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Determining the best pheromone-baited traps for capturing *Scyphophorus acupunctatus* (Coleoptera: Dryophthoridae) in mezcal agave

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The agave weevil, *Scyphophorus acupunctatus* Gyllenhal (Coleoptera: Dryophthoridae), is the main pest on wild and cultivated agaves, *Agave angustifolia* Haw., and *Agave cupreata* Trel. and Berger (Asparagaceae) (González-Hernández et al. 2007; Aquino-Bolaños et al. 2014), and the tuberose crop *Polianthes tuberosa* L. (Asparagaceae) (Camino-Lavin et al. 2002) in Mexico. This insect has cryptic habits, with all of its life stages taking place inside host tissues (González-Hernández et al. 2007; Terán-Vargas et al. 2012) making its control difficult. Weevils can emerge and move from infested hosts to new plants to start an infestation (Figueroa-Castro et al. 2015). Therefore, control strategies can be directed mainly to immigrating adult weevils.

Sampling agave fields is complicated because leaves are succulent and rigid and end in a dangerous sharp terminal spine. Thus, the direct sampling method requires dissection of agave crowns (Solís-Aguilar et al. 2001), but it increases operating costs, as it is time consuming. On the other hand, the indirect method is by monitoring the immigrating weevil adults with a pheromone-based trapping system developed in blue agave (*Agave tequilana* Weber 'Azul'; Asparagaceae) (Ruiz-Montiel et al. 2003, 2008; Rodríguez-Rebollar et al. 2012). Until now, 3 types of promising pheromone and food attractant based traps have been tested for monitoring agave weevil in Mexico; on Jalisco State's blue agave, the TOCCI and TOCCIA traps were evaluated by Bravo-Pérez (2009) and Figueroa-Castro (2014). A 20 L container trap was tested by Azuara-Domínguez et al. (2014), and a 5 L container trap was tested on *P. tuberosa* 'Perla' (Asparagaceae) by López-Martínez et al. (2011) and García-Ramírez et al. (2014).

Recently, the agave industry in Guerrero has increased to 1,814.41 ha with agaves "papalote" and "espadín" (SIAP 2016) dedicated to low technology mezcal production. Local farmers have requested more efficient traps to monitor the agave weevil under local environmental conditions. Here, we evaluated the 3 main types of pheromone and food baited traps used previously in Mexico for capturing immigrating *S. acupunctatus* adults in mezcal agave fields.

We performed 2 experiments in a 4-yr-old "maguey espadín" plantation at "El Rancho Frio" (18.386778°N, 99.166111°W; 1,120 m asl); this plantation is located at Quetzalapa, Guerrero, Mexico. The 1st experiment was performed from 16 Sep to 27 Nov 2015, and the 2nd experiment was performed during 2 mo from 27 Nov 2015 to 29 Jan 2016.

In the 1st experiment, we evaluated 3 types of traps to capture the agave weevil: 1) TOCCI trap (Fig. 1A) at ground level (as recommended

Fig. 1. Handmade designs of traps evaluated for capturing agave weevil on "maguey espadín" in Guerrero, Mexico. (A) TOCCI trap, (B) TOCCIA trap, and (C) container trap. In the 2nd experiment, TOCCIA traps were buried in the soil to the level of the holes.

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by Figueroa et al. unpublished); 2) TOCCIA trap (Fig. 1B) at ground level as used by Figueroa-Castro (2014); and 3) a 4 L container trap (Fig. 1C) buried 5 cm in the soil as used by García-Ramírez et al. (2014). A completely randomized experimental design was used, and each trap was replicated 5 times. The distance between traps was 50 m, and traps were placed in a square distribution pattern as recommended by Figueroa-Castro et al. (2016). Traps were checked 5 times, i.e., every 15 d from 16 Sep to 27 Nov 2015.

In the 2nd experiment, the 2 traps with the best performance in experiment 1 were compared: TOCCI trap, and TOCCIA trap (buried at the level of "cones" for weevils entry). The experiment was established in a completely randomized design, and each treatment was replicated 6 times. The distance between traps was 50 m, and all traps were distributed in a square pattern as indicated previously. Traps were checked 4 times, every 15 d, from 27 Nov 2015 to 29 Jan 2016. In both experiments, on each date, we emptied the traps and collected the captured weevils.

The response variable was the average number of captured agave weevils per trap per evaluation date, and within each experiment. Captured weevils were taken to the laboratory for counting and sexing with a stereoscopic microscope (Motic® SMZ-168, British Columbia, Canada) (Ramírez-Choza 1993).

Each trap was baited with an *S. acupunctatus* synthetic aggregation pheromone dispenser (FeroComps, Mexico City, Mexico) plus 300 g of recently cut agave tissue (Figueroa-Castro et al. unpublished). The agave tissue was placed in a 0.5 L plastic container with 8 holes (0.5 cm diameter each), and sprayed with malathion (Malathion 1000®, Anajalsa, S. A. de C. V., Jalisco, Mexico) at doses of 10 mL/L of water. The pheromone dispenser was changed on a monthly basis, and the agave tissue was replaced biweekly.

All statistical analyses were performed using SAS statistical software (SAS Institute 2004). The data were analyzed by analysis of variance (ANOVA) using PROC GLM. Prior to ANOVA, data normality (Shapiro–Wilk test) and homogeneity of variances (Bartlett test) were tested and data transformation was not necessary for the 1st experiment. Treatment means were separated with a Tukey test (a = 0.05). For the 2nd experiment, data were transformed by $\sqrt{(x+0.5)}$ and a *t*-test was performed. A chi-squared test was performed to determine differences in the number of females and males captured in both experiments.

In the 1st experiment, all 3 traps captured the agave weevil, although the TOCCI captured more weevils than TOCCIA and container traps ($F = 5.84$; df = 2,12; $P = 0.0045$) (Fig. 2). In the 2nd experiment, TOCCI vs. buried TOCCIA capture rates were not significantly different ($F = 0.50$; df = 1,10; $P = 0.4843$) (Table 1). The higher efficiency of the TOCCI trap has been consistently reported on blue agave in Jalisco (Bravo-Pérez 2009; Figueroa 2014), and our results support this result for agave "espadín" in Guerrero.

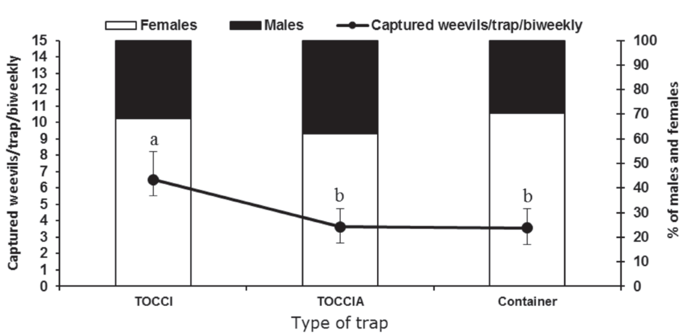

Fig. 2. Mean (± SE) number and percentage by sex of *Scyphophorus acupunctatus* adults captured per trap biweekly in the TOCCI, TOCCIA, and container traps during the 1st experiment. Treatments with different letters are significantly different ($P \leq 0.05$; ANOVA and Tukey's test at $\alpha = 0.05$).

Table 1. Mean (± SE) number and percentage by sex of *Scyphophorus acupunctatus* adults captured per trap biweekly in TOCCI and TOCCIA traps during the 2nd experiment.

Trap type	Weevils captured per trap biweekly	*P*	Percentage	
			Females	Males
TOCCI	3.46 ± 0.43 a	0.4843	74.70 ± 4.45 aA	25.30 ± 4.20 bB
TOCCIA	3.00 ± 0.89 a		81.94 ± 4.23 aA	18.06 ± 4.22 bB

Means in a column followed by different lowercase letters are significantly different ($P \leq 0.05$; ANOVA and Tukey's test at $\alpha = 0.05$).

The low efficacy of container traps could be a result of a natural variation in weevil populations between the dates of the 1st and 2nd experiment (345 and 155 specimens collected in 1st and 2nd experiments, respectively). Apparently, container trap design could play a role in capturing agave weevils at high densities. In other crop species, López-Martínez et al. (2011) and García-Ramírez et al. (2014) deployed these traps for *S. acupunctatus* on *P. tuberosa* and captured up to 700 weevils per trap per wk. This aspect has not been adequately studied. Furthermore, we detected important disadvantages for container trap design in agave "espadín" as follows: many non-target Lepidoptera, Diptera, and Coleoptera species were collected; soapy water used in traps was an alternative source for wild fauna's hydration, affecting its efficacy; and some rodents consumed the captured weevils affecting the results.

In addition, we found that in the 1st experiment more females than males were captured (Fig. 2) in TOCCI traps ($\chi^2 = 22.28$, $P = 0.0001$), in TOCCIA traps ($\chi^2 = 5.38$, $P = 0.02$), and in container traps ($\chi^2 = 17.73$, $P = 0.0001$). Also, in the 2nd experiment more females than males were captured (Table 1) in TOCCI traps ($\chi^2 = 20.25$, $P = 0.0001$) and in TOCCIA traps ($\chi^2 = 29.39$, $P = 0.0001$). Differences between captures of females and males in pheromone-baited traps were reported also by Figueroa-Castro et al. (2013) on blue agave in Jalisco, and by Macedonio-Guevara (2015) in mezcal agave in Guerrero. Capturing large numbers of females has an important impact on future population densities of agave weevil, with the potential of reducing egg laying in agave crops.

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Summary

Three traps (TOCCI, TOCCIA, and container) lured with synthetic aggregation insect pheromone and food attractant, were evaluated in the capture of *Scyphophorus acupunctatus* Gyllenhal (Coleoptera: Dryophthoridae**)** under field conditions on mezcal agave in Guerrero, Mexico. TOCCI and TOCCIA traps were the most efficient for capturing migrant adults. Most of the captured specimens were females, so these traps can reduce future populations of this insect.

Key Words: agave weevil; pest monitoring; integrated pest management

Sumario

Se evaluaron tres tipos de trampas (TOCCI, TOCCIA y garrafón) cebadas con feromona de agregación y atrayente alimenticio, en la captura de *Scyphophorus acupunctatus* Gyllenhal (Coleoptera: Dryophthoridae**),** en plantaciones de agave mezcalero en Guerrero, México. Las trampas TOCCI y TOCCIA fueron las más eficientes en la captura de adultos migrantes. La mayoría de los especímenes capturados fueron hembras, por lo que estas trampas pueden reducir futuras poblaciones del insecto.

Palabras Clave: picudo del agave; monitoreo de plagas; manejo integrado de plagas

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