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Effect of density and color on the trapping efficiency of the Kairo-pheromonal trap for date palm fruit stalk borer, *Oryctes elegans* Prell (Coleoptera: Scarabaeidae)

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Abstract

The date palm fruit stalk borer, *Oryctes elegans* Prell (Coleoptera: Scarabaeidae), is one of the most destructive endemic pests of palm groves in Iran. Recently, there has been a trend toward using kairomone or pheromone trapping as a preferred method of controlling this borer to preserve and protect the environment. The current field study examined the effects of trap density (6 or 10 traps/ha) and trap color (black, white, red, and yellow) on the attraction of adults of *O. elegans* to a Kairo-pheromonal diffuser (Ferrolure manufactured by Econex Ltd, Spain) in four infested date palm groves in Shalheh-ye Emam Hasan, Abadan, southwestern Iran. Among the test density, 6 traps/ha could accurately detect the presence of adults of *O. elegans* in the field and help monitor *O. elegans*. However, 10 traps/ha caught significantly more adults than 6 traps/ha. At both densities, trap colors significantly affected adults' mobility and dispersal to traps. The black traps captured the most significant number of adults in the field, followed by the yellow, red, and white traps. In addition, there was no significant difference between the total numbers of adults captured in traps with different colors during four different times of sampling. As a result, the black traps with 10 traps/ha yield better results at capturing in the field. Our results provide the basic information for developing a safe mass trapping system to control *O. elegans*.

Keywords: Oryctes elegans, Palm tree, Kairo-pheromonal trap, trap color, trap density

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Introduction

Oryctes elegans Prell (Coleoptera: Scarabaeidae), a date palm fruit stalk borer, is a pest of palm trees found throughout Southeast Asia and the Middle East (Buxton, 1920; Al- El-Haidari & Al-Hafidh, 1986; Deghairi, 2007; Ratcliffe & Ahmed, 2010) and is endemic in Iran (Gharib, 1970). *Oryctes elegans* adults bore tunnels into the palm's living parts, such as the petioles of fronds, the stems of inflorescences, and the stalks of fruit bunches, causing them to break off in the wind (Buxton, 1920; Hussain, 1963). The larvae are found in frond axils and at the junction of dead and living tissue in crowns, where they may dig a gallery toward the growing point (Buxton, 1920; Bedford, 1980; Al-Deghairi, 2007). Thus, other pathogens gain access to these galleries, resulting in secondary infections and complications (Gurr et al., 2009; Ghaedi et al., 2020). This pest results in economic losses to young date palms between 10 and 20 years old (Latifian et al., 2012). This palm borer is univoltine in Iran, producing only one generation per year (Gharib, 1970; Fasihi, 2011; Ghaedi et al., 2020). Because this pest is nocturnal and attracted to light, Ghaedi et al. (2020) investigated the pest's seasonal activity in Khuzestan province and discovered that the population began activity in late February to early March (winter). The population continued to grow throughout the spring and early summer, and the maximum density was calculated at the end of June and ended in October.

Controlling *O. elegans* populations has always been difficult, owing to the species' unique biology, the damaged larval stages inside the trunk, and the fact that insecticides are rarely effective in controlling them (Fasihi, 2011). Behavioral control, which may include using pheromones, is a more effective and safer method of managing the date palm borer population in date palm orchards (Khalaf et al., 2013). Male *O. elegans* produce a pheromone called male aggregation pheromone (4-methyloctanoic acid) that attracts both sexes in nature. The presence of odor from fresh date palm tissue significantly enhances the attractiveness of this pheromone (Rochat et al., 2004). Rochat et al. (2004) and Tabrizian et al. (2006) provide additional information on the laboratory protocols for synthesizing this olfactory compound (pheromones).

Numerous companies, such as Econex Ltd., Murcia, developed this male aggregation pheromone as a pheromone or Kairo-pheromone for use in detecting, monitoring, and mass trapping *O. elegans* in IPM (Econex Ltd, Murcia, Spain). However, as with other insects whose volatile semiochemicals are extracted and studied in ecological relationships, it should always be noted that factors such as density (Faleiro et al., 2011; Giblin-Davis et al., 2013), trap location (Mohammadpour & Avand-Faghih, 2008; Reddy et al., 2011), host plant bait quantity (odor from fresh date palm tissue) (Hallet et al., 1999; Abdallah & Al-Khatri, 2005; Abuagla & Ali Al-Deeb, 2012; Mohammadpour et al., 2018), trap shape (Ávalos & Soto, 2013; Vacas et al., 2013), and trap color (Hallett et al., 1999; Faleiro, 2005; Al-Saoud et al., 2010; Abuagla & Ali Al-Deeb, 2012) act as pheromone synergists affecting pheromone trapping and adult attraction.

Regarding *O. elegans*, despite research on its pheromone or Kairo-pheromone, no data on its efficiency in nature are available, which means that improving trap performance and making traps more reliable tools for integrated control programs will require a more precise characterization of the factors affecting trap capture efficiency. The purpose of this study is to determine the effect of trap density and color on *O. elegans* adult attraction in a field experiment in order to develop an efficient Kairo-pheromone-based trapping method for controlling *O. elegans* in date palm groves throughout the world.

Materials and methods

Study Area

The experiment was conducted between early June and late July 2020 in four infested date palm groves consisting of (1) 30°12'14.4"N, 48°24'48.6"E, (2) 30°12'15.6"N, 48°24'52.6"E,

(3) 30°13'17.6"N, 48°24'31.1"E and (4) 30°12'36.3"N, 48°25'32.5"E, respectively, in Shalheh-ye Emam Hasan, a village on the Arvandkenar river in Abadan, Khuzestan Province, southwestern Iran. Date palm trees were the dominant vegetation, predominately Barhi and then Estameran varieties of various ages (5-60 years old).

Trap characteristics and treatment

The traps were constructed using 20-L plastic buckets (height = 39 cm; bottom = 32 cm; upper= 32 cm) with four radial openings (7 cm) spaced 10 cm apart from the bucket's base and one opening on the bucket's lid. Chemical attractants included a Kairo-pheromonal dispenser hound attached to the trap lid (Ferrolure manufactured by Econex Ltd, Murcia, Spain). Additionally, each trap had a 5-liter soapy water solution poured into the bottom to kill and retain trapped *O. elegans*. This experiment tested 6 and 10 traps/ha densities, with traps colored black, white, red, and yellow. Traps were placed beneath the palm tree canopy in the manner described by Mohammadpour and Avand-Faghih (2008); in this position, the adults have a larger landing surface, which facilitates their entry; as a result, the traps capture more beetles. The distance between traps was set at ten meters.

The traps were checked at regular intervals of 15 days to collect *O. elegans* adults. The pheromone-kairomone dispensers had a two-month shelf life (Econex Ltd, Murcia, Spain).

Three light traps equipped with 250-watt lamps were installed at three different plantation date palms infested with *O. elegan*s to evaluate their performance and collect data on adult activity. From mid-May to the end of August, the light traps were operated daily from sunset to sunrise. Every two weeks, collected *O. elegans* adults were removed from traps.

The experimental design included 64 traps distributed in six or ten replications, each with four treatments (one of each color under study) and adults captured at four different times between early June and late July 2020. SAS procedures were used to analyze the data (SAS Institute Inc. 2003). The GLM procedure fitted a one-way ANOVA model to analyze the data for each density. The data was analyzed using a randomized complete block design (RCBD) with two factors: trap color and time, to determine whether trap color affects the number of female/male captures at four different times. The data were checked for normality and, if deemed necessary, corrected. Duncan's Multiple Range Test ($\alpha = 0.05$) was used to separate the means. At the $P < 0.05$ level, the mean differences were considered significant. Additionally, the Mann–Whitney U test compares males' and females' attraction to color traps.

Figure 1. (a) The four colors tested trap (b) the inside and lid of the trap.

Results

The results in Table 1 demonstrate the field efficiency of the colored Kairo-pheromonal trap in both densities, four distinct colors, and a time factor of "two weeks interval" on the mean number of *O. elegans* male/female captured during an eight-week sampling period from early June to late July 2020. When the number of *O. elegans* adults captured in the 6 and 10 traps/ha densities was compared, a significant difference between the two densities was observed. The 10 traps/ha captured a significantly greater number of *O. elegans* adults (Table 1). Furthermore, the colored bucket trap investigation revealed that adults were significantly more attracted to the black trap than to the yellow, red, and white traps in both densities (Figure 2).

The 6 trap/ha results indicated a significant difference in the mean number of *O. elegans* adults captured in each colored trap (sum of male and female) (H = 8.294; *df*=3, 23; *P* =0.040). The evaluation of colored traps (6 traps/ha) revealed that a total of 12 *O. elegans* adults were captured over an eight-week sampling period from early June to late July 2020 (sum of male: female/ 2:10), 7 in the black trap (0.40 ± 0.5), 2 in the yellow trap (0.09 ± 0.06), 2 in the red trap (0.09 ± 0.06), and 1 in the white trap (0.04 ± 0.04). Tables 1 and 2 present the results of a possible effect of trap color on the number of captured female/male adults at four different times and their significance. The results indicated that the two males captured in traps were caught using black bucket traps, but this was not significantly different from other traps. However, the number of adult males captured in different trap colors varied over time, and male attraction was observed only during the first two weeks. Furthermore, the number of adult females captured in bucket traps of various colors at various times and in bucket traps of various colors did not differ (Table 1 and 2).

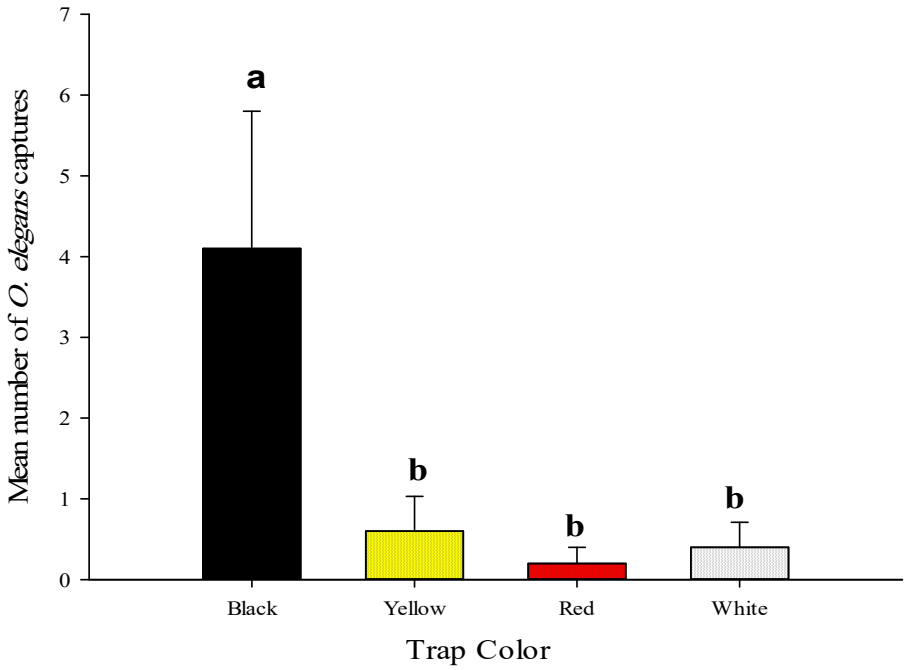

Figure 2. Mean (± SE) number of *Oryctes elegans* adults captured in different colored traps from early June to the end of July 2020, in three palm tree groves at Shalheh-ye Emam Hasan, Abadan, Iran.

Table 1. Mean (± SE) number of *Oryctes elegans* female/male captured in colored Kairo-pheromonal diffuser traps from early June to end of July 2020, in three palm tree groves at Shalheh-ye Emam Hasan, Abadan, Iran.

Trap density	Trap color							
Weeks	**Black**		**Yellow**		**Red**		**White**	
6 Traps	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
The 1st 15 days	0.33±0.22A*a**	0.17±0.17Aa	0 Aa	0 Aa	0.17±0.17 Aa	0 Aa	0 Aa	0 Aa
The 2nd 15 days	0.33±0.22 Aa	0.17±0.17Aa	0.17±0.17 Aa	0 Aa	0.17±0.17 Aa	0 Aa	0.17±0.17Aa	0 Aa
The 3rd 15 days	0.17±0.17 Aa	0 A	0.17±0.17Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa
The 4th 15 days	0 Aa	0 A	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa
10 Traps								
The 1st 15 days	0.7±0.3 Aa	0.4±0.27 Aa	0 Ab	0 Aa	0 A	0 A b	0 A	0 Ab
The 2nd 15 days	0.7±0.26 Aa	0.3±0.21 Aa	0.3±0.21 Aa	0.2±0.13 Aa	0 Aa	0 Aa	0.2±0.2 Aa	0 Aa
The 3rd 15 days	0.8±0.2 Aa	0.2±0.13 Ab	0.1±0.1 Ab	0 Aa	0 Ab	0.2±0.2 Aa	0.2±0.2 Ab	0 Aa
The 4th 15 days	0.4±0.27 Aa	0.4±0.27 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa

* Means in a row with followed by same capital letter were not significantly different based on Duncan's Multiple Range Test (α=0.05).
** Means in a column followed by same small letter were not significantly different based on Duncan's Multiple Range Test (α=0.05).

Table 2. Split-plot analysis of variances of the effect of different trap colors and time of checking these traps on the number of captured female/male adults *Oryctes elegans* from early June to the end of July 2020, in three palm tree groves at Shalheh-ye Emam Hasan, Abadan, Iran.

	df	SS Mean Square	F Value	Pr > F
Male (6 trap)				
Rep.	5	0.04046296	2.79	0.0285
Color	3	0.01201499	0.83	0.4849
Rep.* Color	15	0.01404321	0.97	0.5011
time	3	0.03979277	2.75	0.0544
Color* time	9	0.01414609	0.98	0.4723
Rep.* time	15	0.04182099	2.89	0.0033
Female (6 trap)				
Rep.	5	0.30766667	1.81	0.1312
Color	3	0.25248843	1.48	0.2323
Rep.* Color	15	0.17203704	1.01	0.4626
time	3	0.19693287	1.16	0.3370
Color* time	9	0.10509259	0.62	0.7758
Rep.* time	15	0.21648148	1.27	0.2602
Male (10 trap)				
Rep.	9	0.19085644	1.77	0.0866
Color	3	0.38239064	3.55	0.0181
Rep.* Color	27	0.15582647	1.45	0.1052
time	3	0.22129960	2.06	0.1128
Color* time	9	0.08988477	0.84	0.5861
Rep.* time	27	0.10250960	0.95	0.5405
Female (10 trap)				
Rep.	9	0.72062521	4.55	<.0001
Color	3	3.57197592	22.56	<.0001
Rep.* Color	27	0.42975173	2.71	0.0003
time	3	0.26440476	1.67	0.1802
Color* time	9	0.11027167	0.70	0.7101
Rep.* time	27	0.21083130	1.33	0.1646

Table 1 shows the results from 10 colored traps/ha. The evaluation of colored traps revealed that 47 *O. elegans* adults were caught in colored traps over an eight-week sampling period from early June to late July 2020, 35 in black traps, 6 in yellow traps, and 2 in red and 4 in white traps. A statistical comparison of the mean number of *O. elegans* adults captured during an eight-week sampling period using the four different colored traps revealed a significant difference between the black and other colored traps (Table 1 and 2, Figure 3). The data for the effect of colored traps and the time factor "two weeks interval" on the mean number of *O. elegans* male/female captured with ten traps over an eight-week sampling period indicates that there was no significant difference in the mean number of males captured between the four trap colors tested or between male captures at different times.

Moreover, these findings indicate that the trap's color had a significant effect on the number of females captured in these traps. Black traps captured the greatest number of *O.elegans* adult females, significantly more than yellow, red, or white traps (Table 1 and 2). Despite this finding, the number of *O. elegans* females captured in traps during the first 15 days (F = 12.97; df=3, 39; P =0.0005), the second 15 days (F = 6.185; df=3, 39; P =0.103), the third 15 days (F = 15.385; df=3, 39; P =0.002) and the fourth 15 days (F = 6.158; df=3, 39; P =0.104) were significantly different.

However, there was no statistically significant difference in the mean number of *O. elegans* females captured in each colored trap during these weeks. Females were significantly more attracted to traps than males (females 0.2 ± 0.04/ males 0.09 ± 0.03, 68:32) (Mann–Whitney U = 11920, P = 0.038).

However, this field evaluation of Econex's Kairo-pheromonal diffuser revealed that it did not attract enough adults of *O. elegans* and was inefficient for commercial operations.

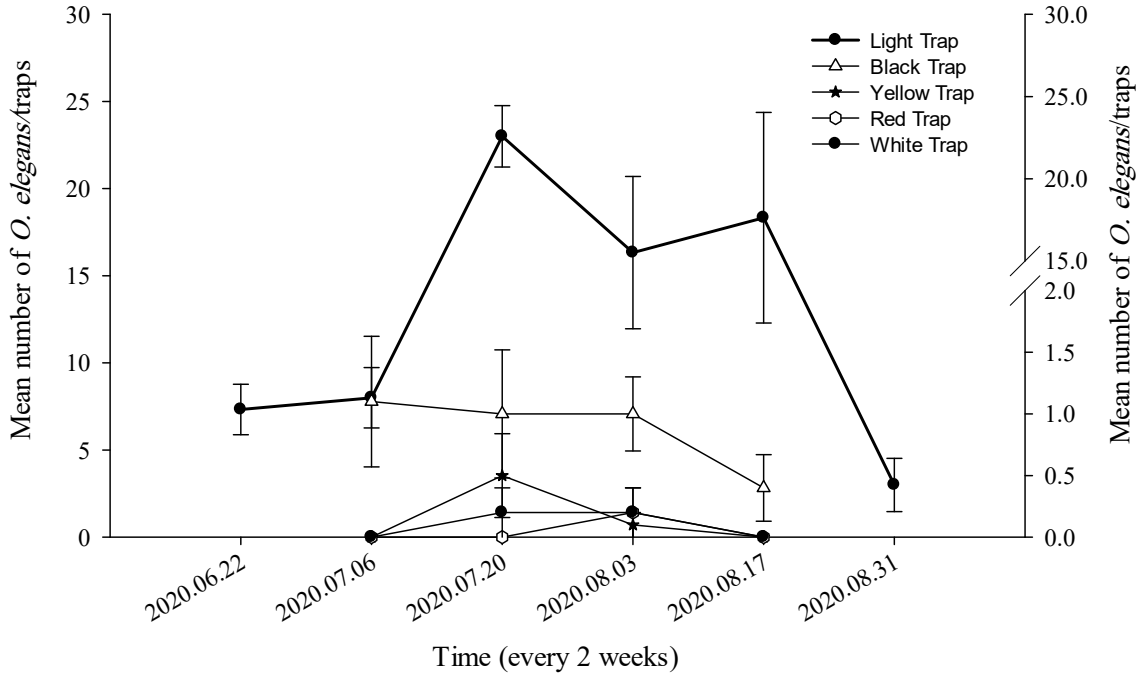

Figure 3. Mean (± SE) number of *Oryctes elegans* adults captured in light and colored traps from early June to the end of July 2020, in three palm tree groves at Shalheh-ye Emam Hasan, Abadan, Iran.

Discussion

Oryctes elegans is an endemic pest of Arecaceae, particularly palm groves in Iran (Gharib 1967; Ghaedi et al., 2020). In general, physical control of this borer in this area is accomplished through annual servicing, which includes mechanical sanitation, pruning of old and nearly dried fronds, removing fiber layers between fronds and old dried bunches, and handpicking of larvae discovered later on serviced the palm at the axils of fronds, the junction of dead and living tissue in crowns, or beneath offshoots (Gharib, 1970; Rochat et al., 2004). Another common technique is mass trapping an adult with a suitable light source, such as a mango trap equipped with a lamp of 320-420 wavelength or a 250-watt white lamp, during their activity in palm groves (Khalaf and Al-Alrubiae, 2015 ; Ghaedi et al., 2020).

Recently, integrated pest management has emphasized using pheromones and kairomones trapping as effective methods for monitoring and controlling pests, particularly date palm borer, in areas where pesticide application is ineffective while also minimizing pesticide use in the ecosystem. The majority of research in this field on date palm pests focuses on the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Dryophthoridae) (Hallett et al*.,* 1999; Abuagla & Ali Al-Deeb, 2012; Giblin-Davis et al., 2013).

However, the Kairo-pheromonal diffuser managed by Econex did not perform satisfactorily in mass capturing adults of *O. elegans* in this study. Nonetheless, traps at a density of 6/ha were capable of accurately detecting the presence of adults of *O. elegans* in the field and assisting in *O. elegans* monitoring. Oehlschlager (1994) recommended a trapping density of one trap/ha for *R. ferrugineus* mass traps. According to Giblin-Davis et al. (2013), trap densities range from 1 trap/ha to 1 trap/100 ha for monitoring and between 1 and 10 traps/ha for mass trapping of *R. ferrugineus*. However, it should be considered that after a period of using the traps in an area, the trapping density will decrease as the initial level of infestation decreases (Soroker et al., 2005).

In the current study, the trap colors most likely influenced the mobility and dispersal of adults to traps, thereby indirectly affecting the efficacy of *O. elegans* Kairo-pheromonal traps. The black traps captured the most adults, followed by the yellow, red, and white traps, respectively. Similarly, Ávalos and Soto (2015) found that adults of *R. ferrugineus* were significantly more attracted to black traps than to red or white traps. Additionally, Abuagla and Al-Deeb (2012) noted that adults were more attracted to the 10-liter black bucket trap than to the red, white, or yellow bucket traps in the case of *R. ferrugineus*. The higher temperatures in the black traps could result in increased pheromone release, which would increase adult captures (Hallett et al. 1999). According to Ávalos and Soto (2015), *R. ferrugineus* adults are attracted to traps through a two-step process: first, long-distance attraction to semiochemicals, and second, short-distance visual attraction to trap color and semiochemicals. Both factors may act synergistically to increase the number of adults trapped.

Although many research studies found that black was the preferred color of *R. ferrugineus*, Ajlan and Abdulsalam (2000) found that green bucket traps captured the most adult weevils, Sansano et al. (2008) discovered that reddish-brown traps were more attractive to *R. ferrugineus* than white traps or traps disguised with palm stem fibers. According to Al-Saoud et al. (2010), red traps captured significantly more weevils than white or yellow traps.

Yellow was the second most efficient trap color in our study, capturing significantly more adults than other colors. Martnez et al. (2008) captured more *R. ferrugineus* adults in yellow traps than red or white traps. Abuagla and Al-Deeb (2012) obtained more weevils in a red bucket trap than in a white bucket trap and the fewest in a yellow bucket trap.

The population dynamics of *O. elegans* revealed that the adult sex ratio is always female-biased (Zarghami et al., Unpublished data). Thus, the higher female capture rate than male capture rate in all traps is due to the presence of more females

in the field and the fact that females are more strongly attracted to semiochemicals bait traps than males, regardless of their color. This behavior results from their need for new breeding locations, food sources, and oviposition sites.

In conclusion, our study demonstrated that trap density and color of the traps significantly affect *O. elegans'* response to Kairo-pheromonal traps. In particular, a black bucket trap set at a density of 10 traps/ha effectively captured *O. elegans* in the field. These findings should be incorporated into the development of mass trapping techniques for this significant palm borer pest.

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بررسی نقش تراکم و رنگ در شکار تله کایمون-فرمونی سوسک شاخدار خرما *Oryctes elegans* Prell (Coleoptera: Scarabaeidae)

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چکیده

سوسک شاخدار خرما *Oryctes elegans* Prell (Coleoptera: Scarabaeidae) یکی از مخرب‌ترین آفات چوب‌خوار نخیلات در ایران می‌باشد. در سال‌های اخیر استفاده از فرمون‌ها و کایرمون‌ها به عنوان یک روش ایمن در کنترل آفات به منظور حفاظت از محیط زیست بسیار رایج شده است. پژوهش حاضر مطالعه صحرایی جهت ارزیابی نقش تراکم تله (٦ و ١٠ تله/هکتار) و رنگ تله (سیاه، سفید، قرمز و زرد) در جلب و شکار تله کایرمون-فرمونی پیشنهادی شرکت اکونکس در ٤ نخلستان آلوده به سوسک شاخدار واقع در روستای شلحه امام حسن، آبادان، جنوب غرب ایران می‌باشد. نتایج نشان داد اگرچه تعداد ٦ تله در هکتار می‌تواند در ردیابی آفت در منطقه کمک کند، اما تعداد ١٠ تله در هکتار به طور معناداری شکار بیشتری خواهد داشت. در هر دو تراکم رنگ تله به طور معناداری نقش موثری در حرکت سوسک‌های بالغ به سمت تله‌ها داشت و در میان ٤ رنگ انتخابی، رنگ مشکی و سپس به ترتیب زرد، قرمز و سفید حداکثر شکار بالغین را داشتند. اگرچه در ٤ بازه زمانی (دو هفته یک‌بار) مورد بررسی شکار بالغین در تله‌ها تفاوت معناداری نداشت. بر اساس نتایج بدست آمده، به منظور شمار انبوه بالغین، تعداد ١٠ تله کایرمون-فرمونی با رنگ مشکی بیشترین شکار را خواهد داشت. پژوهش حاضر نخستین تحقیق در دنیا در خصوص نقش تراکم و رنگ تله در کارایی تله کایرمون-فرمونی سوسک شاخدار خرما می‌باشد و این نتایج اطلاعات ارزشمندی در نحوه استفاده از تله کایرمون-فرمونی جهت شکار انبوه سوسک‌های شاخدار خرما دارد.

کلیدواژه ها: Oryctes elegans، نخل خرما، تله کایرمون-فرمونی، رنگ تله، تراکم تله

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