Journal of Plant Diseases and Protection
https://doi.org/10.1007/s41348-024-00917-x

ORIGINAL ARTICLE

Comparison of yellow sticky trap traits and placement for monitoring *Anthonomus eugenii* (Coleoptera: Curculionidae) adults in outdoor peppers (*Capsicum* spp.)

Walter Arturo Rubio-Aragón[1] · Jorge Alberto Edeza-Urías[1] · Azareel Angulo-Castro[1] · María Alejandra Payán-Arzapalo[1] · Jesús Enrique Retes-Manjarrez[2] · Guillermo Gómez-González[3] · Edgardo Cortez-Mondaca[4] · Carlos Alfonso López-Orona[1]

Received: 9 January 2024 / Accepted: 30 March 2024

Abstract
Opportune detection of *Anthonomus eugenii* is a fundamental aspect of any management program to this pest. Yellow traps are the most common monitoring strategy, and its efficacy is related with the trap design and placement within crops. However, there's limited information on this. Two outdoor experiments were performed to determine the efficiency of traps with six different shapes (circle, square, diamond, ellipse, rectangle, and triangle) and seven frame colors (yellow, dark green, black, red, white, purple, and blue); seven to the traps placement at four orientations (North, South, East and West), five aside distances from the bed center (0, 20, 40, 60 and 80 cm aside to the inter-bed space) and six heights (0, 20, 40, 60, 80 and100 cm) on *A. eugenii* adults. There wasn't significant difference among shapes and orientations. Traps with yellow, dark green and black frames had the highest number of insects. For the aside distance, the plots were categorized according to their width as narrow (54–65 cm) and wide (71–81 cm), the highest insects caught was exhibited on traps at 0–20 and 0–40 cm, respectively. Regarding the traps height, they were classified according to their height as short (62–64 cm), medium (78–82 cm) and tall (90–92 cm), the highest insects caught was exhibited on traps at 20–40, 40–60, and 40–80 cm, respectively. Regression analyzes indicate that catches decrease as the traps are installed into the inter-bed space and above the canopy. This study provides novel information to improve outdoor programs to monitor *A. eugenii*.

Keywords Trapping system · Trap design · Monitor · Catch · Pepper weevil

Introduction

Pepper (*Capsicum* spp.) is one of the most economical important crops in the Americas; North America is the main producer region within the continent, with around 167,149 ha cultivated in 2021, representing about 70.80% of the total area cultivated to peppers in the Americas (FAO 2019). Peppers growing in outdoors conditions are the most common in North America with over 85% of its total area cultivated in 2021 under this growing system (SIAP, 2023).

The pepper weevil, *A. eugenii* (Cano) (Coleoptera: Curculionidae), is one of the most damaging pests of peppers in North America, especially in the southern United States and Mexico (Fernández et al. 2020). Every cultivated pepper specie and typology are susceptible to *A. eugenii* (Seal and Martin 2016; Chabaane et al. 2021; Rubio-Aragón et al. 2021, 2022). Heavy outdoor losses have been reported to reach over the 30% up to 100% of the total yield when the insect is not detected and/or the management is not proper (Segarra-Carmona and Pantoja 1988, Riley and Spark 1995, Avendaño-Meza et al. 2015).

One generation is completed in 20–30 days depending on weather, but 3 to 5 generations are normally produced per year; a female lays 5–7 eggs daily with an average fecundity of 340 eggs per lifetime (Capinera 2002). Eggs are deposited

✉ Carlos Alfonso López-Orona
clopezorona@uas.edu.mx

[1] Facultad de Agronomía, Universidad Autónoma de Sinaloa, Culiacán, Sinaloa, Mexico

[2] Fyffes, Finca el Oasis La Fragua, Zacapa, Guatemala

[3] Centro de Investigación en Alimentación y Desarrollo A. C., Culiacán, Sinaloa, Mexico

[4] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Juan José Ríos, Sinaloa, Mexico

individually within a small cavity on the host plants reproductive structures (buds, flowers, and fruits) and covered with a slight filling of mucilaginous anal secretion (Toapanta et al. 2005). All immature life stages of *A. eugenii* occur inside these structures and the larvae internal damage causes their premature drop (Elmore et al. 1934; Riley and Sparks 1995; Chabaane et al. 2021). After pupation, the adults chew a circular hole through the reproductive structure pericarp to emerge (Fernández et al. 2020). Pepper growers typically notice *A. eugenii* presence in their fields when dropped pods, flowers and fruits with yellow peduncle, blackened conditions, immature stages, and emergence holes are plenty and widespread on the ground which is a common sign of heavy and/or late infestations, (Elmore 1934, Capinera 2002) and the action threshold has been exceeded (Riley and Sparks 1995). Since *A. eugenii* immature stages are restricted and protected in these structures its control is focused on the reduction of the exposed adults mainly through foliar pesticide applications (Qureshi and Kostyk 2020).

An accurate monitoring of *A. eugenii* is a fundamental factor needed to decision-making in an Integrated Management Program designed to keep the insect damage at a minimum possible; direct counting and yellow sticky traps are the most efficient monitoring techniques to opportune detect *A. eugenii* adults within crops (Segarra-Carmona and Pantoja 1988). Among these two methods, the use of the yellow traps is the most used by farmers since is easier to carry out and has lower cost over direct counts (Riley and Schuster 1994).

The effectiveness of agricultural pest sampling programs using yellow traps is highly related with different factors such as the trap design and properly installation within crops. Trap shape and the contrast between colors by adding a colored frame have been reported to influence the perception of major agricultural pests such as *Scirtothrips citri* (T hysanoptera: Thripidae)*, Frankliniella occidentalis* (Thysanoptera: Thripidae) and *Bemisia tabaci* (Hemiptera: Aleyrodidae) (Moreno et al. 1984, Vernon and Gillispie 1995, Mainali and Lim 2010, Kim and Lim 2011, Ren et al. 2020, Rubio-Aragón et al. 2023). So far, there are no studies designed to evaluate these trap traits to *A. eugenii.*

On the other hand, the placement of the sticky traps is also a fundamental aspect to consider, and this is affected by different factors such as the insect involved, crop, production system, orientation, aside distance (installation site of the traps from the center of row/bed to the inter-row/bed space), and deployment height (Bian et al. 2016, Pobozniak et al. 2020, Rubio-Aragón et al 2023). To the best of our knowledge, there is only one study done in *A. eugenii* where the trap orientation and height were evaluated in outdoor conditions (Riley and Schuster 1994) and it results indicate differences among typologies which were attributed to the crops height and structure, being bell pepper smaller (54.8 ± 8.1 height) and more compact in comparison with Jalapeno (83.1 ± 7.8 cm height). On the other hand, recently, the trap aside distance to the inter-bed space have been reported as a major aspect that influence the capture of agricultural pests (Shin et al. 2020; Rubio-Aragón et al. 2023) and for *A. eugenii* this factor has not been evaluated. Therefore, the goals of this study were to determine the efficacy of yellow sticky traps with different traits such as shape, frame color, and placement factors such as orientation, aside distance from the center of bed to inter-bed space and deployment height to monitor *A. eugenii* adults in peppers in outdoor conditions.

Materials and methods

Study establishment

The study was performed in seven pepper plots in three commercial pepper (*Capsicum* spp.) farms in outdoor conditions in Sinaloa, Mexico in three consecutive years (2021–2023). Wooden stakes and nylon ropes were used to keep the plants erected. All peppers were planted on 0.6 m width beds with 1.60 m among bed centers and 0.3 m spacing between plants. All assays were carried out at plant fruiting stage and no insecticides were used. The total area for each assay was approx. of 3275 m^2. Plants width and height was recorded (Table 1).

Manufacture of the traps

The sticky traps were made from cardboard (58 × 89 cm) (250 g/m^2) (José Luis Mondragón y compañia S.A de C. V.), sealed with clear laminating film (polyethylene terephthalate [PET]) (3 mil [0.076 mm]) and coated with an entomological adhesive (Imex-Adhesive, Distribuciones IMEX S. A. de C. V., Zapopan, Jalisco, México) mixed with a commercial insecticide (Oxamil) (Avendaño-Meza et al. 2015) to reduce insects escaping from the layer (Riley and Schuster 1994). Only one side of the traps was glued.

Trap shape and frame color

The trap shape and frame color assays were carried out independently in the winter (February) of 2021 in an Anaheim plot (Table 1). The traps were orientated facing North and located in the center of the bed at the plant canopy (the bottom edge of the trap was just above the top of the plant, Fig. 1). Six different geometrical shapes of 350 cm^2 were evaluated to compare the response of *A. eugenii*. Yellow cardboard [Cyan, Magenta, Yellow, and Key (CMYK), 0.00, 0.09, 0.76, 0.01] was cut into triangle (25.0 cm base and 28.0 cm height), ellipse (15.0 and 8.0 cm axis), rectangle (25.0 cm long and 14.0 cm width), diamond (26.4

Table 1 Tested fields information plus plants width and height ($n=20$)

Species	Crop	Coordinates		Year	Plant width	Width category	Plant height	Height category
		N	W					
Capsicum annuum	Anaheim	25°09′18″	108°05′24″	2021	65 ± 6 cm	Narrow	82 ± 7 cm	Medium
Capsicum annuum	Jalapeno	25°09′18″	108°05′24″	2021	56 ± 4 cm	Narrow	64 ± 5 cm	Short
Capsicum annuum	Caribe	25°09′18″	108°05′24″	2022	58 ± 4 cm	Narrow	62 ± 7 cm	Short
Capsicum annuum	Poblano	25°09′18″	108°05′24″	2022	81 ± 7 cm	Wide	90 ± 8 cm	Tall
Capsicum annuum	Chilaca	25°11′12″	108°05′07″	2023	77 ± 6 cm	Wide	93 ± 10 cm	Tall
Capsicum annuum	Serrano	25°11′12″	108°05′07″	2023	54 ± 4 cm	Narrow	60 ± 6 cm	Short
Capsicum chinense	Habanero	25°27′28″	108′02′24″	2023	64 ± 5 cm	Narrow	78 ± 8 cm	Medium

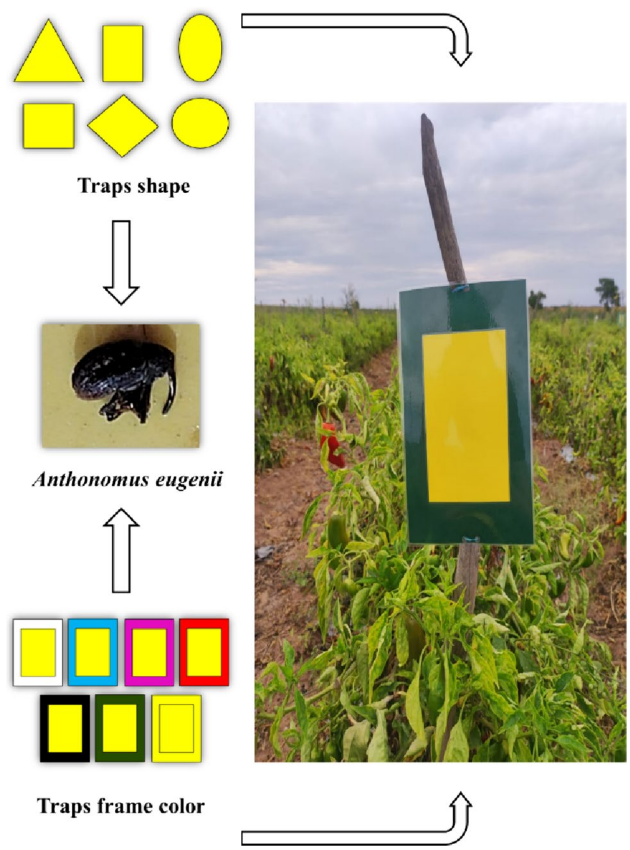

Fig. 1 Diagram of the materials and methods used to evaluate the effect of yellow sticky traps with different shape and frame color to capture *A. eugenii* on an Anaheim pepper plot

and 26.4 cm diagonals), circle (10.6 cm radius) and square (18.70 cm per side) (Fig. 1). Due to its common use and commercial availability rectangle shape was considered as control. Regarding the frame color, yellow rectangles (250 cm^2 [20.0 cm long and 12.5 cm width]) were attached in the center of a larger (500 cm^2 [27.9 cm long and 17.9 cm width]) red (CMYK, 0.00, 0.83, 0.95, 0.03), white (CMYK, 0.00, 0.00, 0.00, 0.00), black (CMYK, 1.00, 1.00, 1.00, 1.00), dark green (CMYK, 0.94, 0.00, 0.41, 0.74), purple (CMYK, 0.00, 0.88, 0.29, 0.25), blue (CMYK, 0.94, 0.18, 0.00, 0.09) and yellow rectangles, the resulting traps (yellow rectangles plus frames) were sealed and glued avoiding the colored frames (Fig. 1). Due to the frame and trap color were similar, yellow frame was used as control.

Trap orientation, aside distance, and height

The effect of the trap orientation, aside distance, and height on the capture of *A. eugenii* was evaluated in every of the seven different crops included in the current study (Table 1). A rectangle-yellow trap of 375 cm^2 (25.0 cm long and 14.0 cm width) was used for the evaluation of these three placement factors. To evaluate the effect of the orientation factor, the traps were installed in the center of the bed at the plant canopy facing North, South, West, and East directions. For the aside distance factor, the traps were installed at the plant canopy level at intervals of 20 cm from the center of the bed to the inter-bed space (Fig. 2). To evaluate the height effect, the traps were installed at intervals of 20 cm from the bed top (Fig. 2); on every plot the traps were 20 cm aside the bed center, excepting Poblano and Chilaca where the traps were at 40 cm aside. When it was necessary the branches were carefully manipulated to avoid obstruction among the traps and the insects, and the fallen pods, flowers and fruits were removed from the ground to avoid adults emergency from these reproductive plant structures (Elmore 1934; Capinera 2002).

Experiment design and statistical analysis

All the assays carried out in the present study were established as a completely randomized design with 15 replications per treatment where a single sticky trap was considered as a replication. The traps were differently installed according with the goal of the experiment as described above using a wooden stake. The sticky traps remain in the field for 12 h and after the period, the insects were directly counted. Every assay was performed twice.

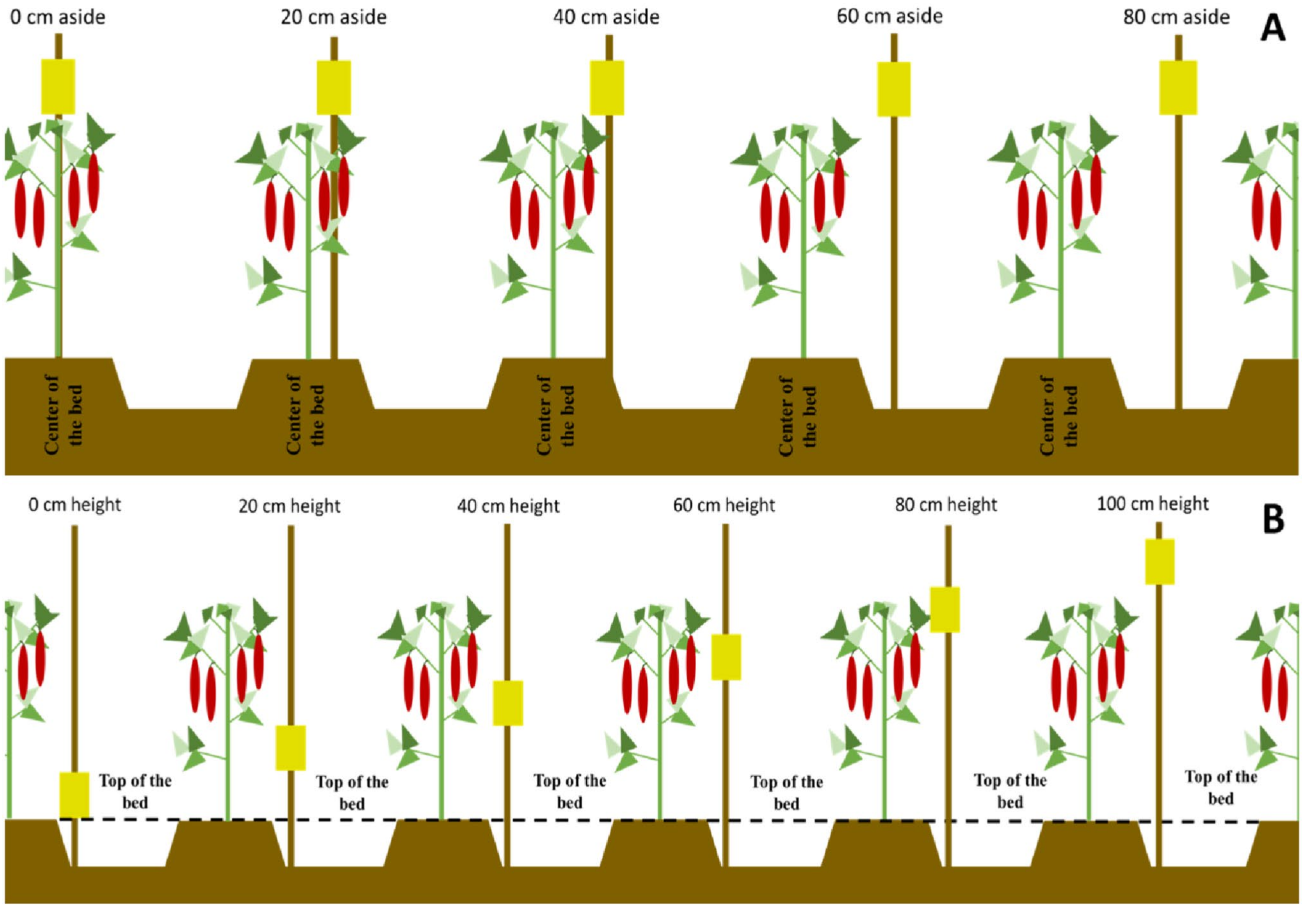

Fig. 2 Diagram of the traps deployment methodology used to capture *A. eugenii* adults. **A** Aside distance (traps were placed starting at the bed center to the inter to the inter-bed space, the center of the traps was at those distances). **B** Height (traps were placed starting from the top of the bed and the bottom edge of the traps was at those heights)

All data were analyzed with the SPSS version 26 statistics software (George and Mallery 2019). The data was transformed to log (x + 1) before analysis to meet the assumptions of normality and homogeneity of variance. Data generated from both replications were combinate since there was no statistical difference among the number of *A. eugenii* caught ($P > 0.05$). Every experiment was analyzed by one-way analysis of variance and Tukey means test to determine significant differences among treatments ($P \leq 0.05$).

Riley and Schuster (1994) report that pepper plants structure traits such as width and height are major aspects that influence *A. eugenii* catch by yellow sticky traps, therefore, for the aside distance of traps to the inter-bed space, data from the crops was combined according with their width into narrow and wide, and for height, short, medium, and tall categories were generated according with their height (Table 1). Additionally, a regression analysis was carried out among the number of insects caught with the trap aside distance and height.

Results and discussion

Trap shape and frame color

There was no significance difference in the number of *A. eugenii* adults caught among the different trap shapes ($F = 0.28$; $df = 5$; $P = 0.925$) (Fig. 3A). The preference of the insects to certain trap shape has been related with their habits (Ren et al. 2020; Rubio-Aragón et al. 2023), since *A. eugenii* oviposition and feeding is not restricted to a single plant structure (Chabaane et al. 2021; Rubio-Aragón et al. 2021, 2022), this might have influenced a lack of shape preference. On the other hand, this lack of shape effect on *A. eugenii* may also be related with the insect relaying on different stimuli to locate its host such as visual and olfactory, including a male-produced aggregation pheromone and plant volatiles (Eller et al. 1994; Addesso et al. 2009, 2011).

A significative difference in the number of *A. eugenii* caught among traps with different frame colors was found ($F = 9.84$; $df = 6$; $P \leq 0.001$). Sticky traps with yellow, dark

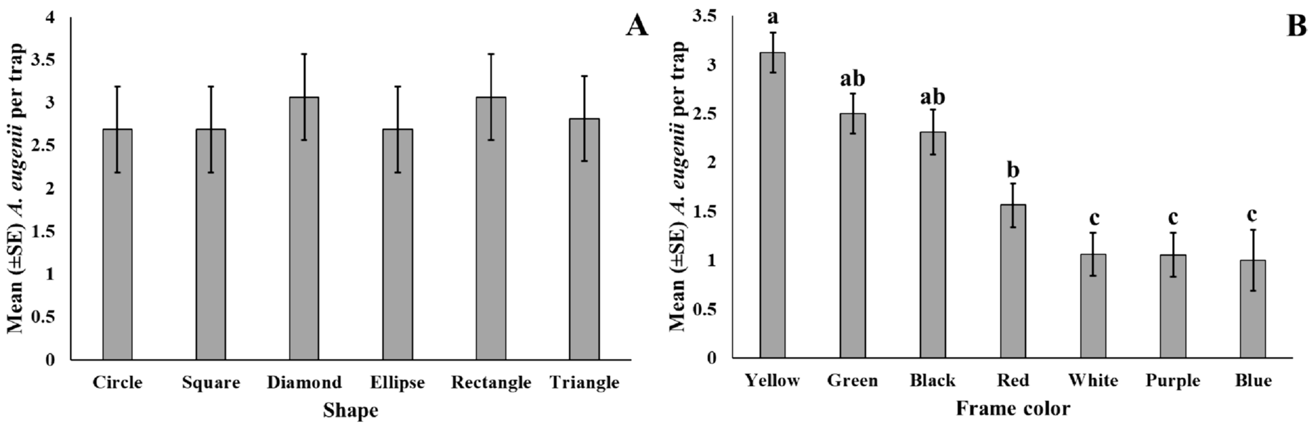

Fig. 3 Mean (± SE) number of *A. eugenii* captured per sticky trap with different geometrical shape **A** and frame color **B**. Columns without and similar letters indicate no significant difference among treatments according with the Tukey means test ($P \leq 0.05$)

green and black frames showed the highest number of insects captured with 3.1, 2.5 and 2.3 average adults per trap, respectively, followed by red with 1.7 insects, and the remaining colors had an average of 1.0 adults per trap (Fig. 3B). These results indicate that the addition of a color frame have an effect in the capture of *A. eugenii* and varies among the different frames of the traps. The combination of a similar colored frame as the trap only increases the total surface since no contrasting effect is created, this might result in a more visible target to farther insects. It has been reported the trap size influence the capture of *A. eugenii* and more adults are caught in bigger sizes (Riley and Schuster 1994). On the other hand, the addition of a dark color frame such as dark green and black minimize the interception from other sources of reflectance, focusing the insect attention to the remaining area (Döring et al. 2004). Yellow sticky traps with a black background have been reported to enhance the capture of *F. occidentalis* (Mainali and Lim 2010) and do not reduce the attraction of *B. tabaci* (Rubio-Aragón et al. 2023) in comparison with standard-monochromatic yellow traps and since both species share peppers as hosts in the Americas with *A. eugenii* (Knapp et al. 2020), these traps could be used in monitoring programs to the three species.

Trap orientation, aside distance, and height

There was no significative difference in the number of *A. eugenii* adults caught among traps installed facing the main four cardinal points (North, South, East, and West) in any of the pepper plots evaluated ($P \geq 0.05$). The trap perception is a function of reflected sunlight, and it changes based on the angular variation of the incident light (Bian et al. 2016) and these results indicate that *A. eugenii* catch is not affected by this factor, agreeing with Riley and Schuster (1994) who also found no difference exhibited by the insect to the trap orientation.

Crops morphological traits are commonly related with the traps optimal installation site and for the aside distance from the bed center to the inter-bed site, the crop width influences this parameter (Rubio-Aragón et al. 2023). The seven plots considered for the study were classified in two categories according to their width as narrow (54–65 ± 5 cm) and wide (77–81 ± 7 cm) (Table 1). A significative difference in the number of *A. eugenii* adults caught among traps installed at different distances from the bed center to the inter-bed space in both width categories was found ($P \leq 0.05$). For the narrow, the highest number of insects caught was exhibited on traps installed at 0 and 20 cm aside the bed center (Fig. 4). Regarding the wide category, was from 0 to 40 cm aside ($F = 12.48$, $df = 4$, $P \leq 0.001$) (Fig. 4). These results indicate that *A. eugenii* catch is affected by the lateral placement of the traps and varies among crops according to their width. Regression analysis of *A. eugenii* (Ae) showed a significant linear approach with the trap aside distance on both categories (Narrow, $Ae = 2.31 - 0.40x$, $R^2 = 0.88$, $P \leq 0.001$; Wide, $Ae = 2.29 - 0.37x$, $R^2 = 0.94$, $P \leq 0.001$), suggesting that the number of insects caught sharply decreases when the traps are installed beyond the plant foliage. A plausible explanation to these results is that *A. eugenii* adults make short, low and semicircular flights between plants (Riley and Schuster 1994) which could make easier they dispersion among plants within the same bed, avoiding the traps installed in the inter-bed space beyond the foliage. The aside distance goal is to exploit the insects flying zone to make the traps more visible and accessible by the insects, and to reduce the collection of plant debris (Shin et al. 2020; Rubio-Aragón et al. 2023). So far, there is a limited number of studies that considers the aside distance of the traps when evaluating they optimal placement site within crops including peppers, to the best of our knowledge, this is the first study which includes the aside distance of

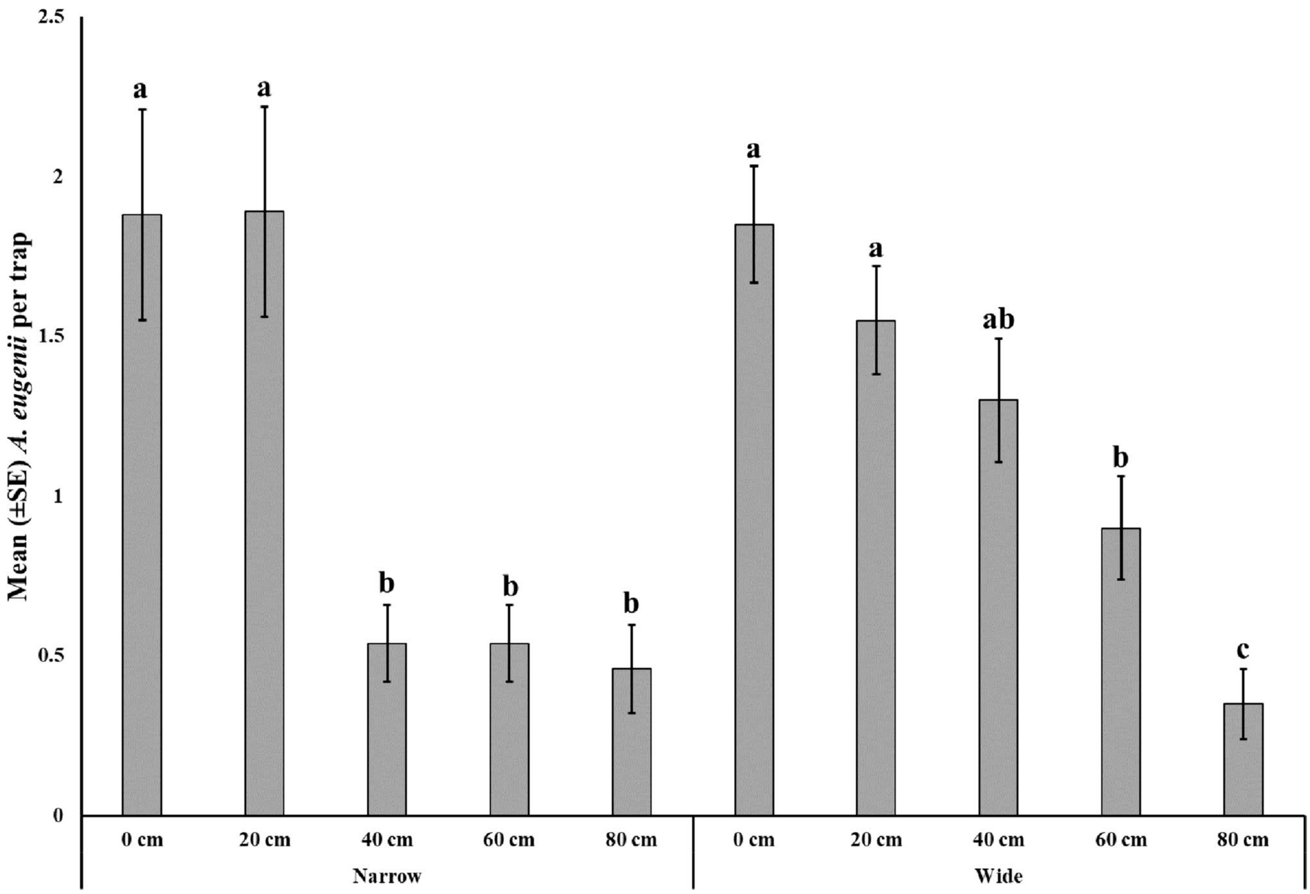

Fig. 4 Mean (± SE) number of *A. eugenii* captured per sticky trap located at different aside distances from the bed center to the inter-bed space in pepper plots categorized as their width. Columns without and similar letters indicate no significant difference among treatments according with the Tukey means test ($P \leq 0.05$)

the traps to the inter space as a relevant placement factor to improve the catching of *A. eugenii* with yellow traps.

On the other hand, the optimal trap height has been associated with the height of the crops (Riley and Schuster 1994), therefore, the plots were classified in three categories according to their height as short (62–64 ± 6 cm), medium (78–82 ± 8 cm) and tall (90–92 ± 9 cm) (Table 1). There was a significative difference in the number of *A. eugenii* adults caught among traps installed at different heights in every of the three categories ($P \leq 0.05$). On the short category, traps installed at 20 and 40 cm above the bed top had significantly the highest number of insects caught ($F = 105.95$, df = 5, $P \leq 0.001$) (Table 2). For the medium, was at 40 and 60 cm height ($F = 63.95$, df = 5, $P \leq 0.001$) (Table 2). Regarding the tall category, traps installed at 40, 60 and 80 cm height had the highest number of insects ($F = 9.65$, df = 5, $P \leq 0.001$) (Table 2). These results indicate that *A. eugenii* capture is affected by the trap height and varies among crops according with their height. Regression analysis of *A. eugenii* (Ae) showed a significant quadratic approach with the trap height within every category (Short, $Ae = 1.10 + 1.67x – 0.31x^2$, $R^2 = 0.71$, $P \leq 0.001$; medium, $Ae = - 1.26 + 2.25x – 0.34x^2$, $R^2 = 0.82$, $P \leq 0.001$; tall, $Ae = - 0.52 + 1.85x – 0.26x^2$, $R^2 = 0.85$, $P \leq 0.001$) suggesting that as the trap increases in

Table 2 Mean (± SE) number of *A. eugenii* captured per sticky trap located at different heights from the bed top in pepper plots categorized as their height

Trap height (cm)	Plant height category				
	Short	Medium	Tall	Short*	Tall*
0	1.9 ± 0.1 b	1.0 ± 0.1 b	1.4 ± 0.2 c	5.4 ± 0.6 a	3.3 ± 0.4 a
20	3.6 ± 0.3 a	1.2 ± 0.1 b	1.7 ± 0.2 b	6.0 ± 0.5 a	3.0 ± 0.4 a
40	4.2 ± 0.4 a	2.9 ± 0.3 a	2.7 ± 0.3 a	6.1 ± 0.4 a	3.0 ± 0.3 a
60	1.5 ± 0.2 b	2.7 ± 0.2 a	3.0 ± 0.3 a	2.8 ± 0.4 b	3.7 ± 0.6 a
80	1.5 ± 0.1 b	1.3 ± 0.1 b	2.5 ± 0.3 ab	1.3 ± 0.3 c	3.1 ± 0.4 a
100	0.3 ± 0.1 c	0.2 ± 0.1 c	1.2 ± 0.2 c	1.4 ± 0.4 c	1.6 ± 0.2 b

Different literals in columns indicate significant difference among treatments according with the Tukey means test ($P \leq 0.05$)

*Extra assay without remotion of fallen buds, flowers and fruits was carried out height so does the number of insects caught but the catches sharply decrease when traps are installed above the plant canopy. A plausible explanation to these results is that *A. eugenii* adults feed and reproduce on young plant structures (Seal and Martin 2016; Chabaane et al. 2021; Rubio-Aragón et al. 2021, 2022), especially those on the plant terminal buds (Riley et al. 1992). On the other hand, Riley and Schuster (1994) reported that due to the insect narrow flying traits within plants, upper canopy level traps are difficult to reach. These results agree with those by Riley and Schuster (1994) who indicated that the optimal catching height for *A. eugenii* varies according to the crop height and the catching rates sharply decrease above the top of the plant canopy, nevertheless, they did not find significative differences among heights below the canopy level as we did. The difference in the results may be due to the conditions of how the studies were carried out. For instance, they counted the insects caught every 2 h to avoid error due to *A. eugenii* was escaping from traps and this could trigger the insect defensive mechanisms such as an intentional fallen from the top of the plants to the ground (Torres-Ruíz and Rodríguez-Leyva 2012) which may have led to greater capture from the traps deployed at low heights. On the other hand, in our assays the fallen buds, flowers and fruits were removed to avoid insects emergence from the ground to avoid an abnormal capture from the traps deployed at low heights (Elmore 1934; Capinera 2002), and in theirs is not indicated. To discard this possibility, an additional evaluation in one plot of short and tall categories (Serrano and Chilaca) was performed without the remotion of fallen reproductive structures. There was no significant difference in the lowest height in comparison with those near the canopy but with those above the canopy level ($P \geq 0.05$) (Table 2). It has been reported that the emergency site of the insects is a major aspect that influence significantly in the capture rates of the nearest sticky traps (Mao et al. 2018; Rubio-Aragón et al. 2023). However, regarding *A. eugenii*, when reproductive structures infested with this insect are found on the soil its populations have exceeded the action threshold (Riley and Sparks 1995).

In summary, *A. eugenii* monitoring can be carried out with yellow sticky traps regardless they geometric shape with a dark green, black or none frame. Traps can be placed in the inter-bed space just next to plants leaf limits and regardless their orientation, traps should be installed just below the plant canopy level.

Contributions

WARA and CALO conceived and designed the experiments. WARA, JAEU, AAC, MAPA, GGG and ECM performed experiments. WARA, JERM and CALO analyzed the data. The first draft of the manuscript was written by WARA and CALO, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgements Authors thanks the Consejo Nacional de Ciencia y Tecnología (CONACYT) for the scholarship granted to Walter Arturo Rubio-Aragón to carry out his Doctoral Studies, the pepper growers Mr. Christian Tapia, Mr. Raúl Sánchez and Mr. Antonio, and Huicharabito S.P.R. de R.I. for the support provided for this research.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The authors declare that (i) The manuscript has not been submitted to another journal, (ii) The submitted work contains original data not published earlier, (iii) The data published are not split up into several parts to increase the personal number of publications, (iv) The current publication is not a secondary publication with the same content, (v) The presented data were not at any manipulated, and (vi) No data, text or theories by others not explicitly cited for their origin are presented in the current publication.

References

Addesso KM, McAuslane HJ (2009) Pepper weevil attraction to volatiles from host and nonhost plants. Environ Entomol 38:216–224
Addesso KM, McAuslane HJ, Alborn HT (2011) Attraction of pepper weevil to volatiles from damaged pepper plants. Entomol Exp Appl 138:1–11
Avendaño-Meza F, Parra-Terraza S, Corrales-Madrid JL, Sánchez-Peña P (2015) Resistencia a insecticidas en tres poblaciones de picudo del chile (*Anthonomus eugenii* Cano) en el estado de Sinaloa, México. Fitosanidad 19:193–199
Bian L, Yang PX, Yao YJ, Luo ZX, Cai XM, Chen ZM (2016) Effect of trap color, height, and orientation on the capture of yellow and stick tea thrips (Thysanoptera: Thripidae) and nontarget insects in tea gardens. J Econ Entomol 109:1241–1248
Capinera JL (2002) Pepper weevil, *Anthonomus eugenii* Cano (Insecta: Coleoptera: Curculionidae). Florida, USA
Chabaane Y, Haseeb M, Benrey B (2021) domestication of chili pepper has altered fruit traits affecting the oviposition and feeding behavior of the pepper weevil. InSects 12:630
Döring TF, Kirchner SM, Kühne S, Saucke H (2004) Response of alate aphids to green targets on coloured backgrounds. Entomol Exp Appl 113:53–61
Eller FJ, Bartelt RJ, Shasha BS, Schuster DJ, Riley DG, Stansly PA, Mueller TF, Shuler KD, Jhonson B, Davis JH, Sutherland CA (1994) Aggregation pheromone for the pepper weevil, *Anthonomus eugenii* Cano (Coleoptera: Curculionidae): identification and field activity. J Chem Ecol 20:1537–1555
Elmore JC, Davis AC, Campbell RE (1934) The pepper weevil. Washington D.C, USA
Fernández DC, VanLaerhoven SL, McCreary C, Labbé RM (2020) An overview of the pepper weevil (Coleoptera: Curculionidae) as a pest of greenhouse peppers. J Integr Pest Manage 11:26
Food and Agriculture Organization of the United Nations (FAO) (2019) Statistics Division. http://www.fao.org/faostat/es/#data.
George D, Mallery P (2019) IBM SPSS statistics 26 step by step: a simple guide and reference. Routledge. https://doi.org/10.4324/9780429056765

Kim S, Lim UT (2011) Evaluation of a modified sticky card to attract *Bemisia tabaci* (Hemiptera: Aleyrodidae) and a behavioural study on their visual response. Crop Prot 30:508–511

Knapp M, Palevsky E, Rapisarda E (2020) Insect and mite pests. In: Gullino ML, Albajes R, Nictot PC (eds) Integrated Pest and Disease Management in Greenhouse Crops, 2nd edn. Springer, Switzerland, pp 101–146

Mainali BP, Lim UT (2010) Circular yellow sticky trap with black background enhances attraction of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Appl Entomol Zool 45:207–213

Mao L, Chang Y, Yang F, Zhang L, Zhang Y, Jiang H (2018) Attraction effect of different colored cards on thrips *Frankliniella intonsa* in cowpea greenhouses in China. Sci Rep 8:13603

Moreno DS, Gregory WA, Tanigoshi LK (1984) Flight response of *Aphytis melinus* (Hymenoptera: Aphelinidae) and *Scirtothrips citri* (Thysanoptera: Thripidae) to trap color, size, and shape. Environ Entomol 13:935–940

Pobozniak M, Tokarz K, Musynov K (2020) Evaluation of sticky trap colour for thrips (Thysanoptera) monitoring in pea crops (*Pisum sativum* L.). J Plant Dis Prot 127:307–321

Qureshi J, Kostyk BC (2020) Insecticidal control of pepper weevil on jalapeño pepper, Spring 2019. Arthropod Manage Tests 45:tsaa027

Ren X, Wu S, Xing Z, Xu R, Cai W, Lei Z (2020) Behavioral responses of western flower thrips (*Frankliniella occidentalis*) to visual and olfactory cues at short distances. InSects 11:177

Riley DG, Schuster DJ (1994) Pepper weevil adult response to colored sticky traps in pepper fields. Southwestern Entomologist 19:93–107

Riley D, Sparks JAN (1995) The pepper weevil and its management. Texas, USA

Riley DG, Schuster DJ, Barfield CS (1992) Sampling and dispersion of pepper weevil (Coleoptera: Curculionidae) adults. Environ Entomol 21:1013–1021

Rubio-Aragón WA, López-Orona CA, López-Meza M, Avendaño-Meza F, Félix-Camacho SA, López-Urquídez GA, Retes-Manjarrez JE (2021) Resistencia a *Anthonomus eugeni* en poblaciones criollas y silvestres de chile de México. Southwestern Entomologist 46:211–222

Rubio-Aragón WA, López-Orona CA, López-Urquídez GA, Payán-Arzapalo MA, Cruz-Mendivil A, Hernández-Verdugo S, Retes-Manjarrez JE (2022) A rapid screening method for resistance to *Anthonomus eugenii* (Coleoptera: Curculionidae) in *Capsicum* (Solanaceae) spp. plants. Fla Entomol 105:101–107

Rubio-Aragón WA, Retes-Manjarrez JE, Molina-Cárdenas L, Tirado-Ramírez MA, Vega-Gutiérrez TA, López-Urquídez GA, López-Orona CA (2023) Efficiency of traps with different shape, background color and location to monitor *Bemisia tabaci* (Gennadius) adults on Anaheim pepper (*Capsicum annuum* L.) crop. Int J Trop Insect Sci 2023:1–8

Seal DR, Martin CG (2016) Pepper weevil (Coleoptera: Curculionidae) preferences for specific pepper cultivars, plant parts, fruit colors, fruit sizes, and timing. InSects 7:9

Segarra-Carmona AE, Pantoja A (1988) Evaluation of relative sampling methods for population estimation of the pepper weevil, *Anthonomus eugenii* Cano (Coleoptera: Curculionidae). J Agric Univ P R 72:387–393

Servicio de Información Agroalimentaria y Pesquera (SIAP) 2023 Anuario Estadístico de la Producción Agrícola. https://nube.siap.gob.mx/cierreagricola

Shin YK, Kim SB, Kim DS (2020) Attraction characteristics of insect pests and natural enemies according to the vertical position of yellow sticky traps in a strawberry farm with high-raised bed cultivation. J Asia-Pac Entomol 23:1062–1066

Toapanta MA, Schuster DJ, Stansly PA (2005) Development and life history of *Anthonomus eugenii* (Coleoptera: Curculionidae) at constant temperatures. Environ Entomol 34:999–1008

Torres-Ruíz A, Rodríguez-Leyva E (2012) Guía para el manejo integrado de plagas del pimiento bajo invernadero, con énfasis en el picudo del chile. Querétaro, México

Vernon RS, Gillespie DR (1995) Influence of trap shape, size, and background color on captures of *Frankliniella occidentalls* (Thysanoptera: Thripidae) in a Cucumber Greenhouse. J Econ Entomol 88:288–293