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Optimizing artisanal plastic traps for monitoring and managing banana weevils: color, odor, and position

Optimización de trampas plásticas artesanales para el monitoreo y manejo de los picudos del banano: color, olor y posición

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ABSTRACT

Banana weevil, *Cosmopolites sordidus* (Germar), and striped weevil, *Metamasius hemipterus* (Linnaeus), are pests of global importance in banana cultivation that are traditionally controlled using synthetic insecticides. Plastic traps offer an alternative method to managing these weevils. However, the effectiveness of artisanal traps, considering color, odor, position, and their influence on trapping efficacy, has been largely neglected. Here, we assessed artisanal plastic traps for capturing banana weevils, testing two trap colors (yellow and brown), two positions (horizontal and vertical), and five types of attractants: pineapple; pineapple combined with molasses; pseudostem; pseudostem combined with molasses; and the pheromone Cosmolure in Ecuadorian banana fields. Under controlled conditions, trap color and position did not significantly influence the preference for *C. sordidus* and *M. hemipterus* ($P<0.05$). Field bioassays revealed significant differences in the capture of *C. sordidus* based on trap position and odor attractants. While trap position did not affect the capture of *M. hemipterus,* the choice of attractant influenced insect capture rates. Cosmolure was the most effective attractant for capturing banana weevils, whereas pineapple baits attracted the highest number of stripped weevils. Over 10 days, the number of captured insects decreased for both weevils across different attractants. Our findings highlight the potential of artisanal plastic traps as a valuable tool for the integrated pest management (IPM) of *C. sordidus* and *M. hemipterus* in banana plantations.

Keywords: capture; control; Musaceae; pest; pheromone; pineapple.

RESUMEN

El picudo negro del banano (*Cosmopolites sordidus*, Germar), y el picudo rayado (*Metamasius hemipterus*, Linnaeus) son plagas de importancia global en el cultivo de banano, que tradicionalmente son controladas mediante insecticidas sintéticos. Las trampas de plástico ofrecen un método alternativo para controlar estos picudos. Sin embargo, la efectividad de las trampas artesanales considerando el color, el olor, la posición y su influencia en la eficacia de la captura ha sido ignorada en gran medida. Aquí, evaluamos trampas plásticas artesanales para capturar gorgojos del banano, probando dos colores de trampa (amarillo y café), dos posiciones (horizontal y vertical), y cinco tipos de atrayentes: piña; piña combinada con melaza; pseudotallo; pseudotallo combinado con melaza; y la feromona Cosmolure en campos bananeros ecuatorianos. En condiciones controladas, el color y la posición de la trampa no influyeron significativamente en la preferencia por *C. sordidus* y *M. hemipterus* (P<0,05). Los bioensayos de campo revelaron diferencias significativas en la captura de *C. sordidus* según la posición de la trampa y los atrayentes de olor. Si bien la posición de la trampa no afectó la captura de *M. hemipterus*, la elección del atrayente influyó en las tasas de captura de insectos. Cosmolure fue el atrayente más eficaz para capturar picudos negros; mientras que, los cebos de piña atrajeron la mayor cantidad de picudos rayados. Durante 10 días, el número de insectos capturados disminuyó para las dos especies de picudos con diferentes atrayentes. Nuestros hallazgos resaltan el potencial de las trampas de plástico artesanales como una herramienta valiosa para el manejo integrado de plagas (MIP) de *C. sordidus* y *M. hemipterus* en plantaciones de banano.

Palabras clave: captura; control; feromona; Musaceae; piña; plaga.

INTRODUCTION

Bananas (*Musa* AAA) are extensively cultivated worldwide, particularly in tropical and subtropical regions (Mago *et al.,* 2021; Ortiz *et al.,* 2020). Major banana-producing countries employ intensive monoculture systems for growing this crop (Ortiz *et al*., 2020). In 2019, global banana production reached 116 million tons (Mago *et al*., 2021) and in 2023, Latin America and the Caribbean exported 14.5 million tonnes (FAO, 2024). Banana production is influenced by various biotic and abiotic factors, including soil type, proper fertilization, irrigation, cultivation practices, insect pests, and disease control (Waweru *et al*., 2014; Okonya *et al*., 2019; Lozano *et al*., 2020; Li. *et al*., 2021; Panigrahi *et al*., 2021; Huang *et al*., 2023).

The banana weevil (*Cosmopolites sordidus*, Germar, 1824) (Coleoptera: Dryophthoridae) is considered a pest in banana and plantain crops (Lozano *et al*., 2020). The immature stages of the pest develop within the plant, which makes controlling it challenging. Eggs are laid near the base of the plant, within 2 mm of the corm or pseudostem surface, and their density is highest on flowering plants, toppled plants, and crop residues (Abera-Kalibata *et al*., 2006). Damage caused by *C. sordidus* larvae destroys the corm and pseudostem of the banana and plantain plants, impairing nutrient and water absorption, and resulting in reduced plant vigor, size, and longevity (Njau *et al*., 2011; Guillen *et al*., 2021).

In contrast, the striped weevil (*Metamasius hemipterus*, Linnaeus, 1758) (Coleoptera: Dryophthoridae) primarily affects sugarcane (Alpizar *et al*., 2012) but has also been found associated with plantains and bananas (Alpizar *et al*., 2012; De la Pava *et al*., 2020). *Metamasius hemipterus* larvae feed on the plant corm, creating galleries and damaging tissues, thus weakening the plant and providing a pathway for penetration by fungi or other pests (Weissling *et al.*, 2003; Osorio *et al*., 2017; De la Pava *et al*., 2020). Both *C. sordidus* and *M. hemipterus* also serve as vectors for diseases, such as *Fusarium oxysporum* f. sp. cubense (Foc) (Heck *et al*., 2021), making their management crucial to prevent the spread of these and other diseases in banana plantations.

Farmers typically manage *C. sordidus* and *M. hemipterus* using synthetic insecticides from various chemical classes, including organochlorines (e.g., chlordecone), organophosphates (e.g., chlorpyrifos, terbufos, ethoprophos), carbamates (e.g., carbofuran), pyrethroids (e.g., cypermethrin), neonicotinoids (e.g., imidacloprid, thiamethoxam), and phenylpyrazoles (e.g., fipronil) (Mongyeh *et al*., 2015; Guzmán, *et al*., 2019; Okolle *et al*., 2020; Bakaze *et al*., 2022; Nicolini *et al*., 2022). Although these insecticides effectively control *C. sordidus* and *M. hemipterus*, their adverse effects on the environment, human health, and the development of resistance have been well-documented (Fancelli *et al*., 2013; Bakaze *et al*., 2020). Consequently, there is an ongoing effort to minimize or replace synthetic insecticides with more efficient and less toxic alternatives (Okolle *et al*., 2020). Understanding pest biology and current management options is essential for achieving this goal (Bakaze *et al*., 2022).

One alternative for managing banana weevils is the use of traps (Bakaze *et al*., 2022). Traditionally, traps for capturing *C. sordidus* consist of pieces of pseudostem placed on the ground. However, their capture efficacy is low and varies depending on trap variability, age, and location (Gold *et al*., 2001; Rhino *et al*., 2010; Fu *et al*., 2019).

With advancements in synthetic pheromones for pest capture, plastic traps have gained popularity. For example, Reddy *et al*. (2009) evaluated the use of pheromone in three types of plastic traps (ground, ramp, and pitfall) for capturing *C. sordidus,* and found the ground plastic trap to be the most effective. Rhino *et al*. (2010) demonstrated the efficiency of pheromone-equipped pitfall plastic traps for capturing *C. sordidus*. Plastic traps with pheromones have also effectively captured *M. hemipterus* (Giblin *et al*., 1996). While the efficacy of commercial plastic traps with pheromones is established, their effectiveness in artisanal traps and with various food attractants remains unexplored.

The present study aims to evaluate the effectiveness of artisanal traps for capturing *C. sordidus* and *M. hemipterus*, considering two trap colors (yellow and brown), two positions (horizontal and vertical), and five types of attractants: pineapple; pineapple combined with molasses; pseudostem; pseudostem combined with molasses; and the pheromone Cosmolure. The traps were deployed in a commercial banana plantation.

MATERIAL AND METHODS

Study site. The experiments to test trap color and position preferences were conducted at La María Campus at the Universidad Técnica Estatal de Quevedo (UTEQ) (Quevedo, Los Ríos, Ecuador) (1° 04’ 49.2’’ S, 79° 30’ 05.3’’ W), under controlled conditions of (27 ± 2 °C of temperature, 75 ± 10% of relative humidity (RH), and 12:12 h photoperiod (D:L). Position and odor attractants were tested in commercial banana plantations (*Musa* AAA cv. Williams) located in Los Ríos Province, especially at Hacienda Oasis No. 2, La Esperanza, Ecuador (0° 58’ 19.6’’ S, 79° 22’ 41.7’’ W), with 27 ± 5 °C of temperature and 84 ± 5% of relative humidity. Agronomic practices were carried out regularly and according to the banana crop requirements (Robinson and Galán-Saúco, 2010).

Artisanal plastic traps. The artisanal plastic traps were designed after the ramp trap design provided by ChemTica Internacional (San José, Costa Rica) for capturing *C. sordidus*. For the artisanal traps, four-liter plastic bottles were repurposed (height 350 mm, width 160 mm). The bottles were painted with yellow (W8402, Wesco) and brown enamel paint (W118, Wesco) and were arranged horizontally and vertically. Two windows (110 mm x 120 mm) were cut into the sides of the bottles at their middle third. One side of each window was left attached at a 45° angle, forming a ramp covered with canvas to facilitate entry by adults of *C. sordidus* or *M. hemipterus*.

Trap color preference bioassay. Colored plastic traps (yellow and brown) were washed three times with water and neutral detergent to remove any paint or odor residue. Once dry, the traps were placed inside an organza and wooden box (100 cm x 100 cm) with a bottom layer of banana cultivation soil to simulate natural conditions. One yellow and one brown plastic traps were placed on each side of the box. Inside each trap, pieces of corm (100 g) and pseudostem (100 g) of banana plants were added. Ten weevils were released in the center of the box, and the number of individuals in each trap was counted after 24 hours. Seven replicates were carried out, each with ten insects of *C. sordidus* and *M. hemipterus* in horizontal and vertical traps. Insects, traps, food attractants, and soil were replaced for each replicate.

Position and odor attractants bioassay. Based on the color preference bioassay results, the color that attracted the most *C. sordidus* and *M. hemipterus* specimens was selected for the field study. Although no significant statistical differences were found between the trap colors, the brown-colored trap attracted more weevils than the yellow trap. Therefore, brown horizontal and vertical artisanal plastic traps were used for the field study. The study was conducted on a 30-hectare banana plantation (cv. Williams). The traps were placed 10 cm deep in the ground, with the trap's ramp level with the surface. Four traps were placed per hectare: two horizontal plastic traps and two verticals, with attractants randomly assigned. A total of 120 traps were deployed on the plantation.

Five attractants were tested: 1) pineapple (250 g); 2) pineapple (125 g) + molasses (125 ml); 3) pseudostem (250 g); 4) pseudostem (125 g) + molasses (125 ml); and 5) pheromone Cosmolure (Sordidin, 6.94 g/L, Chemtica Internacional S. A, Costa Rica). Each attractant was placed in fine plastic mesh bags and suspended 3 cm above soapy water with a nylon string. The attractants were used in both horizontal and vertical traps. Daily captures of *C. sordidus* and *M. hemipterus* were recorded two, five, seven, and ten days post-installation.

Statistical analyses. The trap color, position, and odor attractants were analyzed with a generalized linear model (GLM; family = Gaussian). The number of insects captured by attractants and species was analyzed with a generalized linear model (GLM; family = Negative binomial). The daily captures of *C. sordidus* and *M. hemipterus* with different attractants were subjected to regression analyses using the curve-fitting procedure of SigmaPlot 12.0 (Systat Software, San Jose CA, USA). Significant regression models ($P<0.05$) were selected based on parsimony, high F-values (and mean squares), and a steep increase in R^2 with model complexity. In GLMs, treatment means were compared using Tukey's honestly significant difference (HSD) test ($P<0.05$). The assumptions of normality and homoscedasticity were checked, and no data transformation was required.

RESULTS AND DISCUSSION

Trap color and position preferences. Neither the banana nor the stripped weevils showed significant preferences for trap color (yellow or brown) ($F_{1,25} = 0.02$, $P = 0.87$), trap position (horizontal or vertical) ($F_{1,26} = 0.03$, $P = 0.87$), and the interaction between these variables ($F_{1,24} = 0.64$, $P = 0.43$). Similarly, no significant differences in preference were observed for the striped weevil (*M. hemipterus*); there were no significant effects of trap color ($F_{1,25} = 0.67$, $P=0.41$), trap position ($F_{1,26} = 2.79$, $P = 0.11$), and their interaction ($F_{1,24} = 1.24$, $P = 0.28$).

Trap position and odor attractants. Field bioassay results showed significant differences in the number of *C. sordidus* captured with different trap positions (horizontal and vertical traps) ($F_{1,58} = 5.20$, $P = 0.03$) and the attractants ($F_{4,54} = 66.92$, $P<0.001$).

There was also a significant interaction between position and attractants ($F_{4,50} = 5.20$, $P<0.001$). All *C. sordidus* individuals were attracted to both horizontal and vertical traps by the pheromone Cosmolure (Figure 1A).

In contrast, the position of traps did not significantly influence the capture of *M. hemipterus* ($F_{1,58} = 0.54$, $P = 0.47$). However, significant differences were observed in the capture of *M. hemipterus* with different attractants ($F_{4,54} = 24.89$, $P<0.001$). Traps using pieces of pineapple captured the highest number of *M. hemipterus*, followed by pineapple + molasses; pseudostem; and pseudostem + molasses with similar results. The pheromone Cosmolure did not capture any striped weevils during the evaluations (Figure 1B). Differences in the attraction of *C. sordidus* to pheromone attractants and *M. hemipterus* to pineapple were evident based on non-overlapping standard errors with the respective equation parameters (Table 1).

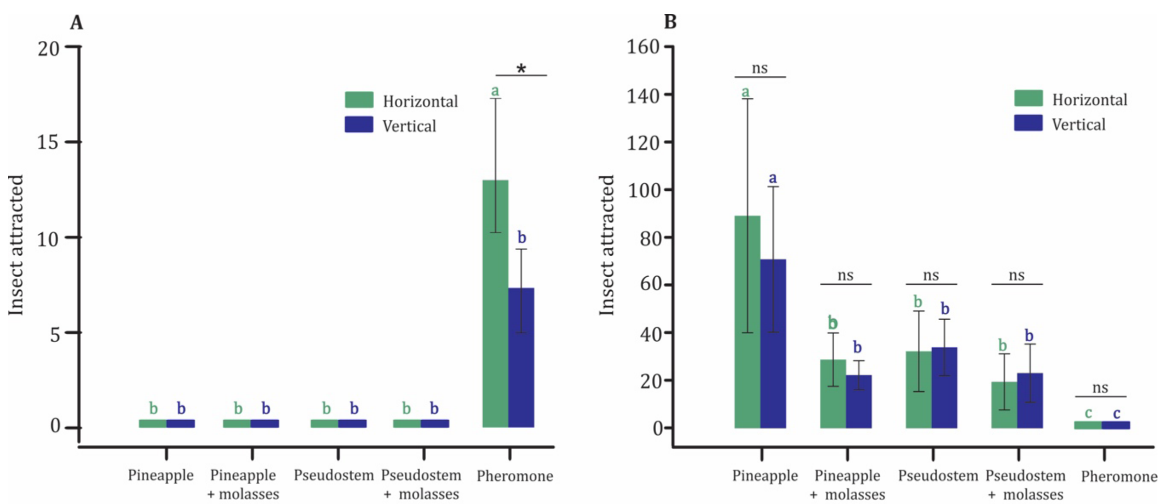

Figure 1. A) Average capture (± SE) of *C. sordidus* (a) and *M. hemipterus* (b) in artisanal plastic traps stocked with different attractants and placed either in horizontal or vertical positions. Asterisks and different letters at the top of the histogram bars indicate significant differences between the trap position for each attractant used, based on Tukey's HSD test ($P<0.05$).

Table 1. Summary of the regression analyses of total capture of adults of *C. sordidus* and *M. hemipterus* obtained with artisanal plastic traps containing

Model	Treatment	***Cosmopolites sordidus*** Parameter estimates (± SE) *a*	*b*	*c*	df_{error}	F	*P*	R^2
Polynomial, Linear y=b+ax	Pineapple	0.00±0.00	0.00±0.00	-	2	-	-	1
Polynomial, Linear y=b+ax	Pineapple + molasses	0.00±0.00	0.00±0.00	-	2	-	-	1
Polynomial, Linear y=b+ax	Pseudosteam	0.00±0.00	0.00±0.00	-	2	-	-	1
Polynomial, Linear y=b+ax	Pseudosteam +molasses	0.00±0.00	0.00±0.00	-	2	-	-	1
Polynomial, Linear y=b+ax	Pheromone (horizontal trap)	-10,400±0.65	45.50±1.77	-	2	257,52	0.004	0.99
Polynomial, Linear y=b+ax	Pheromone (vertical trap)	-8.80±1.29	33.00±3.55	-	2	46.09	0.021	0.96
Model	**Treatment**	***Metamasius hemipterus*** Parameter estimates (± SE) *a*	*b*	*c*	df_{error}	F	*P*	R^2
Polynomial, Linear y=b+ax	Pineapple	-73.40±4.38	424.00±12.00	-	2	280.31	0.003	0.99
Polynomial, Linear y=b+ax	Pineapple + molasses	-13.50±2.48	111.00±6.79	-	2	29.63	0.032	0.94
Peak, Gaussian (3-parameter) y=a exp(-0.5((x-b)/c)2)	Pseudosteam	125.40±25.48	2.26±0.43	1.61±0.68	1	0.83	0.614	0.62
Peak, Gaussian (3-parameter) y=a exp(-0.5((x-b)/c)2)	Pseudosteam +molasses	76.81±6.35	2.49±0.20	1.84±0.38	1	3.12	0.372	0.86
Polynomial, Linear y=b+ax	Pheromone	0.00±0.00	0.00±0.00	-	2	-	-	1

different attractants on different days.
Significant differences were found in the total number of specimens captured by attractants (χ^2 = 1122.09, df = 4, P<0.001) and species (χ^2 = 673.04, df = 1, P<0.001). The number of *C. sordidus* (Figure 2A) and *M. hemipterus* (Figure 2 B) captured using different attractants decreased over the 10-day test period.

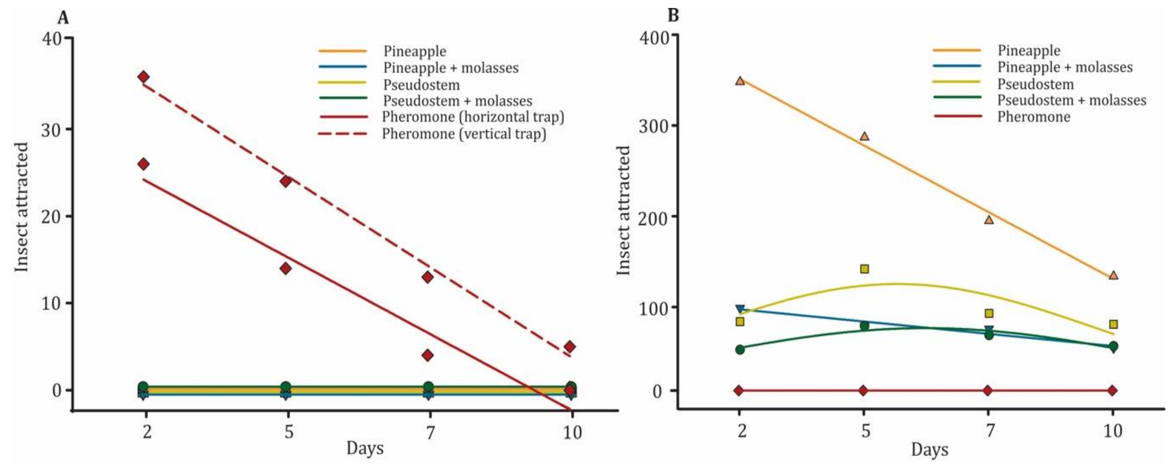

Figure. 2. A) Total number of adults of *C. sordidus* (a) and *M. hemipterus* (b) captured in artisanal plastic traps with different attractants. The equation parameters are exhibited in Table 1.

The use of traps with banana or plantain pseudostems for capturing *C. sordidus* is a common practice among both small and large-scale banana producers (Gold *et al*., 2001; Okolle *et al*., 2020). The advent of synthetic pheromones for trapping banana weevils has emerged as a prominent strategy within the framework of integrated pest management (Tewari *et al*., 2014; Lozano *et al*., 2020). Mass trapping using pheromones can effectively prevent weevil infestation and damage, particularly on young plants. However, the high cost of pheromone-based traps can be a barrier, especially for smallholder farmers (Alpizar *et al*., 2012; Okolle *et al*., 2020).

Pitfall traps are commonly used for trapping *C. sordidus* and *M. hemipterus* with pheromones (Rhino *et al*., 2010), though other trap models can be even more efficient (Giblin *et al*., 1996; Reddy *et al*., 2009). Despite the proven efficacy of synthetic pheromones and commercial traps, their high cost often limits their use, especially among small-scale farmers (Reddy and Raman, 2011; Mertilus *et al*., 2017; Hambalko *et al*., 2021). This underscores the need for alternative, cost-effective methods to reduce production costs in banana and plantain plantations worldwide.

Trap attributes such as type, color, location, size, and the attractant significantly impact insect capture rates (Reddy *et al*., 2009, Bakaze *et al*., 2022). Insects use color cues in various contexts, such as locating shelter, finding food, identifying oviposition sites, or selecting mates (Van der Kooi *et al*., 2019; Van der Kooi *et al*., 2021).

Different colored traps have been used as tools for capturing insects in various crops (Atakan and Pehlivan, 2015). For instance, studies have shown that brown traps are particularly effective for capturing *C. sordidus* (Reddy *et al*., 2009; Fu *et al*., 2019), while no color preference has been reported for *M. hemipterus* (Giblin *et al*., 1996). Neither *C. sordidus* nor *M. hemipterus* showed a significant preference for trap color. These findings align with previous research by Giblin *et al*. (1996) and Reddy and Raman, (2011). However, further studies are needed to explore color preferences under varying conditions and their impact on the capture of both species.

Our research demonstrated that artisanal traps could effectively capture banana weevils. However, no significant difference was found in capture rates based on trap position (horizontal or vertical) for *M. hemipterus*. For *C. sordidus*, horizontal traps proved more effective. This may be because attractants placed closer to the ground in horizontal traps might better mimic natural conditions, similar to the ground traps used by Reddy *et al*. (2009).

Sordidin, a synthetic aggregation pheromone produced by *C. sordidus* males and marketed under the commercial name Cosmolure, has been used for managing this pest (Okolle *et al*., 2020). In our study, only Cosmolure effectively captured *C. sordidus*. The highest capture rates occurred two days after trap installation, with a decline over time. None of the other attractants (pineapple; pineapple + molasses; pseudostem; and pseudostem + molasses) attracted *C. sordidus*. Although pheromone efficiency can be influenced by factors such as density, environmental conditions, and the presence of kairomones (Osorio *et al*., 2017), the effectiveness of Cosmolure was evident in our study.

For *M. hemipterus*, traps with pineapple, pineapple + molasses, pseudostem, and pseudostem + molasses captured specimens, while Cosmolure did not. This indicates that Cosmolure, designed specifically for *C. sordidus*, is not effective for *M. hemipterus*. Pineapple, with its high content of volatile compounds such as esters, lactones, and acids, proved highly attractive to *M. hemipterus* but less so to *C. sordidus*. This indicates that different pheromone blends or attractants may be needed for these two species. The use of pineapple was particularly effective for capturing *M. hemipterus*, though the overall capture efficiency decreased over time.

The use of pineapple is efficient in attracting different species, ranging from fruit flies to palm weevils (Azmi *et al*., 2014; Cuevas *et al*., 2011; Figueroa *et al*., 2017; Lamin *et al*., 2022). Pineapples show a high content of volatile compounds, including esters (87.4%), lactones (5.1%), furanic compounds (3.0%), acids (1.7%), ketones (1.1%), and alcohols (0.2%) that likely contribute to its effectiveness as an attractant (Sinuco *et al*., 2005). Such a mixture of volatile and active compounds from pineapple triggers the attraction of *M. hemipterus*, but not *C. sordidus*, which was far better attracted by pheromone-based traps obtained for the latter species.

CONCLUSIONS

Trap color and position did not influence the preference for banana and stripped weevils under controlled conditions. Trap position and odor attractants influenced the capture of *C. sordidus*, whereas for *M. hemipterus* the trap position did not affect the capture in field bioassays. Among odor attractants, the pheromone Cosmolure was the most effective attractant for capturing banana weevils, whereas pineapple baits attracted the highest number of stripped weevils. Artisanal traps show promise, particularly for *M. hemipterus*, their effectiveness for *C. sordidus* is less pronounced. Over 10 days of captured weevils' evaluation, the number of insects decreased for both weevils across different attractants. This highlights the need for further research to optimize artisanal traps and integrate them into pest management programs for these species.

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