methyl eugenol. *Bactrocera zonata* was not detected during the study period.

In traps baited with cue lure, 6,615 specimens were trapped. More males (n = 6,544) than females (n = 71) were trapped (Table 1). Six different *Dacus* species were trapped and *D. bivittatus* was the most abundant species trapped in each of the 4 years. *Dacus bivittatus* represented 90.16% of total fruit fly catches with cue lure. *Dacus bivittatus* is a common and widespread pest of Cucurbitaceae, but sometimes also attacks other families (White, 2006). *Dacus bivittatus* is not of significance for the production of subtropical crops in South Africa. However, there are host records for *D. bivittatus* from papaya and mango (De Meyer and White, 2004; Rwomushana and Tanga, 2016). *Dacus bivittatus* was also trapped in citrus orchards in Limpopo and Mpumalanga (Manrakhan *et al.*, 2017). *Dacus durbanensis* Munro, *Dacus eclipsis* Bezzi, *D. punctatifrons*, *Dacus venetatus* Munro and *D. vertebratus* were also found in the traps with cue lure. *Dacus durbanensis* is associated with Cucurbitaceae and Passifloraceae, while *D. eclipsis* is only associated with Passifloraceae (White, 2006). *Dacus punctatifrons* is a widespread and common pest that attacks a wide range of Cucurbitaceae, but has also been reared from other families, while *D. venetatus* attacks Apocynaceae and Passifloraceae (White 2006). *Dacus vertebratus* is a widespread pest of Cucurbitaceae, but is not known to respond to cue lure. *Dacus vertebratus* was also trapped with cue lure in Tanzania (Mwatawala *et al.*, 2006). The invasive species *Z. cucurbitae* was not detected during the study.

In traps baited with ammonium acetate, trimethylamine hydrochloride and putrescine, fruit flies of the genera *Bactrocera*, *Dacus*, *Capparimyia*, *Ceratitis, Perilampsis* and *Trirhithrum* were trapped (Table 1). A total of 7,911 specimens were trapped. More females (n = 4,402) than males (n = 3,509) were trapped, which is expected from food bait lures.

Two *Bactrocera* species were trapped, *Bactrocera amplexa* (Munro) and *B. dorsalis*. *Bactrocera amplexa* was also trapped in litchi orchards in South Africa (Grové and De Beer, 2014), and the only host known is *Strombosia schefferi* Engl. (Olacaceae) (White, 2006). *Bactrocera dorsalis* was trapped with methyl eugenol in April 2012, while in traps with three-component lure it was trapped for the first time in April 2014. Therefore, the trapping of females could be improved and necessitates testing of other monitoring systems in order to improve female trapping. Three-component lure does not attract fruit flies over a long distance, but gives an indication of flies in close proximity to the traps. Parapheromone, on the other hand attracts flies over a long distance.

Two *Capparimyia* species were trapped, *i.e.*, *Capparimyia bipustulata* (Bezzi) and *Capparimyia melanaspis* (Bezzi). *Capparimyia* is predominantly an Afrotropical group, developing in plants of Capparidaceae (De Meyer and Freidberg, 2005).

Ten *Ceratitis* species were trapped, with *C. rosa s.l.* being the abundant one, followed by *C. capitata* and *C. cosyra*. *C. rosa s.l.* was also the abundant species trapped with three component lure and represented 51.92% of trapped fruit flies. *Ceratitis capitata*, *C. cosyra* and *C. rosa s.l.* are species of economic significance for the subtropical fruit industry. *Ceratitis rosa s.l.* was also the abundant species trapped in litchi and avocado orchards in previous studies (Grové and De Beer, 2013, 2014). Other *Ceratitis* trapped included *C. connexa* (Bezzi), *C. discussa* Munro, *C. pedestris* (Bezzi), *C. podocarpi* (Bezzi), *C. quinaria* (Bezzi), *C. rubivora* Coquillett and *C. venusta* (Munro). Only one *C. connexa* was trapped and the species is known to attack Sapotaceae (De Meyer and White, 2004). *Ceratitis discussa* is known to attack fruit of the Annonaceae, while *C. pedestris*, *C. podocarp*i and *C. venusta* attack *Strychnos* (Longaniaceae), Podocarpaceae and Solanaceae, respectively (De Meyer and White, 2004). *C. quinaria* is known to be a pest of subtropical fruit like mango, but very low numbers were trapped on the experimental farm (Rwomushana and Tanga, 2016). *Ceratitis rubivora* is of economic significance for the production of berries of the genus *Rubus* (Rosaceae).

Five *Dacus* species were trapped with three component lure. *Dacus bivittatus*, *D. eclipsis*, *D. punctatifrons* and *D. ver-*

tebratus were also trapped with cue lure. *Dacus bivittatus* was the dominant *Dacus* species trapped with three component lure. *Dacus ciliatus* Loew was trapped with three component lure and is known to be of economic importance for the production of Cucurbitaceae but is also reported from non-cucurbits (De Meyer and Ekesi, 2016). One *P. curta* female was trapped with three component lure. *Thrirhithrum occipitalis* Bezzi was the only species from this particular genus trapped and is known to attack fruit of the Vitaceae (De Meyer and White, 2004). The invasive species *B. latifrons* was not detected during the study.

Population dynamic of the abundant fruit fly species

The number of fruit flies trapped fluctuated markedly from year to year. The seasonal fluctuations of *B. dorsalis* trap catches in yellow bucket traps baited with methyl eugenol are given in Figure 1. After the first detection in April and May 2012, no flies were trapped until February 2013. Peak numbers were trapped in April 2013. Trapped numbers increased from January 2014 and reached peak numbers in April 2014. Afterwards, numbers declined and started to increase from January 2015. Catches between July to December 2014 were relatively low. Similar results were found in citrus orchards and natural areas in Mpumalanga and Limpopo, where peak *B. dorsalis* catches occurred between January and May (Manrakhan *et al.*, 2017; Theron *et al.*, 2017). Host availability is one of the important factors that determines population fluctuations. The higher numbers in this timeframe probably correspond with the maturing of subtropical fruit like avocado, guava, litchi, mango, and indigenous fruit like the Marula, *Sclerocarya birrea* subsp. *caffra* (Sond.) Kokwaro (Anacardiaceae) (Grové *et al.*, 2017; Theron *et al.*, 2017).

The seasonal fluctuations of *D. bivittatus* of trap counts in yellow bucket traps baited with cue lure are given in Figure 2. Peak catches were reported during May 2011, while during 2012 numbers were below 1 fruit fly trap^{-1} day^{-1}. In 2013 and 2014, the highest numbers were trapped during July and June, respectively. Therefore, peak numbers occurred from May to July during autumn and winter. These peak numbers probably correspond with the availability of indigenous and cultivated host plants, *e.g.*, Cucurbitaceae.

Numbers of *C. capitata* trapped with three component lure were below 1 fruit fly trap^{-1} day^{-1}, except during August to September 2014 (Figure 3). Zero trap catches were often found. Numbers of *C. cosyra* trapped with three component lure were below 1 fruit fly trap^{-1} day^{-1}, except during August 2014, October 2014 and March 2015 (Figure 3). *C. capitata* and *C. cosyra* numbers were lower in comparison to *C. rosa s.l.* in avocado and litchi orchards in previous studies (Grové and De Beer, 2013, 2014). Therefore, *C. capitata* and *C. cosyra* seem to be of lesser importance for the production of avocado and litchi. Numbers of *C. rosa s.l.* trapped with three-component lure is given in Figure 3. Relatively high numbers were reported in April 2011, January 2012, May 2012, August 2013, February 2014 and August 2014. Peak numbers were therefore reported in months with cooler and warmer temperatures.

Conclusion

The trapping of fruit flies is an important tool in determining the absence or presence of species, and also provides information on the population dynamics. Therefore, effective trapping systems need to be available. Information on the population dynamics of fruit flies of economic importance is crucial in the development of effective integrated control strategies. This study demonstrated the aggressive invasion and establishment of *Bactrocera dorsalis* in a specific area. The presence of *B. dorsalis* in subtropical production areas necessitates in-depth studies of the impact of the pest in order to determine if control actions are needed.

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