Food Attractants for Mass Trapping of Fruit Flies (Diptera: Tephritidae) and Its Selectivity for Beneficial Arthropods

Authors: Delgado, Soledad, Calvo, María Victoria, Duarte, Felicia, Borges, Alejandra, and Scatoni, Iris Beatriz

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Food attractants for mass trapping of fruit flies (Diptera: Tephritidae) and its selectivity for beneficial arthropods

Soledad Delgado[1,], María Victoria Calvo[1], Felicia Duarte[2], Alejandra Borges[3], and Iris Beatriz Scatoni[1]*

Abstract

Fruit fly control in Uruguay is based mainly on toxic baits which are insufficient to reduce the damage caused by these pests. Therefore, alternative management measures such as mass trapping gain relevance for control of flies. Attractants commercially available were designed mainly for *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). However, they also should be attractive to *Anastrepha fraterculus* (Wiedemann) (Diptera: Tephritidae) in our fruit orchards. The aim of this research was to evaluate the effectiveness of food-based attractants for the capture of sexually immature females of *C. capitata* and *A. fraterculus*, as well as their selectivity on the populations of beneficial arthropods (pollinators, predators, and parasitoids). Seven attractants were evaluated in 3 commercial fruit crops during 2 seasons; 4 commercial attractants (hydrolyzed protein, liquid trimethylamine, trimethylamine diffuser card, and ammonium acetate + putrescine diffuser card), 20% natural *Acca sellowiana* (O. Berg) O. Berg (Myrtaceae) juice, 6% sugarcane molasses, and Torula yeast. The attractants were placed in McPhail traps, which were checked each wk and all captured arthropods were removed, counted, and classified. Captured female tephritids were dissected to determine the presence of eggs. All commercial attractants evaluated were effective at capturing sexually immature females of *C. capitata* in the 3 fruit crops evaluated during both seasons. Hydrolyzed protein, liquid trimethylamine, and trimethylamine diffuser card were effective at capturing young females of both species. Most of the captures are post-harvest, so we suggest not moving traps after commercial harvest. These attractants also were selective, capturing few beneficial arthropods. Sugarcane molasses and pineapple guava juice were not effective at capturing fruit fly females.

Key words: *Ceratitis capitata*; *Anastrepha fraterculus*; food baits; auxiliary entomofauna; citrus fruit trees; deciduous fruit trees

Resumen

El control de las moscas de la fruta en Uruguay se basa principalmente en el uso de cebos tóxicos, los cuales han mostrado ser insuficientes para reducir sus daños. Debido a esto, estrategias de control alternativas como el trampeo masivo han tomado mayor relevancia. Los atrayentes disponibles comercialmente fueron diseñados para *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). Sin embargo, en nuestros cultivos frutales también deberían ser efectivos para *Anastrepha fraterculus* (Wiedemann) (Diptera: Tephritidae). El objetivo del presente trabajo fue evaluar la eficiencia de diferentes atrayentes alimenticios en la captura de hembras sexualmente inmaduras de *C. capitata* y *A. fraterculus*, y su selectividad respecto a las poblaciones de artrópodos benéficos. Siete atrayentes diferentes fueron evaluados en tres cultivos frutícolas comerciales en dos temporadas; cuatro atrayentes comerciales (proteína hidrolizada, trimethylamine líquido, trimethylamine tarjeta difusora, y acetato de amonio + putrescina), jugo natural de *Acca sellowiana* (O. Berg) O. Berg (Myrtaceae) al 20%, melaza de caña al 6% y levadura Torula. Los atrayentes se colocaron en trampas McPhail, las que se revisaron semanalmente y todos los artrópodos capturados fueron retirados, contados y clasificados. Las hembras de tefrítidos capturadas fueron disecadas para determinar la presencia de huevos. Los atrayentes comerciales evaluados fueron eficaces en la captura de hembras jóvenes de *C. capitata* en los tres cultivos frutales evaluados y ambas temporadas. La proteína hidrolizada, el trimethylamine líquido, y la trimethylamine tarjeta difusora fueron efectivos en la captura de hembras jóvenes de ambas especies. La mayoría de las capturas se dieron en el período poscosecha, por lo que sugerimos que las trampas de trampeo masivo no se muevan de los cuadros luego de la cosecha comercial. Estos atrayentes fueron además muy selectivos, capturando pocos artrópodos benéficos. La melaza de caña y el jugo de guayabo no fueron eficaces en la captura de hembras de tefrítidos.

Palabras Claves: *Ceratitis capitata*; *Anastrepha fraterculus*; cebos alimenticios; entomofauna auxiliar; cítricos; frutales de hoja caduca

Fruit flies of economic importance (Diptera: Tephritidae) present in Uruguay are *Ceratitis capitata* (Wiedemann), which is distributed worldwide (Liquido et al. 1990) and *Anastrepha fraterculus* (Wiedemann) (both Diptera: Tephritidae), which is native to South America (Norrbom et al. 2012). Both species are multivoltine and do not diapause, so they develop uninterruptedly throughout the yr in the presence of susceptible hosts and have a very high reproductive potential (Malavasi & Zucchi 2000). These are very polyphagous species, with more than 408 hosts registered for *C. capitata* (Liquido et al. 2019) and 177 for *A. fraterculus* (Hernández-Ortiz et al. 2019).

[1]Universidad de la República, Facultad de Agronomía, Departamento de Protección Vegetal, Montevideo, 12900, Uruguay; E-mail: sdelgado@fagro.edu.uy (S. D.), vcalvo@fagro.edu.uy (M. V. C.), aborges@fagro.edu.uy (A. B.), iscatoni@gmail.com (I. B. S.)
[2]Ministerio de Ganadería Agricultura y Pesca, Dirección General de Servicios Agrícolas, División Protección Agrícola, Montevideo, 12900, Uruguay;
[3]Universidad de la República, Facultad de Agronomía, Departamento de Biometría, Estadística y Cómputos, Montevideo, 12900, Uruguay;
E-mail: aborges@fagro.edu.uy (A. B.), E-mail: feliciaduartedgsa@gmail.com (F. D.)
*Corresponding author; E-mail: sdelgado@fagro.edu.uy

As female flies approach ovarian maturation, fruit is attractive and adult females oviposit inside the fruit, where the larvae complete their development feeding on the pulp. Most control tactics target adults because it is the only exposed stage (Malavasi & Zucchi 2000), so its early detection is essential to avoid damage.

Although these pests produce significant losses due to the direct damage (Ekesi et al. 2005), the quarantine status for several Uruguayan export markets have more economic impact. The attacks of fruit flies in Uruguay are increasingly severe and found in all fruit tree species, causing losses of great magnitude. This is due, among other reasons, to the fact that the applications of toxic baits are insufficient in certain cases to reduce the damage (Scatoni et al. 2019). The most common toxic bait used is spinosad + hydrolyzed protein.

Mass trapping is one of the most important pest management tactics that have been introduced in Uruguay. It is being used for control of *C. capitata* females with good results (Scatoni et al. 2019). This technique consists in the use of semiochemicals that, when applied in a large number of traps per ha, remove a significant number of adult flies from orchards (Dominiak et al. 2016). Mass trapping is a strategy increasingly used for the control of tephritids worldwide (Navarro-Llopis et al. 2008; Lasa & Cruz 2014; Dominiak et al. 2016; Villalobos et al. 2017) mostly based on its effectiveness, that it leaves no residues on fruit, and it is safe for humans and the environment (Hafsi et al. 2020). In the case of fruit flies, the most commonly used attractants are food-based, such as trimethylamine, ammonium acetate, putrescine, and hydrolyzed proteins (Morton & Bateman 1981; Dominiak 2006). These attractants are based on the need of newly emerged females to feed on proteins and sugar prior to reproduction (Uchôa 2012). The most efficient attractants will be those that capture the largest number of non-gravid females (young and sexually immature), i.e., before they can cause damage to fruits, and also be selective to pollinators, predators, and parasitoids.

Commercially available attractants used for mass trapping of fruit flies in Uruguay are liquid trimethylamine, trimethylamine diffuser card, ammonium acetate + putrescine diffuser card, and hydrolyzed protein. Due to their proteic nature, they are considered generic and have the potential to attract *C. capitata* and *A. fraterculus*, although they are produced with emphasis on the control of *C. capitata* in addition to many other species of arthropods. For this reason, it is necessary to determine if they affect the beneficial entomofauna of the fruit agroecosystem (Falcó-Garí et al. 2006, 2010).

The aim of this research was to evaluate the effectiveness of food-based attractants for the capture of sexually immature females of *C. capitata* and *A. fraterculus*, as well as their selectivity on the populations of beneficial arthropods (pollinators, predators, and parasitoids).

Materials and Methods

LOCATION OF FIELD TRIALS

Field tests of food-based attractants were carried out during 2 successive fruit growing seasons from Nov 2016 to May 2018 in 3 commercial fruit farms, 2 in the southern area of the country (Canelones department) and 1 in the northern area (Paysandú department). The selected orchards correspond to 3 species and fruit cultivars that frequently are affected by fruit flies: *Prunus persica* (L.) Batsch (Rosaceae) cultivar 'Dixieland' (Canelones, 56.3189444°W, 34.6233528°S, 36 masl), *Malus domestica* Borkh. (Rosaceae) cultivar 'Fuji Kiku' (Canelones, 56.3191806°W, 34.6489861°S, 28 masl), and *Citrus unshiu* Marc. (Rutaceae) cultivar 'Satsuma Okitsu' (Paysandú, 57.4997194°W, 31.9249778°S, 96 masl). During the second season of evaluation (2018), the mandarin orchard was changed for operational reasons to another orchard also in Paysandú (57.8866056°W, 31.9513222°S, 53 masl) of 'Satsuma Owari' mandarin. All orchards selected were at peak production and had an area of about 4 ha, and were divided into 4 blocks (repetitions) for the field trials.

ATTRACTANTS

We evaluated the following attractants: liquid trimethylamine, 15 g L^{-1} ('Plustrap,' trademark SUSBIN®, Quemar SRL, Mendoza, Argentina) – amount 300 mL; hydrolyzed protein, 55 g L^{-1} ('Ceratitistrap,' trademark Bioibérica S.A., Barcelona, Spain) – amount 300 mL; natural pineapple guava juice, 200 mL L^{-1} – amount 300 mL; sugarcane molasses, 60 g L^{-1} (Azucarera del Litoral S.A., Paysandú, Uruguay) – amount 300 mL; trimethylamine diffuser card, 5.74 g L^{-1} ('trimethylamine lure,' trademark SUSBIN®, Quemar SRL, Mendoza, Argentina); ammonium acetate 45 g L^{-1}, and putrescine 0.15 g L^{-1} diffuser card ('Anastrepha lure,' trademark SUSBIN®, Quemar SRL, Mendoza, Argentina); Torula yeast (SUSBIN®, Quemar SRL, Mendoza, Argentina).

Commercial products like hydrolyzed protein, liquid trimethylamine, trimethylamine diffuser card, and ammonium acetate + putrescine were selected for evaluation because they are widely used by fruit growers for mass trapping. Torula yeast is used commonly for monitoring fly populations in McPhail traps, both by growers and by the Official Fruit Fly Monitoring Program of the Ministerio de Ganadería, Agricultura y Pesca, Montevideo, Uruguay. Natural pineapple guava juice (*Acca sellowiana* [O. Berg] O. Berg; Myrtaceae) was made from liquefied fruits and diluted in water. It was selected for evaluation because it is a very attractive native host for *C. capitata* and *A. fraterculus* (Segura et al. 2006; Scatoni et al. 2019) and a possible low-cost homemade bait. Sugarcane molasses, a by-product of the sugar industry, is used principally in citrus crops as an attracting matrix for fruit flies in toxic bait applications, so it was interesting to evaluate its attractiveness in a trap.

In each fruit crop, 6 food attractants in 4 replicates were evaluated using McPhail traps (SUSBIN®, Quemar SRL, Mendoza, Argentina). In the 2017 season in the Dixieland peach field trial, natural pineapple guava juice was evaluated, but sugarcane molasses in the subsequent trials replaced it. This was due to its lack of effectiveness and difficult implementation. However, for the 2018 season, in the Dixieland peach and Fuji Kiku apple field trials, sugarcane molasses was eliminated because of its lack of effectiveness. Baited traps were distributed evenly in each block, separated by at least 30 m from each other. They were hung 1.5 m above the ground in the tree canopy. Traps were placed 45 d before the expected harvest date and were maintained at least 40 d after in the 3 fruit orchards and for 2 fruit growing seasons. Traps were checked and rotated clockwise each wk in order to avoid site effect. Trials lasted an average of 91 d and each trap was reviewed 12 times to ensure uniform data collection and rotation.

In the case of hydrolyzed protein, liquid trimethylamine, sugarcane molasses, and natural pineapple guava juice, each trap was baited with 300 mL of the product. In the case of Torula yeast, 300 mL of tap water and 4 pellets of the commercial product were placed. Trimethylamine diffuser card and ammonium acetate + putrescine diffuser cards were pasted to the top of the traps with double-sided tape, and traps were filled with 300 mL of tap water with 5 mL of neutral pH liquid soap to break the water superficial tension in order to aid insect capture (Hodson 1948).

FIELD EFFICIENCY OF FOOD-BASED ATTRACTANTS

Attractants were filtered to remove the arthropods, which were saved in 96% alcohol for later classification. Commercial attractants were rebaited according to manufacturer recommendation, i.e., hydrolyzed protein and liquid trimethylamine were replaced after 45 d; Torula yeast, sugarcane molasses, and pineapple juice were changed each wk, trimethylamine diffuser card, and ammonium acetate + putrescine were not changed because they last 120 d.

Tephritids collected in traps were counted and classified using taxonomic keys (Foote 1980; Malavasi & Zucchi 2000). The specimens of *C. capitata* and *A. fraterculus* were sexed and cumulative captures were expressed as females per trap per d (FTD). The females per trap per d is a population index that estimates the average number of flies (in this case females) captured in 1 trap in 1 d that the trap is exposed in the field (IAEA 2003). It is calculated as follows: $FTD = F/(T \times D)$, where F = total number of flies captured, T = number of serviced traps, and D = average number of d traps were exposed in the field. This value was determined for the pre-harvest and post-harvest period of the 3 fruit orchards during both fruit growing seasons.

Four hundred fruits per crop were sampled randomly at the time of commercial harvest in order to determine fruit infestation level by tephritids. Once in the laboratory, they were weighed and kept in PVC containers (Galvanotek Embalangens LTDA, Carlos Barbosa, Rio Grande do Sul, Brazil) under controlled conditions of temperature (22 ± 3 °C), humidity (70 ± 5%), and a photoperiod of 12:12 h (L:D). Each container was covered with voile cloth to prevent the proliferation of fungi, and had sand in the bottom to facilitate the pupation of tephritid larvae. They were checked periodically in order to separate and condition the pupae of the fruit flies. The adults obtained were counted, identified, and sexed.

PROPORTION OF GRAVID AND NON-GRAVID FEMALES CAPTURED

Females of *C. capitata* and *A. fraterculus* captured were dissected in Petri dishes; ovaries were extracted and the presence of eggs observed as an indicator of sexual maturity (Bortoli et al. 2016). For the first season of evaluation, all females captured were dissected, but in the second season a maximum of 10 females per sample were dissected due the huge number of females captured. All females without developed eggs were considered non-gravid, and therefore sexually immature.

SELECTIVITY OF ATTRACTANTS REGARDING BENEFICIAL ARTHROPODS

To evaluate the potential impact of the attractants used in mass trapping on pollinator, predator, and parasitoid populations, all arthropods captured were counted and classified at the order and family level following the keys of Bentancourt et al. (2009). Three categories were defined: tephritids, beneficial arthropods, and other non-target insects. Tephritids included fruit fly pests *C. capitata* and *A. fraterculus*. Beneficial arthropods included Hymenoptera (Apidae, Braconidae, Ichneumonidae, Pteromalidae); Neuroptera (Chrysopidae, Hemerobiidae); Diptera (Syrphidae, Tachinidae); Coleoptera (Coccinellidae). Other non-target insects included arthropods captured that do not belong to the above-mentioned categories (e.g., Muscidae, Drosophilidae, Blattellidae, Nitidulidae, Cerambycidae, Culicidae, Cicadellidae, Lepidoptera, etc).

DATA ANALYSIS

Because females cause the damage in fruit, mean captures of females were compared among the different treatments for the evaluation of the effectiveness of attractants. To do this, a Generalized Linear Mixed Model (GLMM) with a Quasi Poisson approach followed by DGC (Di Rienzo, Guzmán and Casanoves), a mean separation procedure (Di Rienzo et al. 2002), with Infostat Software Version 2018 was used (Di Rienzo et al. 2018). Date and location were used as random effects while treatments and blocks were set as fixed factors. The proportion of captures in the pre- and post-harvest period of each field trial, the proportions of tephritids and non-target insects (beneficial arthropods + other non-target insects), and the proportion of gravid and non-gravid females captured were compared by Chi square test, using the statistical software SPSS® for Windows Version 23.0.0.0. (IBM 2015). For all tests, the significance level used was 5%.

Results

EFFECTIVENESS OF FOOD-BASED ATTRACTANTS IN THE FIELD

Ceratitis capitata Evaluation

Dixieland peach field trial. During the first season of evaluation (Nov 2016–Feb 2017), 694 tephritids were captured in the 12 test wk, with 522 females and 172 males. *Ceratitis capitata* represented 94% of the captures and *A. fraterculus* only 6%. Hydrolyzed protein (35%, 6.7 females per trap per d), liquid trimethylamine (24%, 4.9 females per trap per d), and trimethylamine diffuser card (23%, 4.4 females per trap per d) were the more efficient attractants and together captured 82% of total *C. capitata* captured (Fig. 1A). Commercial harvest was on the ninth wk of evaluation. None of the attractants showed significant differences in their efficiency during the pre-harvest period.

In the second season of evaluation (Dec 2017–Apr 2018), a total of 5,634 tephritids were captured in the 16 test wk, with 3,742 females and 1,892 males. *Ceratitis capitata* captures represented 99.7% of the total, while only 0.3% were *A. fraterculus*. In this season, commercial harvest was on the sixth wk. Trimethylamine diffuser card (29%, 22.2 females per trap per d), hydrolyzed protein (25%, 20 females per trap per d), ammonium acetate + putrescine (19%, 14.2 females per trap per d), and liquid trimethylamine (19%, 13.9 females per trap per d) were the more efficient attractants for *C. capitata* and together captured 92% of total tephritids (Fig. 1B). Hydrolyzed protein also was the best attractant in the pre-harvest period. In both seasons of evaluation all attractants captured more *C. capitata* females in the post-harvest period than in the pre-harvest period, and liquid trimethylamine captured *C. capitata* before other attractants.

Fuji Kiku apple field trial. During the first season of evaluation (Feb 2017–May 2017), a total of 1,143 *C. capitata* were captured in the 13 test wk, with 919 females and 224 males. Hydrolyzed protein (30%, 6.4 females per trap per d), ammonium acetate + putrescine (24%, 5 females per trap per d), trimethylamine diffuser card (18%, 3.9 females per trap per d), and liquid trimethylamine (17%, 3.5 females per trap per d) were the more efficient attractants and together captured 89% of *C. capitata* (Fig. 1C). Commercial harvest was on the sixth wk of trial. None of the attractants showed significant differences in their efficiency during the pre-harvest period.

In the second season of evaluation (Feb 2018–May 2018), a total of 1,152 *C. capitata* were captured in the 13 test wk, with 891 females and 261 males. Hydrolyzed protein (39%, 11.6 females per trap per d), liquid trimethylamine (28%, 6 females per trap per d), and trimethylamine diffuser card (19%, 6.3 females per trap per d) were the more efficient attractants and together captured 86% of the *C. capitata* (Fig. 1D). In this season, commercial harvest was on the tenth wk of trial. In both seasons of evaluation, all attractants captured more tephritids in the post-harvest period than in the pre-harvest period. Hydrolyzed protein and liquid trimethylamine also were the more efficient attractants in the pre-harvest period. Liquid trimethylamine was able to detect the presence of *C. capitata* before other attractants on both seasons.

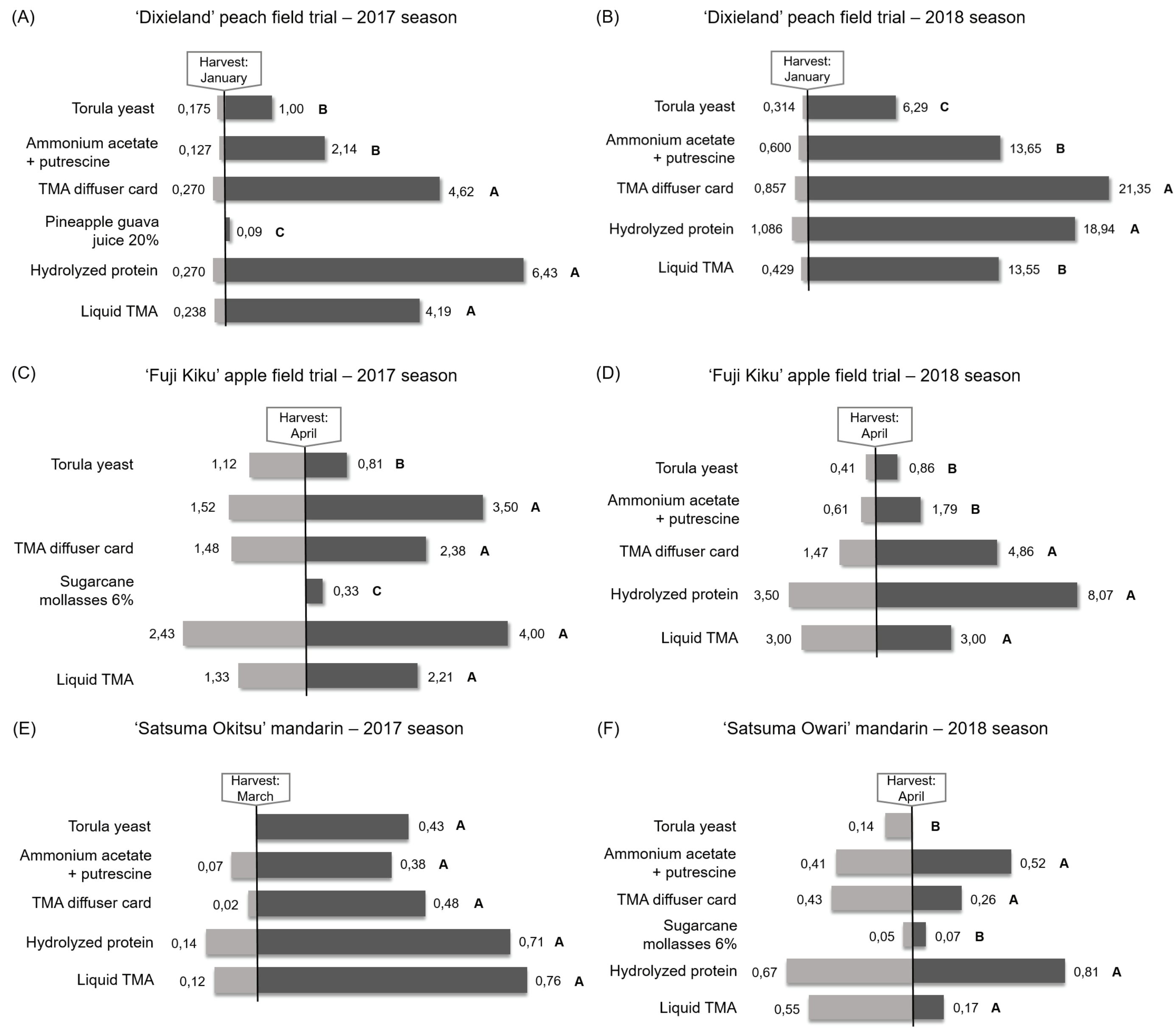

Fig. 1. Cumulative *Ceratitis capitata* captures expressed as females per trap per d index for the pre-harvest (light gray) and post-harvest (dark gray) periods are shown, for the 3 field trials and the 2 seasons of evaluation. Different letters indicate significant differences between treatments in the cumulative captures of females for the total trial period.

Satsuma mandarin field trial. In the case of Satsuma Okitsu mandarin, during the first season of evaluation (Feb 2017–May 2017) only 169 *C. capitata* were captured in the 12 test wks, with 133 females and 36 males. Commercial harvest was on the sixth wk of trial. No significant differences were observed among the attractants (Fig. 1E). The 2017 season was characterized by the low prevalence of *C. capitata* in the study area.

In the second season of evaluation (Feb 2018–May 2018) on Satsuma Owari mandarin, only 211 *C. capitata* were captured in the 12 test wk, with 170 females and 41 males. Commercial harvest was on the sixth wk of trial. Liquid trimethylamine (29%, 0.7 females per trap per d), hydrolyzed protein (27%, 1.5 females per trap per d), trimethylamine diffuser card (16%, 0.7 females per trap per d), and ammonium acetate + putrescine (15%, 0.9 females per trap per d) were the more efficient attractants and together captured 92% of the *C. capitata* (Fig. 1F). These attractants also were more efficient for the pre-harvest period. In all field trials, all treatments were able to capture significantly more females than males.

Anastrepha fraterculus Evaluation

The presence of *A. fraterculus* was detected only in the Dixieland peach field trial but in a very low density, with a *C. capitata*/*A. fraterculus* ratio of 15:1 in the 2017 season and 304:1 in the 2018 season. However, an average infestation of 0.45 pupae of *A. fraterculus* per kilogram of fruit sampled was observed in season 2017. This was the only field trial and season where fruit infestation was detected.

In the 2017 season, hydrolyzed protein (58%, 0.51 females per trap per d), liquid trimethylamine (24%, 0.20 females per trap per d), Torula yeast (9%, 0.08 females per trap per d), and ammonium acetate + putrescine (9%, 0.08 females per trap per d) captured *A. fraterculus* females with no significant differences between them. In the 2018 season, hydrolyzed protein (60%, 0.15 females per trap per d), liquid trimethylamine (16%, 0.04 females per trap per d), Torula yeast (16%, 0.04 females per trap per d), and trimethylamine diffuser card (8%, 0.02 females per trap per d) captured *A. fraterculus* females with no significant differences between them.

PROPORTION OF GRAVID AND NON-GRAVID FEMALES CAPTURED

In the 2017 season, the 1,505 *C. capitata* females captured in the different treatments and fruit crops were dissected. Non-gravid females represented 77% of the females captured, considering the pre- and post-harvest period (Fig. 2). In the 2018 season, 1,947 *C. capitata* females were captured, with 75% non-gravid (Fig 3).

For the case of *A. fraterculus* in the Dixieland peach trial, only hydrolyzed protein was able to capture significantly more non-gravid females (e.g., 7 non-gravid vs. 1 gravid in the second season). This was due to the lack of captures of this species (33 females in the first season and 12 females in the second season).

All treatments evaluated captured non-gravid females. Hydrolyzed protein and liquid trimethylamine captured significantly more non-gravid females during the pre- and post-harvest period in all field trials in both seasons. Trimethylamine diffuser card, ammonium acetate + putrescine, and Torula yeast captured more non-gravid females, mostly in the post-harvest period of the Dixieland peach and Fuji Kiku apple trials (Figs. 2 & 3).

SELECTIVITY OF ATTRACTANTS REGARDING BENEFICIAL ARTHROPODS

Captures of beneficial arthropods were not significantly different among the evaluated food attractants, despite the differences they may present in terms of their efficiency of capturing tephritids (Fig. 4). The more efficient attractants were not necessarily the more selective regarding non-target insects (beneficial arthropods + other non-target insects). The least selective attractant was sugarcane molasses, in which the fraction of beneficial arthropods caught reached 6.7% of total captures in Satsuma Owari mandarin (2018 season) (Fig. 4E).

In most treatments and field trials, non-target insects are the greatest proportion of captured arthropods. Diptera, such as Muscidae and Drosophilidae, dominated captures in all treatments. Only in the Dixieland peach field trial during the 2018 season were *C. capitata* captures significantly larger than non-target insect captures for 3 attractants: trimethylamine diffuser card, liquid trimethylamine, and ammonium acetate + putrescine (Fig. 4B). In this case, trimethylamine diffuser card was the most specific attractant, where tephritids accounted for 74.5% of the captures, followed by liquid trimethylamine (71.5%), ammonium acetate + putrescine (59.2%), hydrolyzed protein (45.3%), and Torula yeast (13.8%).

Discussion

Liquid trimethylamine, hydrolyzed protein, and trimethylamine diffuser card were the more effective attractants for *C. capitata* in all crops and seasons. Several studies (Morton & Bateman 1981; Botton et al. 2012; Bortoli et al. 2016; Da Rosa et al. 2017) have reported previously the effectiveness of hydrolyzed protein capturing *C. capitata*.

All treatments evaluated had female-biased captures, which is the base of an effective mass trapping strategy. Females are lured more often to attractants than males (Manrakhan & Kotze 2009; Jahnke et al. 2014), especially those that are protein-based (Malo 1992; Katsoyannos et al. 1999; Raga & Vieira 2015). Animal protein-based products, such as hydrolyzed protein and liquid trimethylamine, were more effective at capturing *C. capitata*. Females lured to these attractants mostly were sexually immature (Heath et al. 1995; Bortoli et al. 2016) in stages prior to oviposition and damage to fruits.

Some studies (Drew & Yuval 2000; Aluja et al. 2011) have explained the attraction of immature females to protein-based baits due to the physiological needs for egg development. Males also were attracted to these baits, presumably because they increased their success in the search for a female (Pérez-Staples & Aluja 2004). Sugarcane molasses was inefficient in capturing tephritids in all field trials. This lack of effectiveness had been reported for *A. fraterculus* and *A. grandis* (Malavasi et al. 1990). Although there is a lack of response, molasses is still commonly used in toxic baits mixed with an insecticide in southern Brazil (Nava & Botton 2010) and Uruguay, and it is considered effective by the citrus growers.

Based on the fact that fruits are an oviposition stimulus for sexually mature females and protein-based attractants are a stimulus for the development of the ovaries of sexually immature females, the presence of fruits in the field does not compete with traps for capturing females. Tephritid captures were concentrated in the post-harvest period in most of the trials probably due to the increase in the population of fruit flies in the crop area.

This result has a direct implication for the management technique commonly employed for the use of traps. Typically, fruit growers move these traps after harvesting a cultivar to the next susceptible cultivar on the property. According to the results obtained, it would be advisable to keep the traps in the same area for a longer period after the harvest, to allow the capture of as many newly emerged tephritids as possible before they move to attack another cultivar.

Fruit infestation with *A. fraterculus* occurred only on Dixieland peach during the first season. No fruit infestation with *C. capitata* was detected. Despite the captures of *C. capitata* were much greater than the captures of *A. fraterculus* in all treatments (average females per trap per d 1.36 vs. 0.1, respectively), the fruits sampled were infested only with *A. fraterculus*. A plausible reason for this curious result is that, while using attractants more sensitive than traditional Torula yeast for monitoring *A. fraterculus* populations, there is still a problem detecting low but dangerous populations of the pest. A similar situation occurs with peach and other fruit crops in Southern Brazil (Nava & Botton 2010).

Commercial food lures evaluated in the present study had low attractiveness to pollinators, predators, and parasitoids. This is a very important result since a massive trapping strategy uses between 50 and 120 traps per ha (depending on the commercial product and crop), so using a product that attracts beneficial arthropods can cause a significant imbalance in the agroecosystem.

Locally available, cheap food baits (sugarcane molasses and pineapple guava juice) were not efficient and non-selective. There are successful experiences of control of *C. capitata* (Candia et al. 2018) and *A. fraterculus* with locally developed food lures (Lang et al. 2006) such as fermented beverages and baker's yeast. On the other hand, it is relevant to consider the negative effect of low-specific attractants (such as Torula yeast, pineapple guava juice, and sugarcane molasses) on the quality of trap monitoring. Attractants that capture a large number of non-target insects are less efficient and make it difficult to identify tephritids captured. This operational aspect is particularly important when growers control their own traps and use that information to make management decisions on the farm. It will be necessary to continue exploring possibilities of cheap food baits for the Uruguayan agronomic and economic conditions in order to increase the adoption of the mass trapping technique for all fruit growers.

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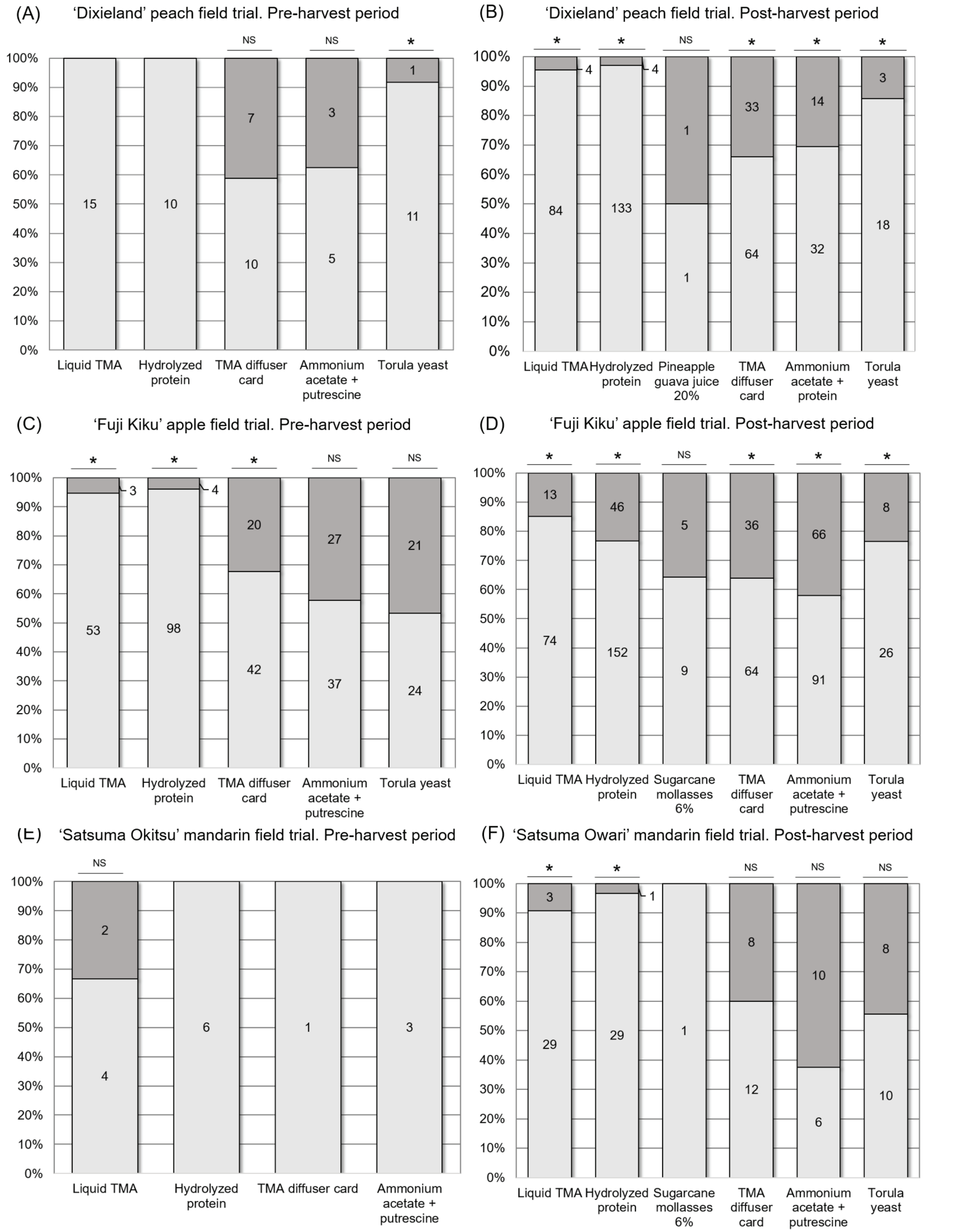

Fig. 2. Proportion of gravid (dark grey) and non-gravid (light grey) females of *Ceratitis capitata* lured to the different treatments on pre- and post-harvest period during the 2017 season (NS = no significant differences, * = $P \leq 0.05$). (A–B) Dixieland peach; (C–D) Fuji Kiku apple; (E–F) Satsuma mandarin. Treatments with no captures are not presented.

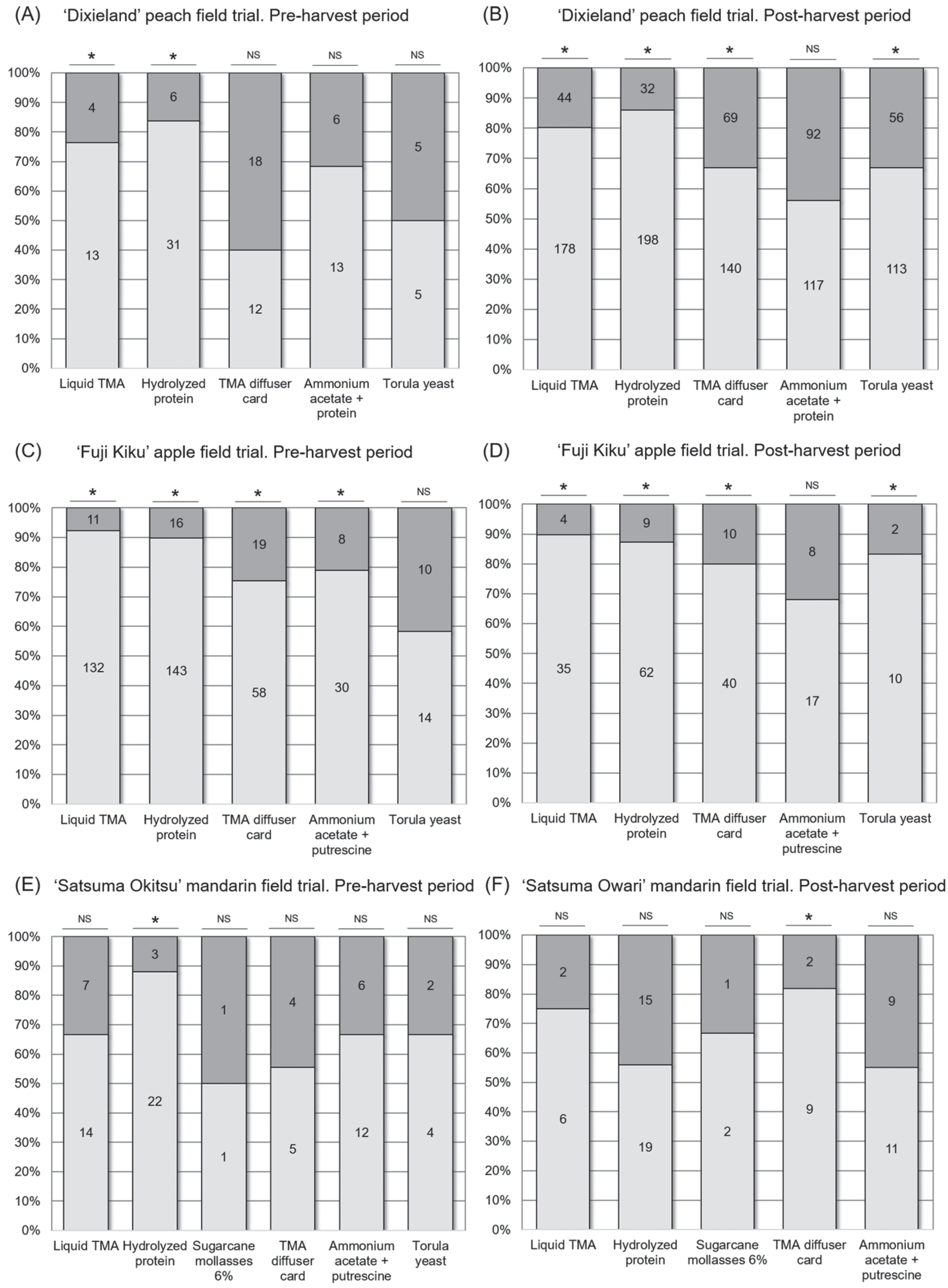

Fig. 3. Proportion of gravid (dark grey) and non-gravid (light grey) females of *Ceratitis capitata* lured to the different treatments on pre- and post-harvest period during the 2018 season (NS = no significant differences, * = $P \leq 0.05$). (A–B) Dixieland peach; (C–D) Fuji Kiku apple; (E–F) Satsuma mandarin. Treatments with no captures are not presented.

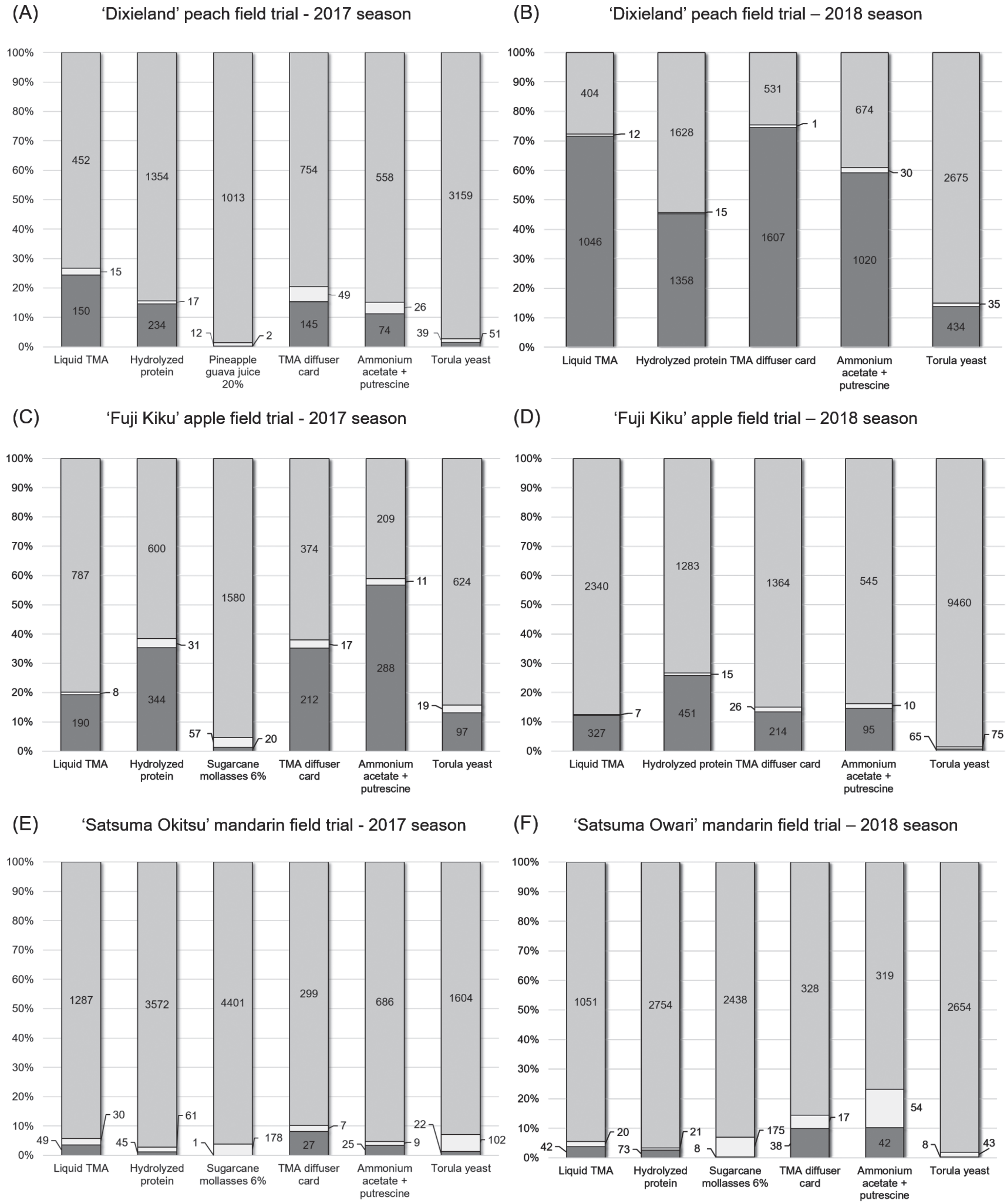

Fig. 4. Proportion of tephritids (dark grey), beneficial arthropods (white), and other non-target insects (light grey) captured by the different treatments in the 2017 and 2018 seasons.

ed; and the fruit growers for allowing us to carry out this research in their orchards. Mention of trade names does not imply recommendation or endorsement.

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