

Investigation the effectiveness of attractants for genders of *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) on citrus varieties

Turunçgil çeşitleri üzerinde *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) cinsiyetleri için cezbedicilerin etkinliğinin araştırılması

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ARTICLE INFO	ABSTRACT
<p>Article history: Recieved / Geliş: 30.12.2023 Accepted / Kabul: 20.02.2024</p> <p>Keywords: Medfly Citrus Attractants Türkiye</p> <p>Anahtar Kelimeler: Akdeniz meyve sineği Turunçgil Cezbediciler Türkiye</p> <p>✉Corresponding author/Sorumlu yazar: Nihat DEMİREL ndemirel@mku.edu.tr</p> <p>Makale Uluslararası Creative Commons Attribution-Non Commercial 4.0 Lisansı kapsamında yayınlanmaktadır. Bu, orijinal makaleye uygun şekilde atıf yapılması şartıyla, eserin herhangi bir ortam veya formatta kopyalanmasını ve dağıtılmasını sağlar. Ancak, eserler ticari amaçlar için kullanılamaz. © Copyright 2022 by Mustafa Kemal University. Available on-line at https://dergipark.org.tr/tr/pub/mkutbd</p> <p>This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.</p> 	<p>The study was conducted in 2016-2017 to investigate the effectiveness of attractants for genders of <i>C. capitata</i> (Wiedemann) (Diptera: Tephritidae) on citrus varieties in Hatay province of Türkiye. In both years, the SEDQ type traps with various attractants were used. After two years of the study, effectiveness of the attractants for genders of <i>C. capitata</i> varied in each of the variety and the sampling year. In 2016, a total of 3.006 <i>C. capitata</i> adults (2.644♀, 362♂) were caught by attractant traps at the 'w-murcott' mandarin orchard located at Narpak farms in Reyhanlı district. The highest mean of male of <i>C. capitata</i> was caught by the combination of ammonium acetate + trimethylamine + putrescine attractant traps, while the highest mean of female and male + female of <i>C. capitata</i> were caught by the ammonium acetate attractant traps. In 2017, a total of 2.338 <i>C. capitata</i> adults (1.375♀, 963♂) were caught by attractant traps at the 'satsuma' mandarin orchard located at Bahçe70 in Dörtiyol district. The highest mean of male, female and male + female of <i>C. capitata</i> were caught by the ammonium acetate attractant traps. In both years, the mean of females was significantly higher than the mean of males. In addition, the percent of females was significantly higher than the percent of males.</p> <p>ÖZET</p> <p>Bu çalışma 2016-2017 yıllarında Hatay ilindeki narenciye çeşitlerinde cezbedicilerin <i>C. capitata</i>'nın cinsiyetleri üzerindeki etkinliğini araştırmak amacıyla yürütülmüştür. Her iki yılda da çeşitli cezbedicilere sahip SEDQ tipi tuzaklar kullanılmıştır. İki yıllık çalışmanın ardından, cezbedicilerin <i>C. capitata</i>'nın cinsiyetleri üzerindeki etkinliği çeşitlere ve örnekleme yıllarına göre farklılık göstermiştir. 2016 yılında Reyhanlı ilçesindeki Narpak çiftliklerinde bulunan 'w-murcott' mandalina bahçesinde toplam 3.006 adet (2.644 ♀, 362 ♂) <i>C. capitata</i> ergini cezbedici tuzaklar tarafından yakalanmıştır. <i>C. capitata</i>'nın en yüksek erkek ortalaması amonyum asetat + trimetilamin + putresin içeren cezbedici tuzakları kombinasyonunda yakalanırken, <i>C. capitata</i>'nın en yüksek dişi ve erkek + dişi ortalaması amonyum asetat içeren cezbedici tuzakları tarafından yakalanmıştır. 2017 yılında Dörtiyol ilçesi Bahçe70'de bulunan 'satsuma' mandalina bahçesinde toplam 2.338 adet (1.375♀, 963♂) <i>C. capitata</i> ergini cezbedici tuzaklar tarafından yakalanmıştır. <i>C. capitata</i>'nın en yüksek erkek, dişi ve erkek+dişi ortalamaları amonyum asetat içeren cezbedici tuzaklar tarafından yakalanmıştır. Her iki yılda da dişilerin ortalaması erkeklerin ortalamasından önemli derecede yüksek bulunmuştur. Ayrıca dişilerin yüzdesinin erkeklerin yüzdesinden önemli ölçüde daha yüksek olduğu görülmüştür.</p>
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INTRODUCTION

Citrus (Sapindales: Rutaceae) is one of the most significant fruit crops widely grown in tropical and subtropical regions of the world (Ollitrault et al., 2020; FAO, 2020). Citrus is grown in Türkiye where it comprises approximately 607,195 da of growing area and a total produce of 1,819,000 tons of yield annually, and Hatay province's share is 179,948 da and 716,732 tons (Anonymous, 2021). The Mediterranean fruit fly (medfly), *Ceratitidis capitata* (Diptera: Tephritidae) is one of the most important pests for citrus fruits (Liquido et al., 1990; White & Elson-Harris, 1992; Gilbert & Bingham, 1999; Thomas et al., 2010; Akyol, 2014; Demirel & Akyol, 2017; Gürbüz, 2018; Yiğit, 2019). The Medfly is a polyphagous species attacking over 350 different host plants (Liquido et al., 1990; Akyol, 2014; Çalıklı, 2015; Kılıç, 2015; Demirel, 2023b). The control program of medfly is based on applications of organophosphate insecticides that are mainly used foliage baiting and cover spraying methods (Roessler & Chen, 1994; Vargas et al., 2001; Urbaneja et al., 2009). However, the intensity of insecticide use for medfly has resulted in the development of resistant populations, harmful effects on human health, beneficial insects and non-target organisms in the environment (Hoelmer & Dahlsten, 1993; Marty et al., 1994; Bachrouh, 2003; Urbaneja et al., 2004). One of the effective control methods as alternative to chemical control is traps containing baits with female and male lures (Papadopoulos et al., 2001; Heath et al., 2004). In addition, the traps baited with trimedlure and attractants are important tools for detection, monitoring and controlling of *C. capitata* on different host plants (Epsky et al., 1999; IAEA, 2003; Navarro-Lopis et al., 2008; Boulahia-Kheder & Jerraya, 2010; Boulahia-Kheder et al., 2011; Shelly et al., 2014; Akyol, 2014; Demirel, 2016; Demirel & Akyol, 2017; Gürbüz, 2018; Yiğit, 2019; Demirel, 2023a). The traps baited with protein-based baits and lures are also used for the capture of male and female of *C. capitata* (Heath et al., 1997; Gazit et al., 1998; IAEA, 2003; Navarro-Lopis et al., 2008; Shelly et al., 2014; Demirel, 2023a). Many commercial formulations of ammonia have been produced for use as lures in fruit fly traps including ammonium acetate (BioLure), ammonium bicarbonate (AgriSense Lure) and ammonium carbonate (ISCA technologies) (Shelly et al., 2014). In addition, several studies have been conducted to evaluate various attractants; a single of ammonium carbonate for females (Reynolds & Prokopy, 1997; Demirel, 2023a), combinations of ammonium acetate + putrescine (Heath et al., 1995); ammonium acetate + trimethylamine + putrescine (Heath et al. 1997; Katsoyannos et al., 1999; Epsky et al., 1999; Miranda et al., 2001; Alemany et al., 2004; Demirel, 2023a) and ammonium acetate + trimethylamine + cadaverine (Navarro-Lopis et al., 2008; Demirel, 2023a) were used for *C. capitata*. Moreover, the food-based baits of diammonium phosphate caught significant number of *C. capitata* (Boulahia-Kheder et al., 2012; Çalıklı, 2015) and the high number of nontarget insects (Boulahia Kheder & Jerraya, 2010; Çalıklı, 2015). The objective of the current study was to investigate the effectiveness of attractants for genders of *C. capitata* (Wiedemann) (Diptera: Tephritidae) on citrus varieties in Hatay province of Türkiye.

MATERIALS and METHODS

The studies were conducted in 2016-2017 to investigate the effectiveness of attractants for genders of *Ceratitidis capitata* (Wiedemann) (Diptera: Tephritidae) on citrus varieties in Hatay province of Türkiye. A single and the combinations of two and three attractants, ammonium acetate (AA), ammonium carbonate (AC), ammonium bicarbonate (AB), trimethylamine (TMA), diaminoalkane (cadaverine) (C) and 1,4-diaminobutane (putrescine) (P) were used as synthetic food-based lures with SEDQ type traps (Table 1). An attractant or mixed attractants impregnated into paper handkerchiefs were used. Each of the paper handkerchief package (10x7.5 cm) had a 3-mm diameter hole and contained 25 g attractant or mix of attractants, 2 ml of 10% propylene glycol to decrease water evaporation and 2 ml of 2% dichlorvos. In the first year, the study was conducted as randomized complete block design with 5 treatments and 10 replications at w-murcott mandarin orchard located at Narpak farms in Reyhanlı, Hatay. In the second year, the study was conducted as randomized complete block design with 5

treatments and 5 replications at satsuma mandarin orchard located at Bahçe70 in Dörtyol, Hatay. The traps were placed at 1.5-2m high on southeastern side of the w-murcott trees (1 trap per three trees) on 29 June 2016. The traps were placed at 1.5-2m high on southeastern side of the satsuma mandarin trees (1 trap per three trees) on 4 August 2017. Traps were removed from w-murcott trees on 10 November 2016 and from satsuma mandarin trees 16 November 2017. Traps brought to the laboratory and captured female and male of *C. capitata* were counted. All data were analyzed by analysis of variance (ANOVA) with the SAS software and means were separated by the Least Significant Difference (LSD) Multiple Comparison Tests ($P < 0.05$) (SAS Institute Inc. 1998).

Table 1. Traps baited with different attractants used at 'w-murcott' and 'satsuma' mandarin orchards in Reyhanlı and Dörtyol districts of Hatay province in 2016-2017

Çizelge 1. 2016-2017 yıllarında Hatay ili Reyhanlı ve Dörtyol ilçelerindeki 'w-murcott' ve 'satsuma' mandalina bahçelerinde tuzaklarda kullanılan cezbedici maddeler

Treatments (Lures) ^a	2016	2017
	Lures (gr)/trap ²	Lures (gr)/trap ²
Ammonium acetate	0.42	7.5
Ammonium carbonate	0.42	7.5
Ammonium bicarbonate	---	7.5
Ammonium acetate+Ammonium carbonate	0.42+0.42	---
Ammonium acetate +Trimethylamine+Putrescine	0.42+0.13+0.01	7.5+3.16+0.05
Ammonium acetate+Trimethylamine+Cadaverine	0.42+0.13+0.01	7.5+3.16+0.05

^aLures abbreviations: Ammonium acetate (AA), Ammonium carbonate (AC), Ammonium bicarbonate (AB), Ammonium acetate+Ammonium carbonate (AA+AC), Ammonium acetate + Trimethylamine + Putrescine (AA+TMA+P), Ammonium acetate+ Trimethylamine +Cadaverine (AA+TMA+C).

²Putrescine and Cadaverine used as (mg) and rest of the treatments (lures) used as (gr).

RESULTS and DISCUSSIONS

Effectiveness of the attractants for genders of *C. capitata* varied in each of the variety and the sampling year. In the first year, the highest mean of males of *C. capitata* was caught by the combination of ammonium acetate + trimethylamine + putrescine attractant traps ($F=1.78$, $P= 0.0860$), while the highest mean of female and male + female of *C. capitata* were caught by the ammonium acetate attractant traps ($F=0.71$, $P= 0.77412$; $F=0.55$, $P= 0.835$) and yet there were no significant differences among treatments (Table 2).

Table 2. Capture of the genders of *C. capitata* traps baited with attractants at w-murcott mandarin orchard in 2016

Çizelge 2. 2016 yılında w-murcott mandalina bahçesinde cezbedici tuzaklar tarafından yakalanan *C. capitata*'nın cinsiyetlere göre ortalamaları

Treatments (attractants)	Means of catches insects per ten traps ²		
	<i>C. capitata</i> (♂)	<i>C. capitata</i> (♀)	<i>C. capitata</i> (♂,♀)
Ammonium acetate	7.40a	74.80a	82.20a
Ammonium carbonate	6.20a	61.10a	67.30a
Ammonium acetate+Ammonium carbonate	6.20a	39.10a	45.30a
Ammonium acetate +Trimethylamine+Putrescine	11.90a	47.50a	59.40a
Ammonium acetate+Trimethylamine+Cadaverine	4.50 a	41.90a	46.40a

²Numbers within a column not followed by the same letter are significantly different ($P<0.05$) by LSD.

In the first year, a total of 3,006 *C. capitata* adults (2,644♀, 362♂) were caught by attractant traps at the 'w-murcott' mandarin orchard located at Narpak farms in Reyhanlı district (Figure 1). The mean of the females was significantly

higher than the mean of the males (F: 14.79; P: 0.0001). In addition, the percent of females (87.95) was significantly higher than the percent of males (12.04).

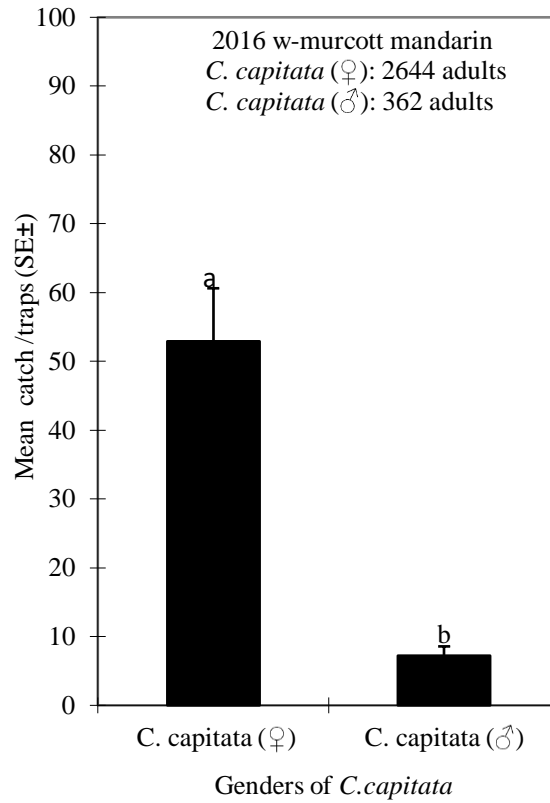


Figure 1. Figure 1. Mean (\pm SE) catches of medfly adults with traps baited with attractants (29 June-10 November, 2016) at w-murcott mandarin orchard. Different letters above bars indicate significant differences according to Least Significant Difference (LSD) ($P < 0.05$)

Şekil 1. W-murcott mandalina bahçesinde (29 Haziran-10 Kasım 2016) tarihleri arasında cezbedici içeren tuzaklar tarafından yakalanan *Ceratitıs capitata* ortalamaları (\pm SE). LSD ($P < 0,05$) göre çubukların üzerindeki farklı harfler önemli farklılıkları gösterir

In the second year, the highest mean of male, female and male + female of *C. capitata* were caught by the ammonium acetate attractant traps (Table 3). The mean of the males was significantly higher for traps baited with ammonium acetate than those of baited with other attractants (F=7.63, P= 0.0003). The mean of the females was significantly higher for traps baited with ammonium acetate than those baited with ammonium carbonate, ammonium bicarbonate and ammonium acetate + trimethylamine + putrescine (F: 2.70, P: 0.0432). The mean of male + female of *C. capitata* was significantly higher for traps baited with ammonium acetate than traps baited with ammonium carbonate, ammonium bicarbonate, ammonium acetate + trimethylamine + putrescine and ammonium acetate + trimethylamine + cadaverine (F: 12.38, P: 0.0001).

Table 3. Capture of the genders of *Ceratitis capitata* traps baited with attractants at satsuma mandarin orchard in 2017

Çizelge 3. 2017 yılında satsuma mandalin bahçesinde cezbedici maddelerle yemlenen tuzakların *Ceratitis capitata* cinsiyetlerini yakalama ortalamaları

Treatments (attractants)	Means of catches insects per five traps ^z		
	<i>C. capitata</i> (♂)	<i>C. capitata</i> (♀)	<i>C. capitata</i> (♂,♀)
Ammonium acetate	170.80a	123.40a	294.00a
Ammonium carbonate	1.80b	15.80b	17.60c
Ammonium bicarbonate	2.20b	28.60b	30.80c
Ammonium acetate+Trimethylamine+Putrescine	4.80b	36.80b	41.60bc
Ammonium acetate+Trimethylamine+Cadaverine	13.00b	70.60ab	83.60b

^zNumbers within a column not followed by the same letter are significantly different ($P < 0.05$) by LSD.

In the second year, a total of 2338 *C. capitata* adults (1375♀, 963♂) were caught by the attractant traps at the 'satsuma' mandarin orchard located at Bahçe 70 in Dörttyol district (Figure 2). The mean of females was significantly higher than mean of males (F: 3.28; P: 0.0024). In addition, the percent of females (58.81) was significantly higher than the percent of males (41.18).

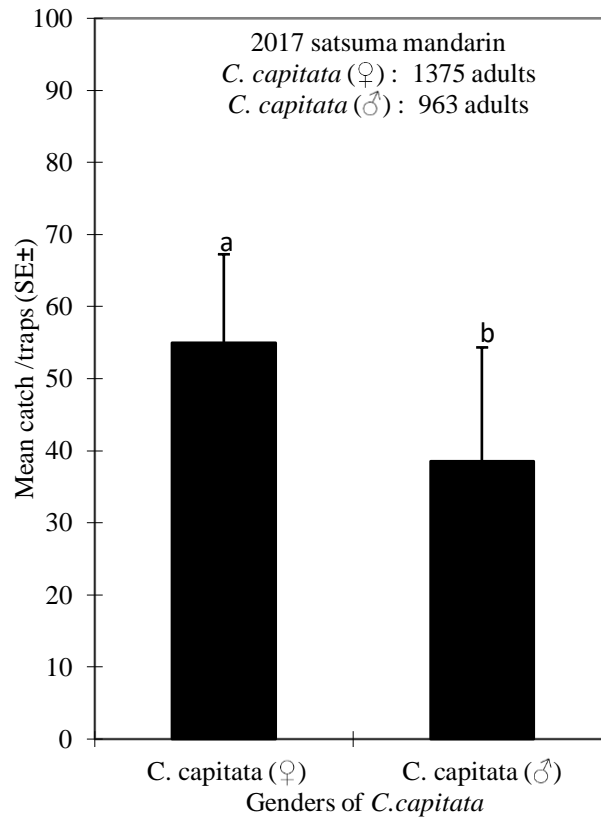


Figure 2. Mean (\pm SE) catches of medfly adults with traps baited with attractants (4 August-16 November, 2017) at satsuma mandarin orchard. Different letters above bars indicate significant differences according to Least Significant Difference (LSD) ($P < 0.05$)

Şekil 2. Satsuma mandalina bahçesinde (4 Ağustos-16 Kasım 2017) tarihleri arasında cezbedici içeren tuzaklar tarafından yakalanan *Ceratitis capitata* ortalamaları (\pm SE). LSD ($P < 0,05$) göre çubukların üzerindeki farklı harfler önemli farklılıkları gösterir

The trimedlure, ceralure, protein-based baits and lures are important components to detect, monitor and control of *C. capitata* on various fruits (Beroza et al., 1961; Cunningham, 1989; Heath et al., 1995; Heath et al., 1997; Gilbert & Bingham, 1999; IAEA, 2003; Navarro-Llopis et al., 2008; Shelly et al., 2014; Demirel & Akyol, 2017; Kılıç & Demirel, 2018; Demirel et al., 2018; Demirel, 2019ab; Sayım, 2019; Demirel, 2023a). The trimedlure and ceralure are widely used as synthetic attractant for males of *C. capitata* (Beroza et al., 1961; Leonhardt et al., 1987; Jang et al., 2003; IAEA, 2003; Akyol, 2014; Kılıç, 2015; Demirel & Akyol, 2017; Gürbüz, 2018; Kılıç & Demirel, 2018; Demirel, 2023a). Traps baited with protein-based baits and lures are also used for capture of males and females of *C. capitata* (Heath et al., 1997; IAEA, 2003; Navarro-Llopis et al., 2008; Shelly et al., 2014; Demirel et al., 2018; Acar, 2019; Demirel, 2019ab; Sayım, 2019; Yiğit, 2019; Çay, 2021; Acımiş Sarigül, 2022; Demirel, 2023a). In addition, the food-based lures capture both females and males (Epsky et al., 1999; IAEA, 2003; Shelly et al., 2014; Demirel et al., 2018; Acar, 2019; Demirel, 2019ab; Sayım, 2019; Yiğit, 2019; Çay, 2021; Acımiş Sarigül, 2022; Demirel, 2023a), whereas food-based baits have been reported to cause the high capture of nontarget insects (Katsoyannos et al., 1999; Boulahia Kheder & Jerraya, 2010; Boulahia-Kheder et al., 2012; Çalıkılı, 2015; Demirel, 2019ab).

The formulations of ammonia have been produced for use as lures in fruit fly traps, including ammonium acetate, ammonium bicarbonate and ammonium carbonate (Shelly et al., 2014; Demirel, 2019ab; Demirel, 2023a). In addition, ammonium acetate, putrescine (Heath et al., 1995; Demirel et al., 2018; Demirel, 2019a), ammonium acetate, putrescine, trimethylamine (Heath et al., 1997; Demirel et al., 2018; Demirel, 2019a; Demirel, 2023a), ammonium acetate, trimethylamine, cadaverine (Navarro-Llopis et al., 2008; Demirel et al., 2018; Demirel, 2019a; Demirel, 2023a), ammonium acetate, n-methyl pyrrolidine (Navarro-Llopis et al., 2008) and ammonium acetate, trimethylamine (Navarro-Llopis et al., 2008; Demirel et al., 2018; Demirel, 2019ab) were used for luring *C. capitata*. Moreover, ammonium carbonate has long been known to attract females of *C. capitata* (Gothilf & Levin, 1989; Reynolds & Prokopy, 1997; Demirel et al., 2018; Demirel, 2019ab; Demirel, 2023a). Furthermore, an effective female-targeted trapping system baited with ammonium acetate, putrescine and trimethylamine was developed (Heath et al., 1997; Katsoyannos et al., 1999; Demirel et al., 2018; Demirel, 2019a; Demirel, 2023a). Several studies have confirmed the high selectiveness and effectiveness of the combinations of several synthetic food attractants based on ammonium acetate, putrescine and trimethylamine for *C. capitata* females capture (Heath et al., 1997; Epsky et al., 1999; Miranda et al., 2001; Alemany et al., 2004; Demirel et al., 2018; Demirel, 2019a; Demirel, 2023a). Demirel (2019b) reported that the trapping the genders of *C. capitata* on pomegranate fruits with various attractants varied in each of the sampling years. In the first year, a total of 2,789 *C. capitata* adults (1619♀, 1170♂) were caught by attractant traps at the 'Katırbaşı' pomegranate orchard. The highest mean of male, female and male + female of *C. capitata* were caught by the combination of ammonium acetate + ammonium carbonate attractant traps. In the second year, a total of 7,787 *C. capitata* adults (5271♀, 2516♂) were caught by attractant traps at the 'Hicaz' pomegranate orchard. The highest mean of male *C. capitata* was caught by the combination of ammonium acetate + ammonium bicarbonate attractant traps. Demirel et al. (2018) reported that effectiveness of various attractants to medfly on pomegranate fruits in Hatay province. The effectiveness of various attractants to *C. capitata* on pomegranate fruits varied in each of the sampling years and variety of pomegranate. In 2015, a total of 6,444 medfly adults were caught by attractant traps at the 'Hicaz' pomegranate and the highest mean of catches were caught by the combination of ammonium acetate + ammonium bicarbonate attractant traps. In 2016, a total of 5,482 medfly adults were caught by attractant traps at the 'Katırbaşı' pomegranate and the highest mean of catches were caught by the combination of ammonium acetate + trimethylamine + diaminoalkane (cadaverine) attractant traps. Demirel (2023b) reported that the study was conducted in 2016-2018 to determine comparison of food-based synthetic attractants for capture of *C. capitata* on persimmon fruits in Dörtöyol and Antakya district of Hatay province. As a result of two years of investigations, efficacy of various attractants varied in each of the sampling years. In 2016, the highest mean of *C. capitata* were observed by the combination of ammonium acetate

+ ammonium carbonate attractant traps. In 2018, the highest mean of *C. capitata* were observed by a single of ammonium carbonate and ammonium bicarbonate attractant traps.

In conclusion, after two-year of the study, the effectiveness of attractants for genders of *C. capitata* varied in each of the variety and sampling year. In 2016, the highest mean of the males of *C. capitata* was caught by the combination of ammonium acetate + trimethylamine + putrescine attractant traps. In 2017, the highest mean of male, female and male + female of *C. capitata* were caught by the ammonium acetate attractant traps. In both years, the mean of females was significantly higher than the mean of males. In addition, the percent of females was significantly higher than the percent of males.

STATEMENT OF CONFLICT OF INTEREST

The author(s) declare no conflict of interest for this study.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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