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Insights into the use of a mass trapping strategy to control fruit fly populations (Diptera: Tephritidae) in Guatemala: a study case in a citrus growing-area

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Abstract

Mass trapping is a control method for fruit fly pests (Diptera: Tephritidae) in fruit-growing areas. This study aimed at providing information on the use of mass trapping using Cera Trap® to control fruit fly pests in a citrus-growing area in Guatemala. We analyzed the "flies per number of traps × exposure d" index and sex ratios of fly populations based on 3 trapping types: a mass trapping network, a monitoring trap in the center of a plot involving mass trapping, and another trap installed in a plot without mass trapping. Sex ratios within and between trapping types, as well as the flies per number of traps × exposure d between trapping types were compared. Eleven fruit fly species were identified, and 4 of them were used in the analysis: *Anastrepha ludens* (Loew), *Anastrepha distincta* (Greene), *Anastrepha serpentina* (Wiedemann), and *Ceratitis capitata* Wiedemann (all Diptera: Tephritidae). No differences in the sex ratio were observed between the trapping types, but it was female-biased within mass trapping. A negative effect of mass trapping on the flies per number of traps × exposure d of pest populations was noted. We discussed the use of mass trapping highlighting citrus agroecosystems as a shelter for fruit fly communities including pest species. Further research on agroecological variables and their effect on the mass trapping strategy is suggested.

Key Words: *Anastrepha ludens*; *Ceratitis capitata*; Cera Trap®; flies per number of traps × exposure d; pest; trap

Resumen

El trampeo masivo es un método de control para plagas de moscas de la fruta (Diptera: Tephritidae) en áreas frutícolas. Este estudio tuvo como objetivo proveer información sobre el uso del trampeo masivo con Cera Trap® para el control de plagas de moscas de la fruta en áreas citrícolas de Guatemala. Se analizó el índice de "moscas por número de trampas × días de exposición" and la proporción de sexo de las poblaciones de mosca basados en 3 tipos de trampeo: una red de trampeo masivo, una trampa de monitoreo en el centro del sitio involucrando el trampeo masivo, y otra trampa instalada en otro sitio sin trampeo masivo. Se comparó las proporciones de sexo dentro y entre los tipos de trampeo, así como las moscas por número de trampas × exposición dia entre los tipos de trampeo. Once especies de moscas de la fruta fueron identificadas, y 4 de ellas fueron utilzadas en el análisis: *Anastrepha ludens* (Loew), *Anastrepha distincta* (Greene), *Anastrepha serpentina* (Wiedemann), and *Ceratitis capitata* Wiedemann (todos Diptera: Tephritidae). No se observaron diferencias en la proporción de sexo entre los tipos de trampeo, sin embargo, hubo un sesgo hacia las hembras dentro del trampeo masivo. Se determinó un efecto negativo del trampeo masivo sobre las moscas por número de trampas × exposición dia. Se discute el uso del trampeo masivo destacando los agroecosistemas citrícolas como refugio de comunidades de moscas de la fruta incluyendo las especies plaga. Se sugiere mayor investigación sobre variables agroecológicas y su efecto en la estrategia de trampeo masivo.

Key Words: *Anastrepha ludens*; *Ceratitis capitata*; Cera Trap®; moscas por número de trampas × exposición dia; parásito; trampa

Fruit flies (Diptera: Tephritidae) represent one of the most important pests of fruit crops worldwide. Species of the genera *Anastrepha* Schiner, *Bactrocera* Macquart, *Ceratitis* MacLeay, and *Rhagoletis* Loew (all Diptera: Tephritidae) are common pests associated with fruit crops of economic importance in the Americas (Norrbom 2004; Hernández-Ortiz et al. 2010). Suppression and control strategies of fruit fly populations rely on an area-wide integrated pest management approach focused on entire populations at a regional scale (Hendrichs et al. 2007; Klassen 2007). As such, the use of agrochemicals, release of sterile flies, and biological control strategies play a crucial role in the success of management programs, as noted for *Ceratitis capitata* Wiedemann and *Anastrepha ludens* (Loew) (both Diptera: Tephritidae) (Montoya et al. 2007; Gutiérrez 2010; Enkerlin et al. 2015).

Mass trapping is an environment-friendly strategy that is as effective as bait sprays to suppress *Anastrepha* spp. and *C. capitata* populations in fruit crops (Leza et al. 2008; Flores et al. 2017; Villalobos et al. 2017). However, such a strategy may be considered expensive for local growers or regional pest management programs because of the required trapping devices and the variability of recommended densities (from 50 up to 200 traps per ha for *C. capitata*) (Navarro-Llopis & Va-

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cas 2014). A cheaper alternative is the use of polyethylene terephthalate bottles (water or soft drink plastic bottles) baited with Cera Trap® (Bioiberica SA, Barcelona, Spain), a recognized attractant for pest species of Tephritidae (Lasa et al. 2014b, 2015; Villalobos et al. 2017).

In Guatemala, *A. ludens*, *Anastrepha obliqua* (Macquart) (Diptera: Tephritidae), *A. serpentina* (Wiedemann), *Anastrepha striata* Schiner (Diptera: Tephritidae), and *C. capitata* are pests of citrus (*Citrus* spp. L.; Rutaceae), mango (*Mangifera indica* L.; Anacardiaceae), sapote (*Pouteria* spp. Aublet; Sapotaceae), guavas (*Psidium guajaba* L.; Myrtaceae), and coffee (*Coffea arabica* L.; Rubiaceae), respectively (Hedström 1985; Eskafi & Cunningham 1987; Enkerlin et al. 2015). Such pest species are of quarantine importance worldwide affecting the commercialization of host fruits in free zones or other countries. For pest species such as *C. capitata*, combined efforts of the governments of Mexico, Guatemala, and the US are conducted to avoid the establishment of this exotic fly in fruit-growing areas of these countries (Enkerlin et al. 2015). Therefore, several field studies are focused on the effectiveness of lures, trapping devices, bait stations, and the release of sterile insects to control *C. capitata* and pest species of *Anastrepha* (Shelly et al. 2003; Martinez et al. 2007; Epsky et al. 2012; Cotoc-Roldán et al. 2021). However, to our knowledge, mass trapping as a control method of tephritid pests is not documented in Guatemala as in other countries such as Mexico and Spain (Leza et al. 2008; Lasa et al. 2014a, b; Navarro-Llopis et al. 2015; Flores et al. 2017; Bali et al. 2021; Elimem et al. 2021).

Citrus production in Guatemala is calculated at about 300,000 tons per yr (FAO 2021), which may be affected by fruit fly populations leading to the analysis of additional control methods under a pest management approach. This study provides evidence of the effect of mass trapping on pest species of fruit flies and its potential use as an alternative or additional control method in citrus orchards in Guatemala. Therefore, we aimed to provide data on mass trapping, its impact on suppressing pest species of fruit flies, and its role in detecting other fruit fly species in a citrus-growing area. Also, we discuss the practical implications of these findings in the context of pest management in the citrus agroecosystems of Guatemala.

Materials and Methods

STUDY SITE

The fieldwork was conducted in a mixed citrus orchard (about 50 ha, 290 masl) (14.167222°N, 90.369305°W) with sweet oranges (*Citrus sinensis* (L.) Osbeck; Rutaceae) and mandarin (*Citrus reticulata* Blanco; Rutaceae) in the municipality of Chiquimulilla, Santa Rosa, Guatemala (Fig. 1). The orchard is between 16 and 18 yr old, and shows a tree spacing of 6 m between every tree. The site is characterized by the absence of phytosanitary measures for control of tephritid pests and is considered a heterogeneous orchard because of uncultivated areas. An average temperature of 26 °C and annual precipitation of 2,200 mm are reported in the region. Moreover, the site is mainly surrounded by tropical vegetation characterized by plant species such as *Annona macroprophyllata* Donn. Sm. and *Annona muricata* L. (both Annonaceae), *Eriobotrya japonica* (Thunb.) Lindl. (Rosaceae), *Inga* spp. (Fabaceae), *M. indica*, *Passiflora ligularis* Juss. (Passifloraceae), *Pouteria* spp., *Syzygium samarangense* (Bl.) Merr. & L. M. Perry (Myrtaceae), *Spondias* spp. (Anacardiaceae), and *Tamarindus indica* L. (Fabaceae). Also, some coffee crops (*C. arabica*) were distinguished adjacent to the orchard.

FRUIT FLY TRAPPING

The study was conducted in the spring of 2021 from 28 Jan to 27 Apr, a period that covered the season of the yield of Valencia orange.

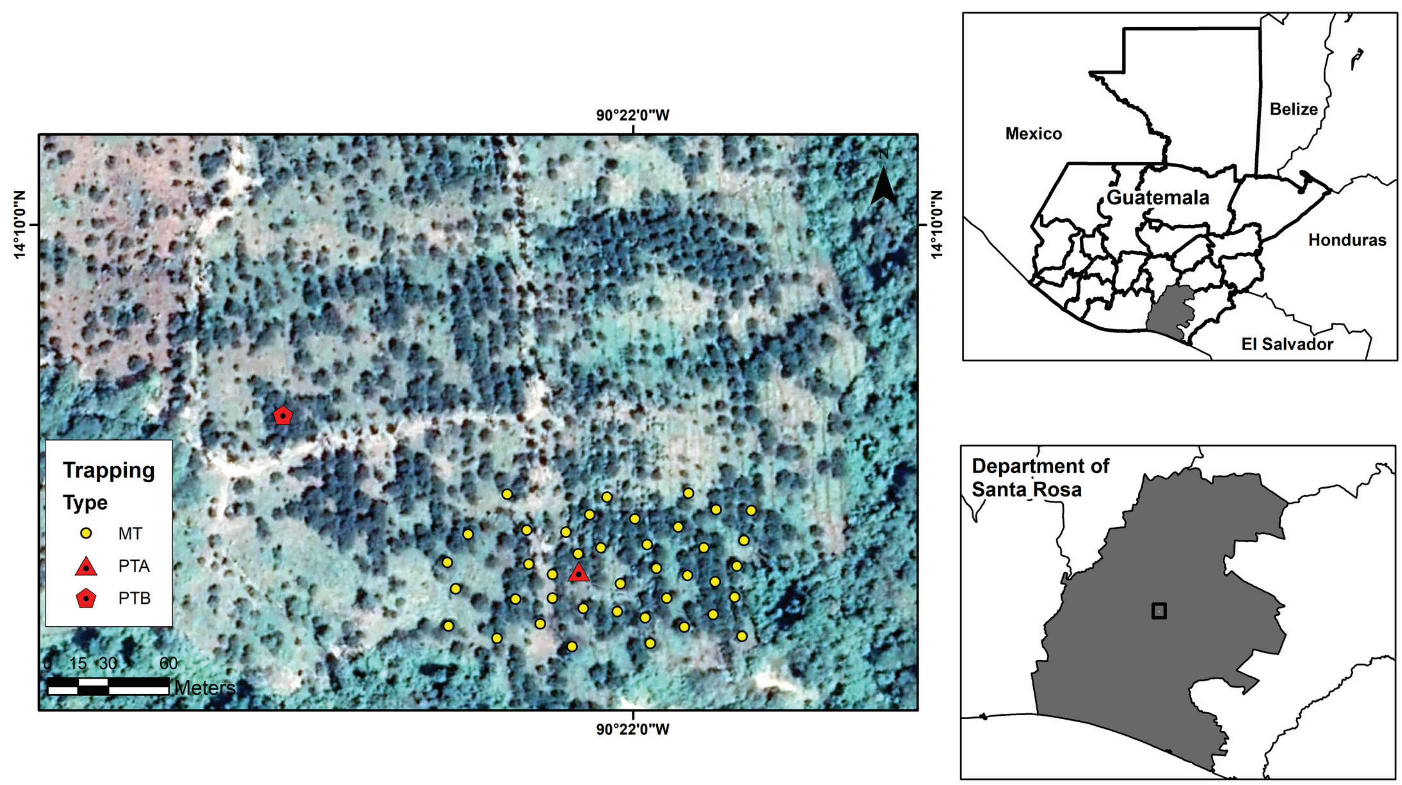

Fig. 1. Geographical location of the study site in the municipality of Chiquimulilla, Santa Rosa, Guatemala. MT = mass trapping; PTA = monitoring trapping under the influence of mass trapping; PTB = monitoring trapping without the influence of mass trapping.

We sampled adult fruit fly populations using 650 mL transparent bottles baited with 300 mL of enzymatically hydrolyzed protein Cera Trap® (Bioiberica SA, Barcelona, Spain). Cera Trap acts as a food attractant releasing volatile compounds (amines and organic acids) attractive for fruit fly populations, particularly females (Bioiberica 2022). Each bottle was modified by drilling four 5 mm diam holes, 5 cm apart, and 3/4 of the distance above the base (Fig. 2). The size of the holes aimed to minimize the capture of non-target insects.

Three types of trapping were established in the orchard: mass trapping in 40 evenly distributed bottles per ha. Each bottle was installed every 6 or 7 trees apart at a density of 277 trees per ha. For the flies per trap per d in this plot, a 1.5 L bottle baited with 500 mL of Cera Trap was installed as a monitoring trap in the center. Traps were placed using the IAEA (2013) theory that 1 trap per Km^2 may be used to measure fruit fly populations. This trap aimed to monitor the flies per trap per d using mass trapping. To compare the flies per trap per d between sites with or without mass trapping, another monitoring trap (bottle baited with 500 mL of Cera Trap) was placed in another plot without mass trapping in the same citrus orchard (Fig. 1). This trap allowed us to monitor the flies per trap per d populations without the influence of mass trapping. These 2 traps (bottle vs. bottle with Cera Trap) were placed at a distance about 180 m apart using the same agro-ecological conditions.

All polyethylene terephthalate traps were hung between 3 and 4 m above the ground within the canopy. We standardized the exposure of all traps to 5 revisions for the 3 types of trapping during the study period based on the field performance of Cera Trap, which can maintain its effectivity up to 3 mo under field conditions. The advantages of using Cera Trap under field conditions are discussed in Lasa et al. (2014b). Fly specimens were collected in vials with 70% alcohol and transported to the laboratory for taxonomic and sex identification at the State Committee of Plant Health of Chiapas facilities in Tuxtla Gutierrez, Chiapas, Mexico. Taxonomic identification of fruit fly specimens was conducted by Amablita Castillo Estudillo in Tuxtla Gutierrez, Chiapas, Mexico. Fly captures were transformed into flies per trap per d values using the formula: total number of captured flies divided by number of inspected traps (average number of d of trap exposure). This phytosanitary index is a comparative measure of the population density of adult fruit flies in a given space and time, allowing the variability in trap number or capture periods to be standardized (IAEA 2013). The flies per trap per d of mass trapping was obtained by averaging flies per trap per d values of traps by each revision. This standardization allowed for a comparison of the population density of fruit flies between monitoring trapping under the influence of mass trapping, 1.5 L bottle baited with 500 mL of Cera Trap, and mass trapping.

DATA ANALYSIS

Statistical analysis was focused on the fly species reported in the 3 types of trapping. We applied an exact binomial test to compare the sex ratio (50:50) of fruit fly capture within each type of trapping. A constant of 1 was added to the specimen counts ($x + 1$) to avoid zeros in the flies per trap per d data. Statistical analyses were based on the natural log of the flies per trap per d, which allowed rescaling the observations and stabilizing the variance. Linear mixed models were used to compare the flies per trap per d (response variable) of fruit fly species between monitoring trapping under the influence of mass trapping, 1.5 L bottle baited with 500 mL of Cera Trap, and mass trapping (categorical variables).

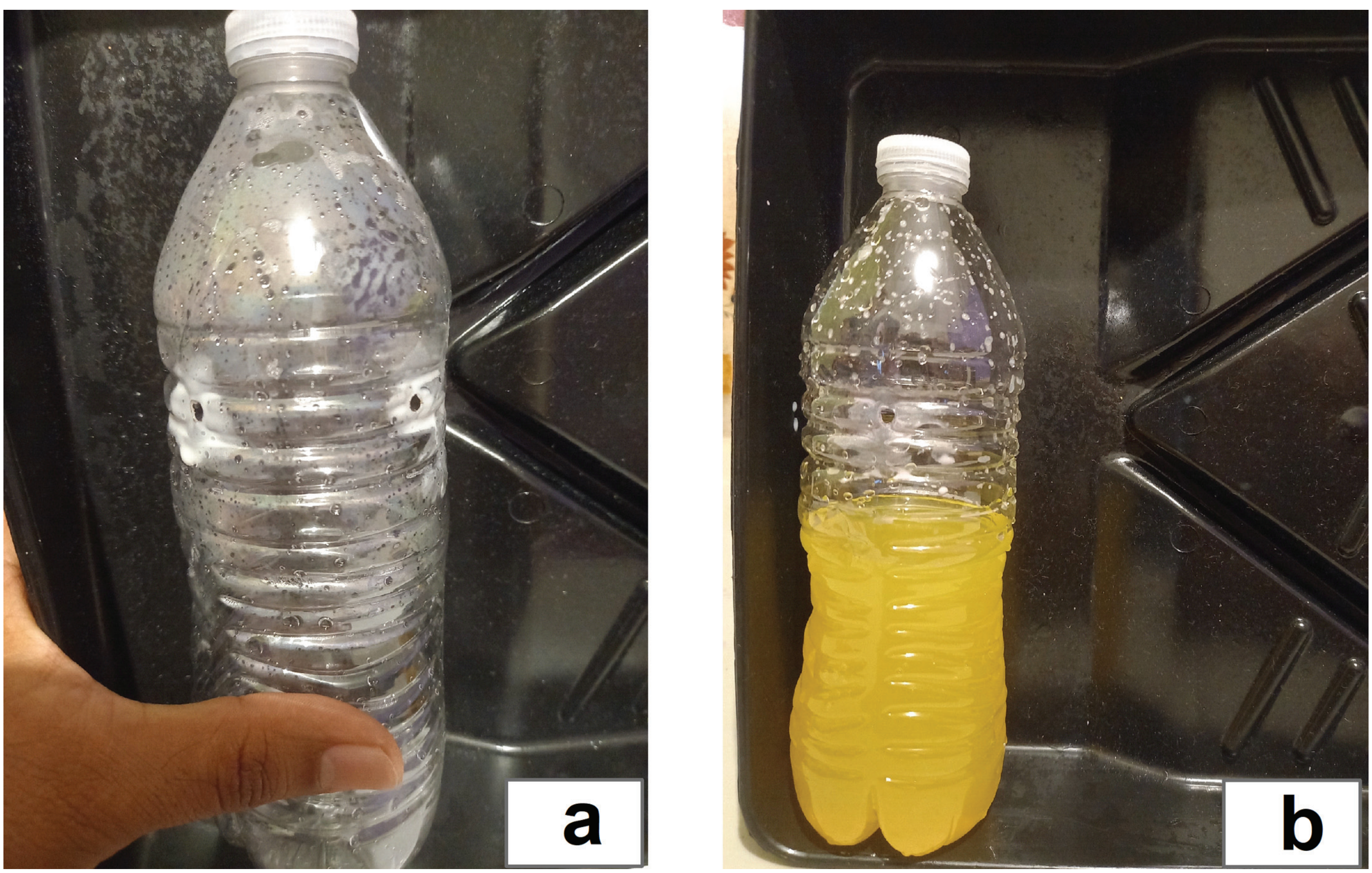

Fig. 2. Polyethylene bottles with 5 mm holes (a) baited with Cera Trap® (b).

Count data of females and males of fly species were treated as proportions in the study. For each fly species, sex proportions between monitoring trapping under the influence of mass trapping, 1.5 L bottle baited with 500 mL of Cera Trap, and mass trapping were compared by performing generalized linear mixed models using a binomial distribution. The number of revisions of traps was introduced as random effects into the linear mixed models and general linear mixed models to deal with pseudoreplication and correlated data (Bolker et al. 2009; Harrison 2014). Comparisons between means of the trapping types were performed via Helmert contrasts, placing the monitoring trapping under the influence of mass trapping as the first level, followed by 1.5 L bottle baited with 500 mL of Cera Trap, and mass trapping as the third level. Linear mixed models and generalized linear mixed models were performed in R (R Core Team 2018) using the lm4 package (Bates et al. 2015). Approximations for the degrees of freedom of linear mixed models were computed using the lmerTest package via Satterthwaite's method (Kuznetsova et al. 2017).

Results

A total of 463 specimens were collected during the fieldwork, distributed in 11 fruit fly species. *Anastrepha* was the most abundant genus, with 10 species: *Anastrepha alveata* Stone, *Anastrepha chiclayae* Greene, *A. distincta*, *Anastrepha fraterculus* (Wiedemann), *A. ludens*, *A. obliqua*, *A. serpentina*, *Anastrepha robusta* Greene, *Anastrepha spatulata* Stone, and *A. striata* (all Diptera: Tephritidae). Moreover, the genus *Ceratitis* was represented by *C. capitata*. The most abundant species were *A. ludens* (34%), followed by *A. distincta* (33%), *A. serpentina* (14%), *A. chiclayae* (8%), *A. fraterculus* (4%), *A. alveata* (2%). The remaining species represented < 1% each. Flies per trap per d and sex proportion analyses were based on *A. ludens*, *A. distincta*, *A. serpentina*, and *C. capitata* that were captured in the 3 trapping types.

The highest flies per trap per d records were registered by *A. ludens* and *A. distincta* populations, whereas the lowest flies per trap per d levels were associated with *A. serpentina* and *C. capitata* populations. Information on flies per trap per d data of females and males based on the type of trapping is summarized in Table 1. Regarding sex ratios (50:50) within trapping types, in mass trapping only were significant differences noted for *A. distincta*, *A. serpentina*, and *C. capitata* (Table 2). Table 2 shows the results of the exact binomial test on sex ratios of fly species according to the trapping type.

According to fitted generalized linear mixed models for sex ratios, no significant differences were noted between monitoring trapping under the influence of mass trapping, 1.5 L bottle baited with 500 mL of Cera Trap, and mass trapping for *C. capitata* (χ^2 = 1.163; *df* = 2; *P* = 0.5589), *A. ludens* (χ^2 = 1.057; *df* = 2; *P* = 0.589), *A. serpentina* (χ^2 = 0.247; *df* = 2; *P* = 0.8838), and *A. distincta* (χ^2 = 2.068; *df* = 2; *P* = 0.355) However, fitted linear mixed models revealed a significant effect ($P < 0.05$) of the trapping type on the flies per trap per d index for each fruit fly species (Table 3). Based on Helmert contrasts, monitoring trapping under the influence of mass trapping and 1.5 L bottle baited with 500 mL of Cera Trap were not different, but the flies per trap per d of mass trapping was significantly different from monitoring trapping under the influence of mass trapping and 1.5 L bottle baited with 500 mL of Cera Trap. Fitted models for mass trapping showed negative coefficients, which indicates a significant negative trend of the flies per trap per dregarding monitoring trapping under the influence of mass trapping and 1.5 L bottle baited with 500 mL of Cera Trap. Also, the same effect was noted when the flies per trap per d was assessed by gender (Table 3).

Discussion

Mass trapping revealed a significant lowering trend of flies per trap per d levels for pest species in citrus orchards such as *A. ludens* and *C. capitata* suggesting that it is a useful method for suppressing tephritid pests in Guatemala. The use of bottle traps baited with Cera Trap in a mass trapping strategy instead of commercial traps is a cheaper option as a phytosanitary measure for control of fruit fly pests in the region. Mass trapping may be an alternative to prevent high levels of adult populations of *A. ludens* and *C. capitata* in citrus orchards. Also, it provided information about fruit fly species assemblages associated with citrus crops.

Anastrepha ludens was the dominant pest species over *C. capitata* in the citrus orchard, which was recognized by Eskafi (1988) and Eskafi and Kolbe (1990) in tropical areas of Guatemala. The comparison of the flies per trap per d index and captured adults of *A. ludens* between mass trapping at a density of 40 traps per ha and monitoring traps (monitoring trapping under the influence of mass trapping and 1.5 L bottle baited with 500 mL of Cera Trap) showed an impact of mass trapping on *A. ludens* and *C. capitata* population levels. According to Lasa et al. (2014b), bottles baited with Cera Trap at a similar density per ha are an inexpensive option for an mass trapping strategy for *A. ludens*

Table 1. Descriptive data of flies per trap per d of 4 fly species based on trapping type in a citrus orchard in Chiquimulilla, Santa Rosa, Guatemala. MT = mass trapping; PTA = monitoring trapping under the influence of mass trapping; PTB = monitoring trapping without the influence of mass trapping. SD = standard deviation.

Fly species	Type of trapping	Female flies per trap per d (mean ± SD)	Male flies per trap per d (mean ± SD)	Average flies per trap per d (mean ± SD)
Anastrepha ludens	PTA	0.0142 ± 0.03	0.0357 ± 0.04	0.0500 ± 0.07
	PTB	0.0414 ± 0.03	0.0571 ± 0.09	0.0986 ± 0.13
	MT	0.0132 ± 0.01	0.0106 ± 0.00	0.0239 ± 0.02
Anastrepha distincta	PTA	0.0557 ± 0.07	0.0371 ± 0.04	0.0929 ± 0.11
	PTB	0.0271 ± 0.03	0.0414 ± 0.04	0.0686 ± 0.07
	MT	0.0125 ± 0.01	0.0078 ± 0.00	0.0202 ± 0.02
Anastrepha serpentina	PTA	0.0125 ± 0.03	0.0000 ± 0.00	0.0143 ± 0.03
	PTB	0.0129 ± 0.02	0.0000 ± 0.00	0.0129 ± 0.02
	MT	0.0143 ± 0.01	0.0031 ± 0.00	0.0108 ± 0.01
Ceratitis capitata	PTA	0.0000 ± 0.00	0.0000 ± 0.00	0.0000 ± 0.00
	PTB	0.0057 ± 0.01	0.0000 ± 0.00	0.0057 ± 0.01
	MT	0.0019 ± 0.00	0.0006 ± 0.00	0.0025 ± 0.00

Table 2. Analysis of female:male ratios (50:50) of *Anastrepha distincta*, *Anastrepha ludens*, *Anastrepha serpentina*, and *Ceratitis capitata* within each trapping type in a citrus orchard in Chiquimulilla, Santa Rosa, Guatemala. MT = mass trapping; PTA = monitoring trapping under the influence of mass trapping; PTB = monitoring trapping without the influence of mass trapping.

Fly species	Trapping	Females	Males	Total	Sex ratio (F:M)	Confidence intervals	*p*-value
Anastrepha ludens	PTA	2	5	7	0.4	0.036 – 0.709	0.453
	PTB	6	8	14	0.8	0.176 – 0.711	0.790
	MT	75	61	136	1.2	0.463 – 0.636	0.264
Anastrepha distincta	PTA	9	6	15	1.5	0.322 – 0.836	0.607
	PTB	4	6	10	0.7	0.121 – 0.737	0.753
	MT	77	49	126	1.6	0.520 – 0.696	0.015*
Anastrepha serpentina	PTA	2	0	2	—	0.158 – 1	0.500
	PTB	2	0	2	—	0.158 – 1	0.500
	MT	44	18	62	2.4	0.580 – 0.818	0.001*
Ceratitis capitata	PTA	0	0	0	—	—	—
	PTB	1	0	1	—	0.025 – 1	1.000
	MT	12	4	16	3.0	0.476 – 0.927	0.076**

*Significant difference between sex ratios.
**Significant marginal difference between sex ratios ($p < 0.1$).

in Mexico. However, because of the presence of both *A. ludens* and *C. capitata* in the region, further research is required because similar trap densities (50 traps per ha) are complemented with bait sprays for the control of *C. capitata* populations (Leza et al. 2008; Lasa et al. 2014b). Likewise, the use of higher trap densities would be an appropriate method for organic management, but an impractical measure for traditional pest management in Guatemala given the material and human effort required. So, in our view, taking into account the phenology of the main citrus cultivars and historical records of *A. ludens* adults, a trap density of about 40 traps per ha baited with Cera Trap may be a summative strategy to prevent high infestation levels by this pest.

Low flies per trap per d levels of *C. capitata* in monitoring traps and mass trapping indicated low adult populations during this season (Feb–Apr). This flies per trap per d behavior likely is associated with the fact that sweet citrus varieties (mandarins or oranges) are alternative hosts of *C. capitata* in the lowlands. It is reported that the highest infestations by *C. capitata* occur at higher altitudes linked to larger areas of coffee plantations (Eskafi 1988; Eskafi & Kolbe 1990; Flores et al. 2016). In this context, mass trapping at low altitudes may have a higher effect on *C. capitata* than *A. ludens* in citrus orchards where coffee plantations occupy a smaller area. However, as noted above, citrus agroecosystems are a shared habitat of *C. capitata* and *A. ludens*, which suggests further research on mass trapping associated with pest phenology.

Sex proportions within trapping types showed no differences between monitoring trapping under the influence of mass trapping and 1.5 L bottle baited with 500 mL of Cera Trap. However, mass trapping revealed a significant bias regarding females of *C. capitata*, *A. distincta*, and *A. serpentina*, which indicate a higher effect of mass trapping on female populations. However, for *A. ludens*, a similar proportion of female and male adults suggest a stable population and hence additional control measures, as observed for pest species of Tephritidae (Houston 1981; Leza et al. 2008). A female-biased effect of Cera Trap on *A. obliqua* populations is reported by Lasa and Cruz (2014), whereas Ruiz-May et al. (2020) attribute such a response to the olfactory perception level of sexually immature females. From a practical point of view, mass trapping baited with Cera Trap impacts female populations of pest species of Tephritidae. However, as noted in *A. ludens*, the pest and host phenology are key factors in pest management to achieve success in the mass trapping strategy.

Populations of *A. ludens*, *C. capitata*, and non-pest species in citrus such as *A. serpentina* (Mangan et al. 2011) and *A. distincta* (Oropeza-Cabrera et al. 2015) showed similar flies per trap per d in monitoring trapping under the influence of mass trapping and 1.5 L bottle baited with 500 mL of Cera Trap. Such a result suggests that monitoring trapping under the influence of mass trapping location contributed to detecting an flies per trap per d similar to 1.5 L bottle baited with 500 mL of Cera Trap (a trap without the influence of mass trapping). Orchard heterogeneity, proximity to wild areas, and prevalent citrus cultivars among other variables could have influenced the effectiveness of monitoring traps, as documented for mass trapping essays under field conditions (Lasa et al. 2014a). Also, a higher flies per trap per d variability of monitoring trapping under the influence of mass trapping and 1.5 L bottle baited with 500 mL of Cera Trap than in mass trapping, particularly in *A. distincta* (Table 1), implies less consistency in the flies per trap per d behavior. This result may be a logical response because of the number of traps in mass trapping aimed at suppressing or controlling pest populations.

We highlight the abundance of *A. distincta*, a species associated with *Inga* spp. (Fabaceae), a plant species commonly used as shade in coffee plantations (Peeters et al. 2003; Oropeza-Cabrera et al. 2015). This fly species represented a high percentage of capture and is reported in the trapping systems in Guatemala (Martinez et al. 2007), which is likely related to the *Inga*-shaded coffee plantations. Resource-foraging behavior (Hendrichs & Prokopy 1994) may be the cause of the detected fruit fly community inhabiting the citrus agroecosystem and surroundings. Consequently, this fruit fly community may provide additional agroecological data on fruit fly assemblages and their natural enemies.

In conclusion, this study provided information on the results of a mass trapping network deployed in a citrus orchard using Cera Trap as an attractant. The use of bottles is a reliable alternative for citrus growers for implementing this control strategy for pest species in citrus orchards in Guatemala. Also, the results showed that mass trapping at a density of 40 traps per ha impacts female populations and the general population of pest species of citrus such as *C. capitata* and *A. ludens*. However, the presence of both *A. ludens* as the predominant pest species and *C. capitata* suggests additional research is needed on mass trapping strategies and supplementary control measures in tropical environments. Factors such as installation period, trap density,

Table 3. Fitted linear mixed models comparing flies per trap per d (Helmert contrasts) for *Anastrepha distincta*, *Anastrepha ludens*, *Anastrepha serpentina*, and *Ceratitis capitata* by 3 types of trapping: mass trapping and 2 types of monitoring traps in a citrus orchard in Chiquimulilla, Santa Rosa, Guatemala. MT = mass trapping; PTA = monitoring trapping under the influence of mass trapping; PTB = monitoring trapping without the influence of mass trapping; Coef = coefficient; SE = Standard error.

	Flies per trap per d					Female flies per trap per d					Male flies per trap per d			
Fly species	Contrasts	Coef	SE	*p*-value	Fly species	Contrasts	Coef	SE	*p*-value	Fly species	Contrasts	Coef	SE	*p*-value
Ceratitis capitata	PTB vs. PTA	0.069	0.148	0.653	*Ceratitis capitata*	PTB vs. PTA	0.069	0.126	0.598	*Ceratitis capitata*	PTB vs. PTA	0.00	0.103	1.00
	MT vs. PTA & PTB	−0.872	0.085	< 0.001		MT vs. PTA & PTB	−0.921	0.072	< 0.001		MT vs. PTA & PTB	−1.08	0.059	< 0.001
Anastrepha ludens	PTB vs. PTA	0.189	0.272	0.499	*Anastrepha ludens*	PTB vs. PTA	0.236	0.262	0.384	*Anastrepha ludens*	PTB vs. PTA	0.027	0.234	0.91
	MT vs. PTA & PTB	−0.487	0.157	0.009		MT vs. PTA & PTB	−0.64	0.151	0.001		MT vs. PTA & PTB	−0.639	0.135	0.001
Anastrepha serpentina	PTB vs. PTA	0.028	0.222	0.900	*Anastrepha serpentina*	PTB vs. PTA	0.028	0.203	0.890	*Anastrepha serpentina*	PTB vs. PTA	0.000	0.151	1.000
	MT vs. PTA & PTB	−0.625	0.128	0.001		MT vs. PTA & PTB	−0.727	0.117	0.000		MT vs. PTA & PTB	−0.795	0.087	< 0.001
Anastrepha distincta	PTB vs. PTA	−0.101	0.171	0.570	*Anastrepha distincta*	PTB vs. PTA	−0.125	0.192	0.532	*Anastrepha distincta*	PTB vs. PTA	0.018	0.182	0.922
	MT vs. PTA & PTB	−0.618	0.098	0.000		MT vs. PTA & PTB	−0.685	0.11	0.000		MT vs. PTA & PTB	−0.769	0.105	< 0.001

trapping permanence, and pest and host phenology must be considered for the success of mass trapping. This is the first report on the use of mass trapping for the control of fruit fly pests in citrus orchards in Guatemala.

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