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Evaluation of Fruit Fly (Diptera: Tephritidae) Monitoring Systems on Mango in Limpopo Province, South Africa

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Abstract: Fruit fly species' responses to lures are critically important, especially when a single lure might be recommended for the purpose of trapping multiple fruit fly species in commercial fruit orchards. Fruit industries are facing threats from the recent invasion of the oriental fruit fly *Bactrocera dorsalis* (Hendel) into novel areas in South Africa. The objective of this study was to test the relative efficiency of 13 different trapping systems for fruit fly species in mango orchards in South Africa. Evaluation of the different monitoring systems was conducted during the 2013-2014 mango season in the Vhembe district municipality of Limpopo, South Africa. Four orchards, where Tommy Atkins was cultivated, were used to compare the efficacy of the trapping systems. Trapping data (N = 48 observation incidences per trapping system) were analyzed using a non-parametric ANOVA. Pronounced variation in species attractiveness across the trapping systems was found. The enriched ginger oil (EGO) Pherolure™ captured 33.77% of all the *Ceratitis* spp., while the Invader-lure™ captured 36.47% of the total number of *B. dorsalis* trapped. Torula yeast pellets are not recommended for fruit fly trapping due to the relative low trap catch numbers and high non-target catches. These results are important and significant for on-farm monitoring strategies, as well as for invasion monitoring systems currently in place to detect the distribution of *B. dorsalis* in South Africa.

Key words: Fruit fly lure, Diptera, Tephritidae monitoring systems, mango.

1. Introduction

In Africa, there are approximately 1,000 known fruit fly species (Diptera: Tephritidae), which belong to 150 genera [1], of which 50 species are of economic importance. Fruit fly species of economic importance are also associated with mango production in Africa [2-8]. In South Africa, three *Ceratitis* species pose a significant threat to fruit industries, namely, the Marula fruit fly—*Ceratitis* (*Ceratalaspis*) *cosyra* (Walker), which is especially significant in terms of mango production and is usually the most abundant species in mango orchards; the Natal fruit fly—*Ceratitis* (*Pterandrus*) *rosa* (Karsch); and the Mediterranean fruit fly—*Ceratitis* (*Ceratitis*) *capitata* (Wiedemann) [9, 10]. The oriental fruit fly—*Bactrocera dorsalis* (Hendel) was detected in Africa for the first time in Kenya in 2003; it initially was described as *B. invadens* Drew, Tsuruta and White and now synonymised with *B. dorsalis* [2, 11]. Since the arrival of *B. dorsalis* in Africa, it has rapidly spread throughout the African continent into many newly-invaded fruit-producing countries [5, 12]. *B. dorsalis* was detected in South Africa for the first time in 2010 [13]. It was declared to be present in Vhembe district municipality in northern parts of the country during 2013 [14]. It has since spread rapidly throughout the northern part of the country, where mango is cultivated commercially.

The first step for the successful management of fruit flies in fruit orchards is to have an effective monitoring system. Monitoring is important to: (1) identify species present in the orchard to establish whether there is in fact a pest problem, (2) determine

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seasonal changes in population levels, (3) give an indication of the population present and the severity of pest, (4) determine the time for control actions to be initiated and (5) determine the efficacy of control measures.

Two main types of attractants can be used in the monitoring of fruit fly species, i.e., male lures and food baits. Male lures are mostly parapheromones that are highly species-specific, and they are effective in attracting fruit flies from long distances [15, 16]. Methyl eugenol is a male attractant used for monitoring male *Bactrocera* species and is used in South Africa for the surveillance of *B. dorsalis* [17, 18]. Methyl eugenol can be chemically described as 4-allyl-1,2-dimethoxybenzene [17]. Studies on *B. dorsalis* have demonstrated that ingestion of methyl eugenol increases male mating success [19]. Enriched ginger oil (EGO) is a source of alpha-coapane and is known to be an attractant for *Ceratitis* species [6, 20, 21]. It also has a male enhancing component, because exposure to its aroma increases the mating success of males [22-24]. *C. cosyra* was especially strongly attracted to EGO in a study conducted in mango orchards in South Africa [6].

Attraction of both sexes of *B. dorsalis* to three-component lure, a food bait that consists of ammoniumacetate, trimethylamine hydrochloride and putrescine, had also been reported and is also used in the surveillance of *B. dorsalis* in South Africa [18]. Both males and females of *C. capitata*, *C. cosyra* and *C. rosa* respond to three-component lure [6]. The second food bait, Torula yeast, is an autolysed yeast protein and attracts males and females of different fruit fly species [25].

The general objective of this study was to evaluate the efficacy of different lures and traps (trapping systems) for monitoring the complex of fruit flies associated with mango production in the Limpopo province of South Africa, with the specific objective to identify the best monitoring system to detect *Ceratitis* species and *B. dorsalis* presence in commercial mango orchards and to assess the extent to which non-target species were trapped in the systems.

2. Materials and Methods

2.1 Study Site

Evaluation of the different monitoring systems was conducted during 2014 in the Vhembe district of the Limpopo province in South Africa. Evaluation was done in four mango orchards of the Tommy Atkins cultivar. The site coordinates at 23°06′32″ S and 30°16′33″ E. The orchards were 10-12 years old and under dry land cultivation. No pesticides were used in these orchards during the trial.

2.2 Tephritidae Monitoring Systems

Thirteen different monitoring systems were evaluated and compared. A brief description of each lure (including supplier details) and the trap used in the system is given in Table 1. Three different types of traps were used (Table 1).

The McPhail trap consisted of three parts, i.e. a yellow bottom section, shaped as an inverted funnel, a transparent top and a plastic water ring. The transparent top houses a plastic basket for lures. The height of the trap is 190 mm and the width is 175 mm.

The Chempac yellow bucket trap consisted of a yellow bucket with a transparent lid. Apart from the funnel on the base of the bucket, it has three side holes, through which some transparent cylindrical tubes are introduced towards the inside. The height of the trap is 160 mm and the width is 135 mm.

The Lynfield trap used consisted of yellow bucket and lid. The bucket had with four holes at the side and 12 small holes in the bottom of the trap. The height of the trap is 120 mm and the width 130 mm.

2.3 Trapping Methods

To evaluate the efficacy of the monitoring systems, traps were placed 1.5 m above the ground on the southern side of a mango tree in four mango orchards

Table 1 Description of the lures, traps and killing agents used in 13 trapping systems evaluated.

No.	Abbreviations	Lure description	Trap	Killing agent
1	3CL	3-component lure (Insect Science (Pty) Ltd.); Consists of three components: ammonium acetate at a loading rate of 5 g, trimethylamine hydrochlorid at a loading rate of 1 g and 1,4-diaminobutane (putrescine) at a loading rate of 50 mg	McPhail trap (Insect Science (Pty) Ltd.) 	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
2	BFF	Biolure® fruit fly (Suterra LLC, Bend, USA and distributed in South Africa by Chempac (Pty) Ltd.); Consists of three components: ammonium acetate at a loading rate of 211 g/kg, trimethylamine hydrochlorid at a loading rate of 91 g/kg and 1,4-diaminobutane (putrescine) at a loading rate of 3 g/kg	Chempac bucket trap (Chempac (Pty) Ltd.) 	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
3	CME	Chempac methyl eugenol lure (Chempac (Pty) Ltd., Suider Paarl, South Africa); Contains methyl eugenol at a loading rate of 4 g/lure	Chempac bucket trap (Chempac (Pty) Ltd.)	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
4	EGO	Enriched ginger oil Pherolure™ (Insect Science (Pty) Ltd., Tzaneen, South Africa); Contains alpha-copaene at a loading rate of 2 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd., Strubens Valley, South Africa); Contains 1.17 g dichlorvos
5	EGO ND	EGO Pherolure™ (new device) (Insect Science (Pty) Ltd.); Contains alpha-copaene at a loading rate of 0.5 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
6	EGO + P ND	EGO Pherolure™ + Permethrin (new device) (Insect Science (Pty) Ltd.); Contains alpha-copaene at a loading rate of 0.5 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Permethrin at a loading rate of 0.03 g/lure

(Table 1 continued)

No.	Abbreviations	Lure description	Trap	Killing agent
7	IL	Invader-lure (River BioScience (Pty) Ltd., Addo, South Africa); Contains methyl eugenol at a loading rate of 15 g/block	Lynfield trap (River BioScience (Pty) Ltd.) 	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
8	ME	Methyl eugenol Pherolure™ (Insect Science (Pty) Ltd.); Contains methyl eugenol at a loading rate of 2 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
9	ME + EGO ND	ME + EGO Pherolure™ (new device) (Insect Science (Pty) Ltd.); Contains methyl eugenol at a loading rate of 0.5 g and alpha-copaene of 0.5 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
10	ME+ EGO + P ND	ME + EGO Pherolure™ + Permethrin (new device) (Insect Science (Pty) Ltd.); Contains methyl eugenol at a loading rate of 0.5 g and alpha-copaene of 0.5 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Permethrin at a loading rate of 0.06 g/lure
11	ME ND	ME Pherolure™ (new device) (Insect Science (Pty) Ltd.); Contains methyl eugenol at a loading rate of 1 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Dichlorvos tablet 6 g (Acorn Products (Pty) Ltd.); Contains 1.17 g dichlorvos
12	ME + P ND	ME Pherolure™ + Permethrin (new device) (Insect Science (Pty) Ltd.) Contains methyl eugenol at a loading rate of 1 g/lure	McPhail trap (Insect Science (Pty) Ltd.)	Permethrin at a loading rate of 0.06 g/lure
13	TYP	Torula yeast pellets (ISCA Technologies, Inc., California, USA); One pellet was dissolved in 500 mL water	Chempac bucket trap (Chempac (Pty) Ltd.)	None, insects drown in the water mixture

in a complete randomized block design, following the method described by Leblanc et al. [25]. Trapping systems (≥ 30 m apart) were randomized weekly for six consecutive weeks (November-December, 2013). All the lures and DDVP (dichlorvos) containing tablets were replaced after completion and the trial continued for another six weeks with fresh lures (January-February 2014), randomising the traps weekly as before. Each treatment was replicated four times to result in a total of $N = 48$ observations per trapping system. The fruit flies and non-target by-catch counts were taken weekly from each trap. *Ceratitis* spp. and *B. dorsalis* were identified. Morphological keys were used for identification of species [17, 26-28]. The sex of each fruit fly specimen was recorded. No-target insects were identified to order level and spiders to class level.

2.4 Statistical Analysis

Weekly randomization accounted for the effect of system location in the orchard on population density. The data (average weekly trap catches) for the final 6-week trial were analyzed using generalized linear models in R [29]. The assumption of homoscedasticity was tested for every statistical test to make sure the model was valid and the variance of the data means was equal (residual deviance < degrees of freedom for the model). The mean model estimates were plotted and no overlap in 95% confidence intervals of the mean weekly trap catch data defined statistically heterogeneous treatment groups.

3. Results

Five fruit fly species were captured and identified during this study, namely, *C. capitata*, *C. cosyra*, *C. rosa*, *C. quinaria* (Bezzi) and *B. dorsalis* in addition to *Perilampsis* spp. (Fig. 1). The total number of fruit fly species captured with the percentage of the total number per species is given in Table 2.

As shown in Fig. 1, the most abundant species captured were *C. cosyra*, followed by *C. rosa* and *C. capitata*. Low numbers of *C. quinaria* were present. A small number of fruit flies of the genus *Perilampsis* Bezzi were found in traps. *Perilampsis* is a small Afrotropical genus, not considered of economic importance, with hosts in the Loranthaceae family [30]. The highest percentage of *C. cosyra* (40.67%), *C. capitata* (34.56%) and *C. rosa* (34.73%) responded to EGO Pherolure, which had the highest concentration of α-copaene. EGO Pherolure captured 30.77% of the total number of fruit flies captured in the study. *C. quinaria* responded to EGO-containing products, but

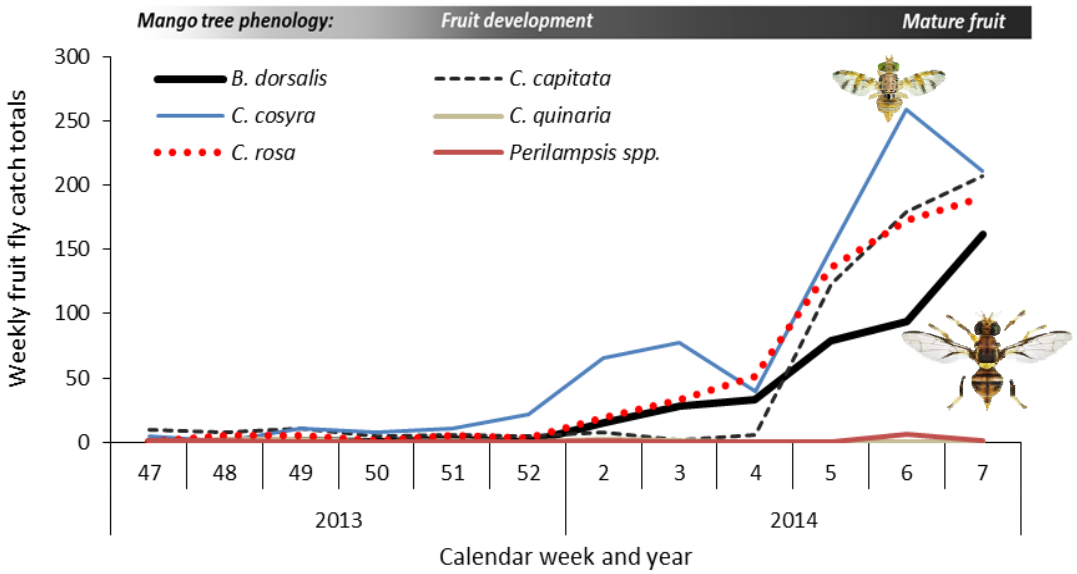

Fig. 1 Number of fruit flies per week across all 13 monitoring systems for the duration of 12 weeks.

Table 2 Total number of fruit fly captured over a period of 12 weeks.

Trapping system	Total number of fruit fly captured						
	C. capitata	*C. cosyra*	*C. rosa*	*C. quinaria*	*B. dorsalis*	*Perilampsis* spp.	Total
3CL	3 (0.53%)	5 (0.58%)	15 (2.41%)	-	3 (0.72%)	-	26 (1.05%)
BFF	27 (4.74%)	27 (3.13%)	119 (19.13%)	-	8 (1.93%)	-	181 (7.28%)
CME	-	-	-	-	98 (23.67%)	1 (10.00%)	99 (3.98%)
EGO	197 (34.56%)	350 (40.67%)	216 (34.73%)	2 (25.00%)	-	-	765 (30.77%)
EGO ND	148 (25.96%)	211 (24.48%)	96 (15.43%)	1 (12.50%)	9 (2.17%)	-	465 (18.70%)
P ND	100 (17.54%)	101 (11.02%)	72 (11.58%)	2 (25.00%)	8 (1.93%)	-	283 (11.38%)
IL	-	-	-	-	151 (36.47%)	8 (80.00%)	159 (6.40%)
ME	-	-	-	-	51 (12.32%)		51 (2.05%)
ME + EGO ND	48 (8.42%)	67 (7.77%)	39 (6.27%)	2 (25.00%)	24 (5.80%)	1 (10.00%)	181 (7.28%)
ME + EGO + P ND	46 (8.07%)	95 (11.02%)	47 (7.56%)		22 (5.31%)	-	210 (8.45%)
ME ND	-	-	-	1 (12.50%)	22 (5.31%)	-	23 (0.93%)
ME + P ND	-	2 (0.23%)	1 (0.16%)	-	12 (2.90%)	-	15 (0.60%)
TYP	1 (0.18%)	4 (0.46%)	17 (2.73%)	-	6 (1.45%)	-	28 (1.13%)
Total	570 (100%)	862 (100%)	622 (100%)	8 (100%)	414 (100%)	10 (100%)	2,486 (100%)

All the traps were re-baited after six weeks; the values given in brackets are the percentage of the total catch data for the respective species; -: indicated zero trap catches.

Table 3 Total number of male fruit fly captured over a period of 12 weeks.

Trapping system	Total number of male fruit fly captured						
	C. capitata	*C. cosyra*	*C. rosa*	*C. quinaria*	*B. dorsalis*	*Perilampsis* spp.	Total
3CL	-	3 (0.36%)	6 (1.15%)	-	2 (0.49%)	-	11 (0.47%)
BFF	11 (2.00%)	5 (0.60%)	41 (7.87%)	-	5 (1.23%)	-	62 (2.67%)
CME	-	-	-	-	98 (24.20%)	1 (10.00%)	99 (4.26%)
EGO	197 (35.82%)	349 (41.90%)	216 (41.46%)	2 (33.33%)	-	-	764 (32.86%)
EGO ND	148 (26.91%)	211 (25.33%)	96 (18.43%)	1 (16.67%)	9 (2.22%)	-	465 (20.00%)
EGO + P ND	100 (18.18%)	101 (12.12%)	72 (13.82%)	2 (33.33%)	8 (1.98%)	-	283 (12.17)
IL	-	-	-	-	151 (37.28%)	8 (80.00%)	159 (6.84%)
ME	-	-	-	-	51 (12.59%)	-	51 (2.19%)
ME + EGO ND	48 (8.73%)	67 (8.04%)	38 (7.29%)	-	24 (5.93%)	1 (10.00%)	178 (7.66%)
ME + EGO + P ND	46 (8.36%)	94 (11.28%)	47 (9.02%)	-	22 (5.43%)	-	209 (8.99%)
ME ND	-	-	-	1 (33.33%)	22 (5.43%)	-	23 (0.99%)
ME + P ND	-	2 (0.24%)	1 (0.19%)	-	12 (2.96%)	-	15 (0.65%)
TYP	-	1 (0.12)	4 (0.77%)	-	1 (0.25%)	-	6 (0.26%)
Total	550 (100%)	833 (100%)	521 (100%)	6 (100%)	405 (100%)	10 (100%)	2,325 (100%)

All the traps were re-baited after six weeks; the values given in brackets are the percentage of the total catch data for the respective species; -: indicated zero trap catches.

one specimen was captured in a trap with methyl eugenol. The highest percentage of *B. dorsalis* (36.47%) responded to Invader-lure (Table 2). A small percentage (< 3%) of *B. dorsalis* responded respectively to the EGO Pherolure (new device) and EGO Pherolure + Permethrin (new device). *C capitata*, *C. cosyra* and *C. rosa* were more responsive to lures containing EGO opposed to the combination with methyl eugenol. The addition of permethrin to EGO Pherolure (new device) seemed to have a negative effect, i.e., less catches on the response of *C. capitata*, *C. cosyra* and *C. rosa*. The addition of permethrin to ME Pherolure + EGO Pherolure (new device) did not seem to have an effect on the response of *C. capitata*, *C. cosyra*, *C. rosa* or *B. dorsalis*. The addition of permethrin to ME Pherolure (new device) had a negative effect on the response of *B. dorsalis*. Trap catch data for males and females are given in Table 3 and Table 4, respectively, and showed in Fig. 2. The food baits, i.e., Biolure fruit fly, 3-component lure and

Torula yeast pellets typically captured the highest percentage of female fruit flies. The highest percentage of *B. dorsalis* females (62.50%) was captured with the Torula yeast pellets, while Biolure fruit fly captured the highest percentage female of *C. capitata*, *C. rosa* and *C. cosyra* (80.00%, 77.32% and 75.86%, respectively) (Table 4).

Biolure fruit fly captured 73.91% of the total number of female flies (Table 4). Fig. 3 shows the results for the standard deviation of the average weekly

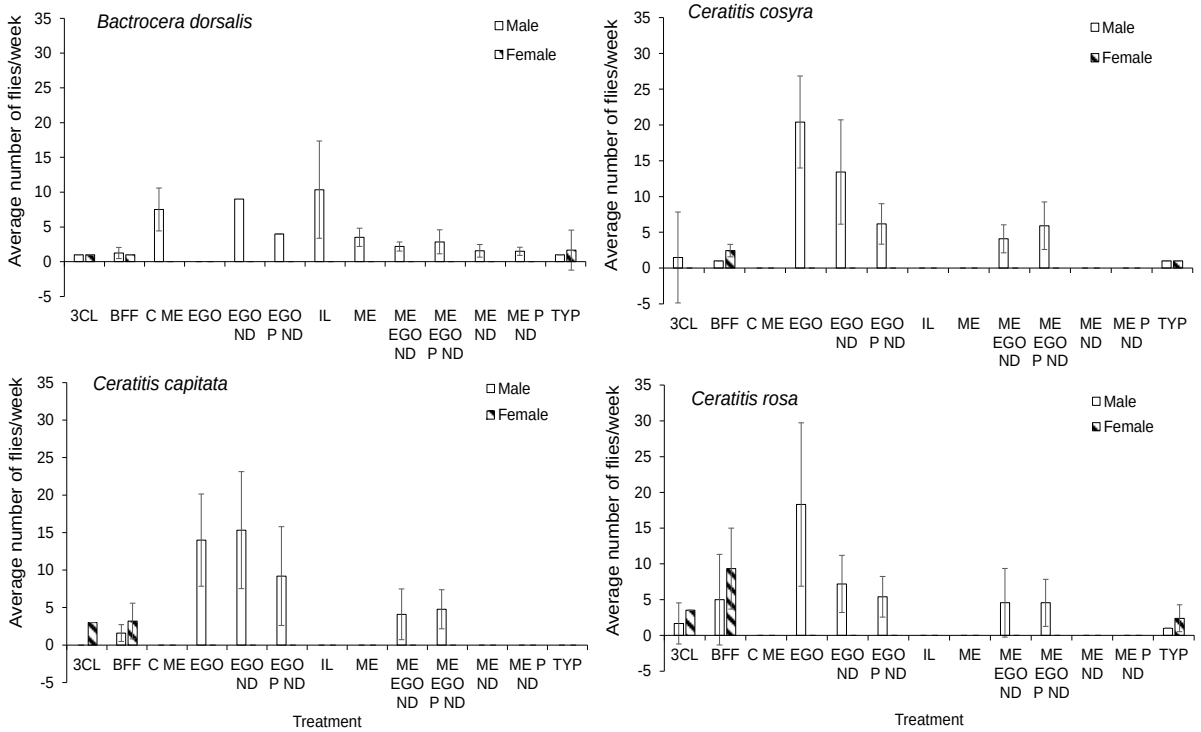

Fig. 2 Fruit fly catches (mean ± 95% confidence intervals) per species per week for 13 monitoring systems during calendar weeks 5-7, 2014 across four mango orchards.

Significant differences between treatments can be distinguished by no overlap in confidence intervals.

Table 4 Total number of female fruit fly captured over a period of 12 weeks.

Trapping system	Total number of female fruit fly captured						
	C. capitata	*C. cosyra*	*C. rosa*	*C. quinaria*	*B. dorsalis*	*Perilampsis* spp.	Total
3CL	3 (15.00%)	2 (6.90%)	9 (8.91%)	-	1 (12.50%)	-	15 (9.32%)
BFF	16 (80.00%)	22 (75.86%)	78 (77.23%)	-	3 (37.50%)	-	119 (73.91%)
CME	-	-	-	-	-	-	-
EGO	-	1 (3.45%)	-	-	-	-	1 (0.62%)
EGO ND	-	-	-	-	-	-	-
EGO + P ND	-	-	-	-	-	-	-
IL	-	-	-	-	-	-	-
ME	-	-	-	-	-	-	-
ME + EGO ND	-	-	1 (0.99%)	2 (100%)	-	-	3 (1.86%)
ME + EGO + P ND	-	1 (3.45%)	-	-	-	-	1 (0.62%)
ME ND	-	-	-	-	-	-	-
ME + P ND	-	-	-	-	-	-	-
TYP	1 (5.00%)	3 (10.34%)	13 (12.87%)		5 (62.50%)	-	22 (13.66%)
Total	20 (100%)	29 (100%)	101 (100%)	2 (100%)	9 (100%)		161 (100%)

All the traps were re-baited after six weeks; the values given in brackets are the percentage of the total catch data for the respective species; -: indicated zero trap catches.

B. dorsalis trap catches (calculated over six weeks) with the average number of *B. dorsalis* caught per trap per week corrected for the loading rate of the methyl eugenol. The results showed that the new device containing ME + EGO + Permethrin performed the best in terms of the corrected average value (Fig. 3).

There was a significant effect of trapping system on non-target catches (χ^2 = 236.09, df = 12, P < 0.001). The numbers of non-target insects and Arachnida captured with the different monitoring systems over the total experimental period are given in Table 5. Of all the non-target species, Diptera was especially attracted to the different monitoring systems. The three food baits attracted the highest number of non-target

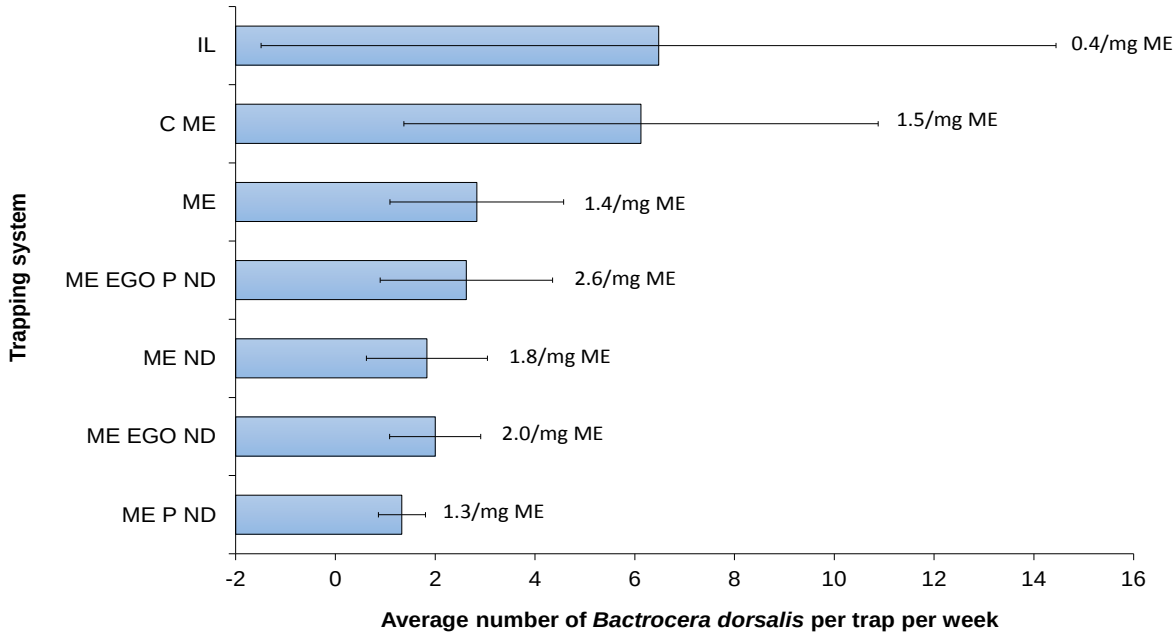

Fig. 3 The average number of *Bactrocera dorsalis* caught per trap per week and the standard deviation of the trap catches over the final six weeks of trapping.

The number of flies trapped per week per mg methyl eugenol is given next to the graph for every trapping system.

Table 5 Total number of non-target insect captured over a period of 12 weeks.

Trapping system	Total number of non-target insect captured				
	Diptera	*Hymenoptera*	*Lepidoptera*	Other	Total
3CL	1,018 (14.88%)	135 (10.45%)	8 (8.79%)	20 (5.15%)	1,181 (13.72%)
BFF	1,291 (18.87%)	153 (11.84%)	8 (8.79%)	49 (12.63%)	1,501 (17.43%)
CME	458 (6.7%)	42 (3.25%)	0 (0.00%)	36 (9.28%)	536 (6.22%)
EGO	100 (1.46%)	52 (4.02%)	1 (1.10%)	22 (5.67%)	175 (2.03%)
EGO ND	97 (1.42%)	98 (7.59%)	0 (0.00%)	24 (6.19%)	219 (2.54%)
EGO + P ND	87 (1.27%)	79 (6.11%)	2 (2.20%)	32 (8.25%)	200 (2.32%)
IL	61 (0.89%)	13 (1.01%)	1 (1.10%)	15 (3.87%)	90 (1.05%)
ME	359 (5.25%)	99 (7.66%)	6 (6.59%)	26 (6.7%)	490 (5.69%)
ME + EGO ND	95 (1.39%)	37 (2.86%)	0 (0.00%)	30 (7.73%)	162 (1.88%)
ME + EGO + P ND	151 (2.21%)	66 (5.11%)	2 (2.20%)	25 (6.44%)	244 (2.83%)
ME ND	257 (3.76%)	58 (4.49%)	8 (8.79%)	34 (8.76%)	357 (4.15%)
ME + P ND	359 (5.25%)	52 (4.02%)	6 (6.59%)	37 (9.54%)	454 (5.27%)
TYP	2,507 (36.65%)	408 (31.58%)	49 (53.85%)	38 (9.79%)	3,002 (34.86%)
Total	6,840 (100%)	1,292 (100%)	91 (100%)	388 (100%)	8,611 (100%)

All the traps were re-baited after six weeks; other non-target insect catches include the orders: Blattodea, Colleoptera, Hemiptera, Isoptera, Neuroptera, Orthoptera and Thysanoptera and the class Arachnida.

Table 6 The non-parametric (generalized linear model with Poisson distribution of errors and log link function) statistics for the effects of monitoring system and species on the count data outcomes for calendar weeks 5-7.

Sex of fruit flies	Parameter tested	χ^2	df	*P* value
Male	Monitoring system	155.42	12	< 0.001
	Species	450.65	4	< 0.001
	Monitoring system × species	126.81	19	< 0.001
Female	Monitoring system	5.29	2	0.071
	Species	12.40	3	0.006
	Monitoring system × species	7.77	4	0.103

χ^2: the Chi-square value; df: degrees of freedom.

species and Torula yeast pellets attracted 34.86% of total non-target species captured. Invader-lure attracted the lowest number of non-target species, followed by ME Pherolure + EGO Pherolure (new device). The non-parametric statistics for the effects of monitoring system and species on the count data outcomes for calendar weeks 5-7 were summarized in Table 6. There were significant differences for male fruit flies in the parameters monitoring system and species.

4. Discussion

Fruit fly numbers were low during the first six weeks of monitoring, and started to increase in the second six weeks of monitoring, i.e., calendar weeks 1-7 (Fig. 1). There was especially a rapid increase during calendar week 4 of 2014, and this rapid increase can be attributed to fruit maturity and the lack of orchard sanitation (Fig. 1). The invasive species, *B. dorsalis* was present and it is evident that this species is becoming more prominent in mango orchards in South Africa. The highest number of *B. dorsalis* males (151 males) was present in Invader-lure, followed by Chempac ME lure (98 males) and then ME Pherolure (51 males). The high capture rates with the Invader-lure system were probably due to the much higher concentration of methyl eugenol in this system (15 g vs. 1-4 g in the other methyl eugenol-containing systems). This monitoring system also attracted the least non-target species. ME Pherolure + EGO Pherolure (new device), ME Pherolure + EGO Pherolure + Permethrin (new device), ME Pherolure (new device) and ME Pherolure + Permethrin (new device) were lesser effective in capturing *B. dorsalis* males. Although EGO Pheroluredid not capture any *B. dorsalis*, EGO Pherolure (new device) and EGO Pherolure + Permethrin (new device) captured nine and eight *B. dorsalis* males, respectively. These findings are in accordance with Mwatawala et al. [21], who also reported a low response to enrich ginger oil-containing products.

EGO Pherolure was very effective in attracting males of *C. capitata*, *C. cosyra* and *C. rosa*. Only one *C. cosyra* female was captured in EGO Pherolure, indicating that it is a male lure. *C. quinaria* was also trapped in EGO-containing products. EGO Pherolure (new device) and EGO Pherolure + Permethrin (new device) were lesser effective in attraction of the *Ceratitis* spp., compared to EGO Pherolure which is probably due to a lower concentration of α-copaene. ME Pherolure + EGO Pherolure (new device) and ME Pherolure + EGO Pherolure + Permethrin (new device) were not as effective as EGO Pherolure (new device) and EGO Pherolure + Permethrin (new device) in attracting *Ceratitis* spp.

5. Conclusions

The presence of *B. dorsalis* in fruit production areas of South Africa has serious implications for the fruit industries. It is therefore important to develop an effective management strategy for fruit flies in this country. Statistical analyses of the results showed a significant effect for the monitoring systems on different fruit fly species. The results suggested that however some trapping systems performed well, there was not a single trapping system adequate for trapping *Ceratitis* spp., and *B. dorsalis* simultaneously. The

EGO Pherolure™ captured 33.77% of all the *Ceratitis* spp., while the Invader-lure™ captured 36.47% of all *B. dorsalis* catches. The food bait Biolure fruit fly attracted the highest number of female fruit flies. Torula yeast pellets attracted the highest number of *B. dorsalis* females and most non-target species. *B. dorsalis* females were rather trapped with 3-component lure, Biolure fruit fly and Torula yeast pellets, but only nine females were captured in total. This study clearly indicates that male lures are much more effective in attracting fruit fly species in comparison with food baits. Food baits attracted the highest number of female fruit flies. Food baits also attracted much higher numbers of non-target species. These results are important and significant for on-farm monitoring strategies as well as for invasion monitoring systems currently in place to detect the distribution of *B. dorsalis* in South Africa.

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