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SHORT COMMUNICATION

Field evaluation of the relative attractiveness of enriched ginger root oil (EGO)lure and trimedlure for African *Ceratitis* species (Diptera: Tephritidae)

M. Mwatawala[1], M. Virgilio[2,3], S. Quilici[4], M. Dominic[1] & M. De Meyer[2]

1 Department of Crop Sciences and Production, Sokoine University of Agriculture Morogoro, Tanzania

2 Entomology Section, Royal Museum for Central Africa Tervuren, Belgium

3 Department of Recent Invertebrates, Royal Belgian Institute of Natural Sciences Brussels, Belgium

4 UMR C53 PVBMT CIRAD-Université de La Réunion CIRAD Pôle de Protection des Plantes Saint-Pierre, La Réunion

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Correspondence

Marc De Meyer (corresponding author), Entomology Section, Royal Museum for Central Africa, Leuvensesteenweg 13, B3080 Tervuren, Belgium.

E-mail: demeyer@africamuseum.be

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Abstract

The males of some fruit flies (Diptera: Tephritidae) are known to be attracted to specific parapheromones. The trapping results between trimedlure (TML) and enriched ginger root oil (EGOlure) were compared at two experimental sites in Morogoro (Central Tanzania) for a period of 12 weeks co-inciding with the main citrus season. Both attractants captured a comparable diversity of fruit flies, except that EGOlure also attracted fruit flies, such as *Ceratitis cosyra*, not normally found in TML-baited traps. Both EGOlure and TML attracted mainly or exclusively male fruit flies, but the catches with EGOlure were equal or superior to those with TML. It is concluded that EGOlure should be considered as a suitable alternative for TML in detection, monitoring and control programs for African fruit flies of the genus *Ceratitis*. It has the added advantage that it combines the attractiveness with regard to species spectrum of both TML and terpinyl acetate.

Introduction

Some male Tephritidae are attracted to specific chemicals, often called parapheromones (Cunningham 1989). The biological significance has been established for a limited number of attractants (Tan and Nishida 1998), while for the majority it remains unknown. New and potentially more powerful components are continuously sought and tested. It has been noted that essential oils of plant species can act as attractants. One such component, alpha-copaene, was reported to attract males of *Ceratitis capitata* (medfly, Fornasiero et al. 1969). Its commercial use was hampered by expensive and impractical extraction procedures but ginger root (*Zingiber officinalis* Roscoe) oil has been shown to be an inexpensive alternative source of alpha-copaene (Shelly and Pahio 2002). Recently, it proved to be a male enhancing component because exposure to its aroma increases the mating success of sterile male medflies (Shelly 2001; Shelly et al. 2004) and is now applied as aromatherapy to increase the competitiveness of sterile males in SIT (Shelly et al. 2007; Steiner et al. 2011). It also increases the competitiveness of male Natal fruit flies, *Ceratitis rosa* (Quilici et al. 2011). Some commercial sources of ginger root oil are called 'enriched ginger oil' (EGO), referring to oil for which the concentration of alpha-copaene has been increased (Shelly and Pahio 2002). Reports on the effectiveness of ginger root oil or EGO are, however, contradictory: Cunningham (1989) refers to field tests where alpha-copaene was shown to be 2–5 times more attractive for male medflies than trimedlure (TML), while Shelly and Pahio (2002) concluded that TML-baited traps were more attractive than EGO-baited traps. No information is available on the taxon spectrum that responds to this particular attractant. In Africa, there are several *Ceratitis* species of economic significance. Studies in this region looking at the relative attractiveness of different lures (Grout et al. 2011; Virgilio et al. 2011) have not included sources of alpha-copaene. The purpose of this study is, therefore, to (i) explore the effectiveness of EGO with regard to taxon range attractiveness, (ii) compare the relative attractiveness of EGO with TML and (iii) compare its attractiveness for both sexes of target species.

Material and Methods

Experiments were conducted in Morogoro (Central-East Tanzania), one of the major horticultural areas in Tanzania and situated in the transition zone between the bimodal and unimodal rainfall belts (Mwatawala et al. 2009). Two experimental sites, 7.5 km apart but in the same agro-ecological zone (Plateau zone, United Republic of Tanzania (URT) 2002), were selected. One is the horticulture unit of the Sokoine University of Agriculture (SUA, 06°50′S-037°35′E, 520 masl). This is a 15 ha research, and semi-commercial orchard dominated by stands of mango, and various citrus with a variety of other commercial crops (details in Mwatawala et al. 2006a). The second is a 4 ha orchard, dominated by citrus trees (mainly orange) with a few mango trees, at Mzinga (06°53′27.6″S-037°36′44.5″E, 516 masl).

At each site, five 'Tephri traps' (Sorygar Ltd, Madrid, Spain) baited with trimedlure and five with EGO were interspersed on orange trees, one of the primary hosts for medfly. Traps at each site were placed in a range of approximately 500 m. Commercially available lures were used: trimedlure (IPS, Ellesmere Port, UK) and EGOlure (Insect Science, Pretoria, South Africa). The concentration of alpha-copaene in EGOlure was not disclosed by the manufacturer, but supposedly is higher than in the commercially available oil. All traps were fitted with DDVP insecticide strips (IPS). Traps were operated for 12 weeks (5 April –28 June 2011), co-inciding with the main fruiting season of citrus hosts in this region (Mwatawala et al. 2006b). Specimens were removed weekly, and

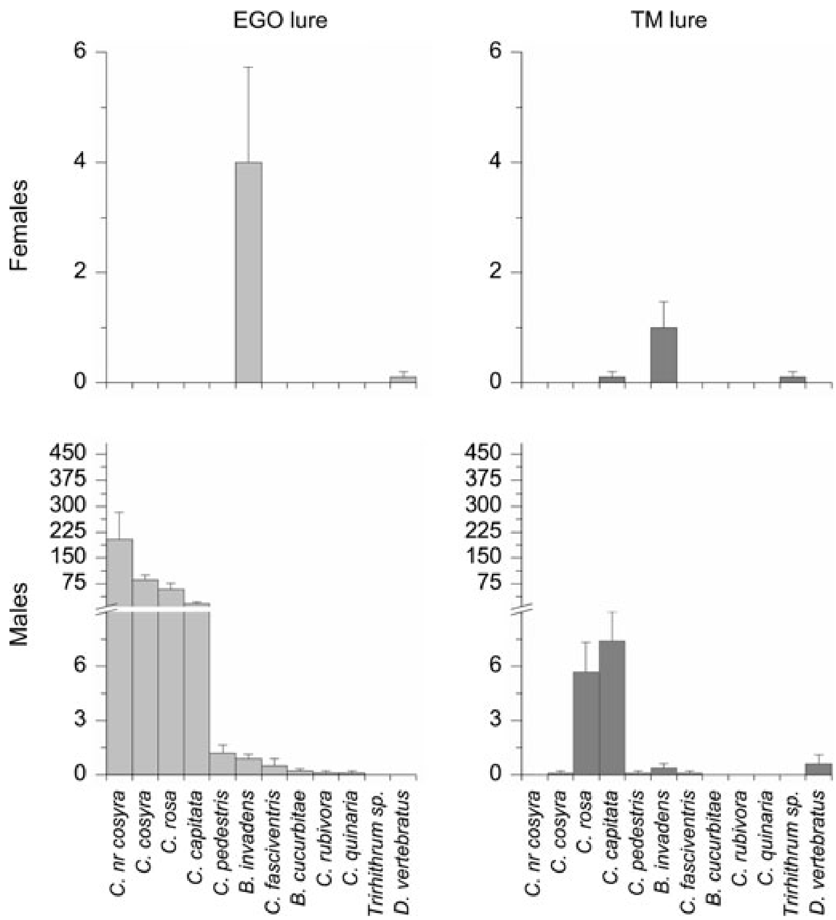

Fig. 1 Total number of fruit flies trapped at Morogoro (Tanzania) using Tephri traps baited with EGOlure and trimedlure during 5 April–28 June 2011 (10 traps for each lure; total capture 3877 specimens; data averaged across sites, standard errors are shown).

morphologically identified at SUA and the Royal Museum for Central Africa (Tervuren, BE). Lures and DDVP strips were replaced at weeks 5 and 9. Three traps without attractant but with a DDVP strip were placed at each of the two sites as a control treatment to evaluate the possible attraction effects of trap shape and colour.

The total abundances of tephritid species as well as of the total number of specimens and species were separately quantified for male and female specimens. Differences in abundances of males were tested using ANOVA with Lure (two levels) as fixed factor and Location (two levels) as random factor orthogonal to Lure. Replicates (n = 5 in each combination of Lure and Location) were represented by the total number of specimens collected in each trap at the end of the 12 weeks sampling. Cochran's *C* tests were used to verify the homogeneity of variances (in all cases reached after fourth root transforming the data) and Student-Newman-Keuls (SNK) tests for *a posteriori* comparisons of means (Sokal and Rohlf 1995).

Results

The weekly catches at SUA and Mzinga for both lures are shown in Supplementary Material. The control traps did not capture any flies at either site and were not further considered.

Overall, 3824 male and 53 female specimens were collected. The total number of male specimens was significantly higher in EGO lure traps (96.0% of males) compared to TML (4.0%), with more pronounced differences in SUA (table 1, Supplementary Material). The most abundant of the 12 tephritid species collected included a hitherto unknown species (hereafter named *Ceratitis* sp. nr *cosyra*) and *C. cosyra*, *C. rosa* and *C. capitata*. Other and less abundant species were *C. pedestris*, *Bactrocera invadens*, *Dacus vertebratus*, *C. fasciventris*, *B. cucurbitae*, *C. rubivora*, *C. quinaria* and *Tririthrum coffeae* (fig. 1).

Trimedlure traps collected eight different taxa while EGOlure 11. Overall, nine species were collected at Mzinga and 10 at SUA. ANOVA did not show significant

Table 1 ANOVAS and *a posteriori* comparisons testing differences in abundances of male specimens between attractants (EGO lure vs. TM lure) and locations (Mzinga vs. SUA)

	Effect	d.f.	MS	F	*a posteriori* comparisons (SNK test)	
Total no. of specimens	Lure (Lu)	1	24.69	8.44		
Cochran's *C* = 0.39; n.s.	Location (Lo)	1	3.863	15.98**		
	Lu × Lo	1	2.924	12.09**	Mzinga: EGO > TM	SUA: EGO > TM
	Residual	16				
Total no. of species	Lure (Lu)	1	0.397	41.04		
Cochran's *C* = 0.56; n.s.	Location (Lo)	1	0.003	0.29		
	Lu × Lo	1	0.010	0.85		
	Residual	16	0.011			
Ceratitis nr cosyra	Lure (Lu)	1	36.256	2.57		
Cochran's *C* = 0.54; n.s.	Location (Lo)	1	14.091	70.79***		
	Lu × Lo	1	14.091	70.79***	Mzinga: EGO > TM	SUA: EGO > TM
	Residual	16	0.199			
Ceratitis cosyra	Lure (Lu)	1	40.171	10337.23**	EGO > TM	
Cochran's *C* = 0.55; n.s.	Location (Lo)	1	0.260	1.39		
	Lu × Lo	1	0.004	0.02		
	Residual	16	0.187			
Ceratitis rosa	Lure (Lu)	1	8.033	221.70*	EGO > TM	
Cochran's *C* = 0.46; n.s.	Location (Lo)	1	1.879	7.46*	SUA > Mzinga	
	Lu × Lo	1	0.036	0.14		
	Residual	16	0.252			
Ceratitis capitata	Lure (Lu)	1	0.505	29.89		
Cochran's *C* = 0.50; n.s.	Location (Lo)	1	0.591	1.28		
	Lu × Lo	1	0.017	0.04		
	Residual	16	0.460			

Homogeneity of variances was verified using Cochran's *C* tests after fourth root transformation of the data (see Underwood 1997).
d.f., degrees of freedom; EGO, enriched ginger root oil; TM, trimedlure; MS, mean square estimates; n.s., not significant at $P < 0.05$.
***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

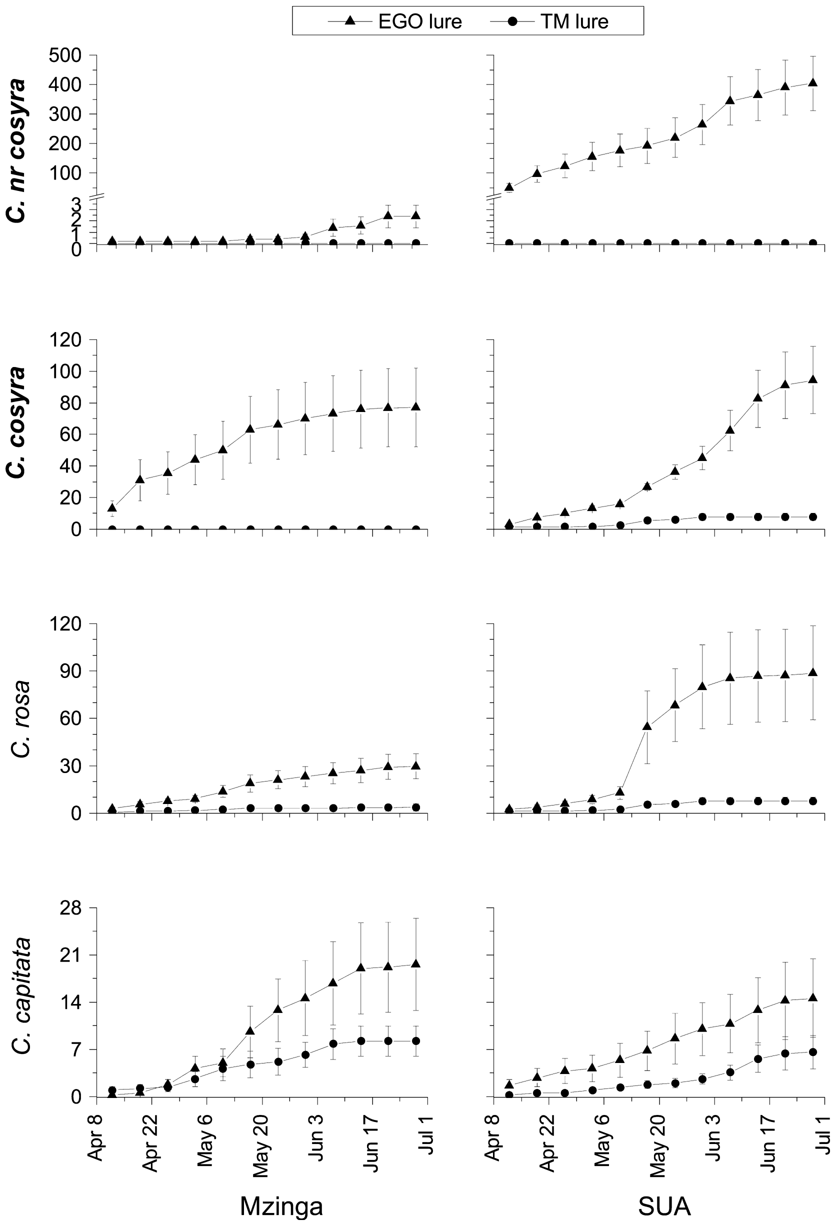

Fig. 2 Cumulative number of male specimens trapped at two sites (Mzinga and Sokoine University Horticultural Unit, both in Morogoro, Tanzania) using Tephri traps, for the four most abundant fruit fly species (data averaged across traps, standard errors are shown).

differences in the number of species trapped either by different lures or at the two sites (table 1). Three of the four abundant species (table 1; fig. 2) showed significant differences in the amount of males trapped by the two lures. For *C. cosyra* and *C. rosa* the effects of lures were consistent between locations, with EGO-lure attracting a significantly higher amount of males. Similarly, EGOlure attracted a significantly higher number of *C.* sp. nr *cosyra* males, yet their abundance was more pronounced at SUA. At both sites, EGOlure attracted higher amounts of *C. capitata* males but these differences were not statistically significant. Fifty of the 53 female specimens were represented by *B. invadens* (fig. 1, Supplementary Material). These were mostly collected at SUA (92% of *B. invadens* females) in EGO lure traps (82% of them).

Discussion

Trimedlure is an effective lure for surveying and monitoring activities for male medflies (Anon 2006; Grout et al. 2011). Also other *Ceratitis* species are known to be attracted to it, such as representatives of the *Ceratitis* FAR complex (Virgilio et al. 2008) including *C. rosa*. Our study shows that EGOlure is a significantly stronger attractant for the male *C. rosa*. For medfly also, a higher number of males were attracted but the difference with TML was not statistically significant. For other species previously reported from TML (*C. fasciventris*, *C. pedestris*), the numbers captured in this study are too limited for comparison.

Ceratitis cosyra males are not attracted to TML but to terpinyl acetate (White and Elson-Harris 1994). The latter is known to attract a number of other species of the subgenus *Ceratitis* (*Ceratalaspis*). This study shows that *C. cosyra* is also strongly attracted to EGOlure. However, as terpinyl acetate was not included in this study, we cannot establish whether EGOlure is a stronger attractant. Remarkable however is the abundant presence of a hitherto unknown *Ceratitis* sp. nr *cosyra* attracted to EGOlure.

The attractiveness of EGOlure for *B. invadens*, the predominant species in the area (Mwatawala et al. 2006a), is unexpected and worthy of further investigation. Methyl eugenol is the traditional male attractant for this species and although no comparison was made during this study, the number trapped with ME in similar experiments at SUA site is generally much higher (Mwatawala et al. 2006b). Interference because of the colour or shape of the trap can be excluded because none of the controls collected any fly. Additionally, pheromone contamination seems implausible as both male and female specimens were interspersed across a large proportion of traps (48%).

In general, EGOlure is a better attractant than TML for *C. rosa* males. It could be considered as an alternative lure for *C. capitata*. In addition, it can be used for attracting *C. cosyra* males and related species. Its role as a valuable alternative for terpinyl acetate seems probable but more comparative studies are needed. EGOlure provides the advantage that it combines the attracting power of both lures.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Total number of specimens trapped during each of the 12 weeks of sampling (April 5th – June 28th, 2011) with trimedlure (TML) and enriched ginger root oil lure (EGO) at Sokoine University of Agriculture (SUA) and Mzinga sites, during 12 weeks.