Effects of Trap Shape, Size, and Color Variations on Capture Rates of Chrysobothris (Coleoptera: Buprestidae) and Related Buprestids

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Effects of trap shape, size, and color variations on capture rates of *Chrysobothris* (Coleoptera: Buprestidae) and related buprestids

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Trap design and capture rates for crop pests are pivotal factors in pest management strategies for tree nurseries (LeBude et al. 2012; Frank et al. 2013). Often, traps need to be designed uniquely for the targeted pest (Vinatier et al. 2012; Cavaletto et al. 2020). Trapping methods have been evaluated for some important metallic wood-boring beetle pests (Coleoptera: Buprestidae) such as emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) (Oliver et al. 2003; LeBude & Adkins 2014; Haack & Petrice 2019), but the genus *Chrysobothris* Eschscholtz (Coleoptera: Buprestidae) is less well studied. *Chrysobothris* are problematic in ornamental tree nurseries on genera such as *Acer* (Sapindaceae), *Cornus* (Cornaceae), and *Malus* (Rosaceae), thus requiring more focused management research (Oliver et al. 2010; Dawadi et al. 2019; Addesso et al. 2020). The objective of this study was to develop suitable traps for buprestid borers commonly found in ornamental tree nurseries. *Chrysobothris* and related buprestids are attracted to purple-colored traps that have a peak reflectance near infrared (~740 nm) (Imrei et al. 2020; Perkovich et al. 2022). To optimize the trap style, the first experiment analyzed trap material, shape, and size. A second experiment further optimized trap design. These trap trials were conducted in 2004 and 2005 with emerald ash borer as the original target for monitoring. Growing concerns about *Chrysobothris* damage in nurseries led to a revisit of these data collections to assess the trap preference of the *Chrysobothris* genus.

A CM2600d spectrophotometer (Konica Minolta Sensing Americas, Inc., Ramsey, New Jersey, USA) was used to determine reflectance characteristics (i.e., lightness [*L**], red to green [*a**], blue to yellow [*b**], and peak reflectance [*PR*]) of traps and trapping materials. Settings for the spectrophotometer were as follows: observer illuminant Daylight 65, observer angle at 10° (CIE 1964 color space), and included specular component SCI and UV at 100% (see Werle et al. 2014 and Perkovich et al. 2022 for further details). Using traps with similar reflectance values and previously demonstrated efficacy for buprestid traps (Perkovich et al. 2022), 12 trap designs were field evaluated for efficiency at capturing *Chrysobothris* and related buprestid species beginning in Apr 2004. Trap designs were made from panels of corrugated plastic (Coroplast, LLC, Vanceburg, Kentucky, USA) or wood and were covered with colored insect glues (Brooks 1919) created by mixing Folkart® 654 (amethyst) or 411 (purple) acrylic violet-like paints (Plaid Enterprises, Inc., Peach Tree Corners, Georgia, USA) into clear Pestick™ glue (Hummert International, Earth City, Missouri, USA) (mix rate: 1 kg glue per 34 g paint). Glitter glue was made by mixing Poly*Flake purple glitter (Glitterex Corp., Cranford, New Jersey, USA) into clear Pestick™ glue (mix rate: 1 kg glue per 21 g glitter). All traps were placed at ground level. Corrugated plastic panel traps included purple traps 3.8, 15.2, or 30.5 cm wide × 1 m tall (covered with clear unmodified glue), or white traps 3.8 cm wide (covered with clear unmodified, purple glitter, amethyst, or purple glues). The corrugated box trap treatment had four 3.8 cm wide purple panels covered with clear unmodified glue. Tan-colored wooden traps consisted of 1.9 × 3.8 cm posts that were 1 m in height covered with clear unmodified, purple glitter, amethyst, or purple glues (see Table 1 for details of trap design combinations and materials used). Traps were placed in a randomized complete block design using 4 replicates along the edge of a mixed deciduous forest on the Tennessee State University Otis L. Floyd Nursery Research Center in McMinnville, Tennessee, USA. There were 5 m between each block, and each trap treatment was placed 2 m apart. Beetles were collected from traps weekly, cleaned in Histo-Clear™ II (National Diagnostics, Atlanta, Georgia, USA) and 70% ethanol (diluted from 200 proof ethanol, Fisher product #BP2818-4; Fisher Scientific, Pittsburgh, Pennsylvania, USA), then frozen until identification to species using Downie and Arnette (1995). Species in the *Chrysobothris femorata* (Olivier) (Coleoptera: Buprestidae) complex were identified with revised keys (Wellso & Manley 2007).

In Apr 2005, 7 new trap design treatments were tested based on the 2004 test results. Treatments included: (1) triangular prism traps with 15.2 cm wide panel sides (created by folding a plastic panel to create three 15.2 cm wide sides) with clear glue; (2) 30.5 cm purple plastic panel with clear glue; (3) 15.2 cm purple plastic panel with clear glue; (4) 30.5 cm white plastic panel with purple glue; (5) 3.8 cm wooden stake with clear glue; (6) 3.8 cm wooden stake with purple glue; and (7) a purple plastic box with 3.8 cm wide sides with clear glue. All traps were 1 m tall and placed at ground level. Specimen collection, handling, and identification were conducted as previously described.

The effect of trap design in both the 2004 and 2005 studies were analyzed using generalized linear mixed models. The model included number of individuals (buprestids, *Chrysobothris*, *Chrysobothris* females, and *Chrysobothris* males) collected (as dependent variables) and trap designs (as independent variable) throughout the trapping season (negative binomial distribution). Models were fitted using the "glmer.nb" function in the lme4 (Bates et al. 2017) package in R (R Core Team 2021). Simultaneous pairwise comparisons of trap designs were made using Tukey's HSD tests. Mean female and male *Chrysobothris*

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Table 1. Mean (± SE) total buprestids, *Chrysobothris*, *Chrysobothris* females, or *Chrysobothris* males captured on different trap designs in 2004.

	Trap features								Mean (± SE) total trap captures			
Material	Width (cm)	Shape	Base color	Glue color[1]	*L**	*a**	*b**	PR (nm)	Buprestids	*Chrysobothris*[2]	Female *Chrysobothris*[3]	Male *Chrysobothris*
Plastic	3.8	Box	Purple	Clear	3.09	2.42	−5.76	740	157 ± 3.2 a	142 ± 2.4 a	83 ± 1.9 a*	59 ± 2.4 a
Plastic	15.2	Panel	Purple	Clear	3.09	2.42	−5.76	740	113 ± 3.0 b	82 ± 1.9 b	49 ± 2.1 b*	33 ± 2.0 b
Plastic	3.8	Panel	White	Ameth	16.76	1.02	−1.13	740	113 ± 1.2 b	50 ± 0.7 c	34 ± 0.6 c*	16 ± 1.1 c
Plastic	3.8	Panel	White	Purple	14.03	4.11	−6.14	740	107 ± 2.3 b	67 ± 0.9 c	52 ± 0.7 b*	15 ± 0.5 c
Wood	1.9 × 3.8	Box	Tan	Ameth	7.72	3.68	5.8	740	70 ± 0.8 c	52 ± 0.7 c	39 ± 1.1 c*	13 ± 1.0 c
Wood	1.9 × 3.8	Box	Tan	Purple	12.03	3.32	1.04	740	59 ± 0.7 cd	24 ± 1.4 d	17 ± 1.2 e*	7 ± 1.2 cd
Plastic	3.8	Panel	White	Clear	20.25	0.15	0.09	720	57 ± 0.6 cd	28 ± 0.8 d	17 ± 0.8 e*	11 ± 0.9 c
Plastic	3.8	Panel	White	Glitter	14.62	1.27	−2.43	720	52 ± 1.1 cd	38 ± 1.0 cd	29 ± 1.1 d*	9 ± 1.3 cd
Plastic	3.8	Panel	Purple	Clear	3.09	2.42	−5.76	740	45 ± 1.0 d	31 ± 1.0 cd	20 ± 1.0 d*	11 ± 1.2 c
Wood	1.9 × 3.8	Box	Tan	Glitter	10.45	3.36	−1.03	740	43 ± 1.2 d	52 ± 1.0 c	34 ± 0.8 c*	18 ± 0.9 c
Plastic	30.5	Panel	Purple	Clear	3.09	2.42	−5.76	740	40 ± 0.8 d	17 ± 0.9 e	14 ± 0.9 e*	3 ± 1.1 d
Wood	1.9 × 3.8	Box	Tan	Clear	11.49	3.43	10.19	740	10 ± 1.0 e	9 ± 0.8 e	8 ± 0.5 f*	1 ± 0.0 d

[1]Glue colors: "Clear" = unmodified Pestick™ glue, acrylic violet-reflecting colored paints that were mixed into the clear glue included "Ameth" = Folkart 654, "Purple" = Folkart 411, "Glitter" = PolyFlake purple glitter flakes of violet-like glitter mixed into the clear glue.

[2]*Chrysobothris* species included *C. adelpha* (*n* = 142), *C. azurea* (*n* = 20), *C. cribraria* (*n* = 4), *C. femorata* (*n* = 28), *C. harrisi* (*n* = 1), *C. quadriimpressa* (*n* = 179), *C. rugosiceps* (*n* = 110), *C. sexsignata* (*n* = 56), *C. shawnee* (*n* = 17), and *C. viridiceps* (*n* = 35).

[3]The asterisk (*) in the total female *Chrysobothris* captured column indicates statistically greater captures of females than males on those traps. "*L**" = lightness, "*a**" = red to green, "*b**" = blue to yellow, "PR" = peak reflectance (nm, see text for description). Different letters within columns indicate significant differences between means in a Tukey's HSD test.

caught in each trap type were compared using Welch's 2-sample *t*-tests.

In 2004, traps that were purple plastic panel boxes with 3.8 cm sides and clear glue captured more buprestids, *Chrysobothris*, *Chrysobothris* females, and *Chrysobothris* males than any other trap ($X^2_{(51)}$ = 97.96; *P* = 0.03; Table 1). Overall, all traps caught more *Chrysobothris* females than males (*t* = 1.47; *P* = 0.028; Table 1). In 2005, traps were made with slight alterations of the successful purple plastic panel box design. The purple 15.2 cm plastic panels with clear glue, the purple 3.8 cm plastic panel box with clear glue, and the white 30.5 cm plastic panel with purple glue captured the most buprestid beetles ($X^2_{(34)}$ = 93.66; *P* = 0.03). However, the 3.8 cm purple plastic box with clear glue trap had the highest number of catches for *Chrysobothris* (Table 2). Males were caught in lower numbers than females in all traps except for the 3.8 cm purple plastic panel with clear glue (females = 9; males = 13), and the 30.5 cm wooden stake with clear glue, which caught no *Chrysobothris*.

Many studies have analyzed the importance of trap color for capturing buprestid beetles (Francese et al. 2011; Cavaletto et al. 2020; Perkovich et al. 2022). Recent studies have concluded that the best trap color for some buprestids, including *Chrysobothris*, reflect in the violet range (300–400 nm) of the electromagnetic spectrum (Cavaletto et al. 2020; Perkovich et al. 2022). Purple colors like the plastic panels and colored glues used in this study reflect in both the violet and visible red (625–750 nm) range. Although color is important for buprestid attraction to traps, trap design also can be a factor in insect catch success (Ryall 2015). In this study, several trap designs caught relatively high numbers of buprestids, but trap designs that were narrow and purple plastic with clear glue caught the most *Chrysobothris*.

The most effective trap designs potentially model the ecological preferences of the target pest. Trap color and shape can promote capture rates if the targeted pest uses these visual cues for locating hosts. Additional elements such as the incorporation of semiochemicals from host plants or conspecific pheromones may increase the specificity of visual attraction (Silk et al. 2019; Peterson et al. 2020). *Chrysobothris* species of economic concern prefer to oviposit on small tree trunks like those found in tree nurseries (Oliver et al. 2010; Başpınar et al. 2018; Dawadi et al. 2019). *Chrysobothris* may prefer the narrower 3.8 cm box design in this study because it mimics a young sapling tree trunk. It is important to note that the original plastic panel box design did not perform well in field conditions. The box trap design often folded in on themselves creating a 2-dimensional flat surface rather than the original 4-dimesional box shape. Despite having a larger surface area than the box design, the triangular prism traps with 15.2 cm wide panel sides did not have a statistically greater catch of *Chrysobothris* than the box trap (*P* = 0.231). However, the triangular prism trap did have a greater structural stability; during field observations, the box design folded in and collapsed. Based on the results of these 2 trials, future trapping experiments should investigate modifications of a purple plastic panel trap in a triangular prism design with smaller panel widths (i.e., 3.8 cm). The triangular prism shape is more structurally rigid and potentially resembles a small tree trunk oviposition target of the female *Chrysobothris*.

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Table 2. Mean (± SE) total buprestids, *Chrysobothris*, *Chrysobothris* females, or *Chrysobothris* males captured on different trap designs in 2005.

Trap features									Mean (± SE) total trap captures			
Material	Size (cm)	Shape	Base color	Glue color[1]	*L**	*a**	*b**	PR (nm)	Buprestids	*Chrysobothris*[2]	Female *Chrysobothris*[3]	Male *Chrysobothris*
Plastic	15.2	Triangle	Purple	Clear	3.09	2.42	−5.76	740	62 ± 1.3 a	37 ± 1.4 a	33 ± 0.9 a*	4 ± 0.2 b
Plastic	3.8	Box	Purple	Clear	3.09	2.42	−5.76	740	61 ± 1.7 a	43 ± 1.4 a	29 ± 1.3 a*	14 ± 0.9 a
Plastic	30.5	Panel	White	Purple	14.03	4.11	−6.14	740	59 ± 2.2 a	25 ± 1.3 b	18 ± 1.3 b*	7 ± 0.2 b
Plastic	30.5	Panel	Purple	Clear	3.09	2.42	−5.76	740	51 ± 1.0 a	22 ± 1.2 b	9 ± 0.8 c*	13 ± 0.6 a
Plastic	15.2	Panel	Purple	Clear	3.09	2.42	−5.76	740	37 ± 1.4 b	23 ± 1.0 b	16 ± 1.1 b*	7 ± 1.2 b
Wood	3.8	Box	Tan	Purple	12.03	3.32	1.04	740	28 ± 0.9 c	16 ± 0.5 b	11 ± 0.8 bc*	5 ± 0.3 b
Wood	3.8	Box	Tan	Clear	11.49	3.43	10.19	740	3 ± 0.1 d	0 ± 0.0 c	0 ± 0.0 d	0 ± 0.0 b

[1]Glue colors: "Clear" = unmodified Pestick" glue, acrylic violet-reflecting colored paint that was mixed into the clear glue included "Purple" = Folkart 411.
[2]*Chrysobothris* species included *C. adelpha* (*n* = 31), *C. azurea* (*n* = 8), *C. cribraria* (*n* = 2), *C. femorata* (*n* = 7), *C. quadriimpressa* (*n* = 72), *C. rugosiceps* (*n* = 13), *C. sexsignata* (*n* = 30), *C. shawnee* (*n* = 1), and *C. viridiceps* (*n* = 2).
[3]The asterisk (*) in the total female *Chrysobothris* captured column indicates statistically greater captures of females than males on those traps. "*L*" = lightness, "*a**" = red to green, "*b**" = blue to yellow, "PR" = peak reflectance (nm, see text for description). Different letters within columns indicate significant differences between means in a Tukey's HSD test.

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Summary

Using an appropriate trap design can significantly increase trap capture rates for specific insect pests. *Chrysobothris* are common buprestid pests in nursery production. Using traps that are shaped to mimic preferred tree hosts captured higher numbers of *Chrysobothris* than other trap designs. Based on these tests, the best trap design (shape and materials) for *Chrysobothris* monitoring was clear glue on a purple plastic trap folded into a triangular prism shape with panel widths (i.e., 3.8 cm) and trap height (i.e., 1 m) similar to a young sapling tree trunk. Our trap design will help in *Chrysobothris* pest management strategies for tree nurseries by increasing capture success rates and leading to overall better monitoring of *Chrysobothris* populations in nursery production.

Key Words: beetles; flatheaded borers; jewel beetles; pest monitoring; visual cues

Sumario

El uso de un diseño de trampa apropiado puede aumentar significativamente la tasa de captura de las trampas para plagas de insectos específicos. *Chrysobothris* son plagas bupréstidas comunes en viveros en producción. El uso de trampas que imitan la forma de los árboles hospederos preferidos capturó un mayor número de *Chrysobothris* que otros diseños de trampas. Con base en estas pruebas, el mejor diseño de trampa (forma y materiales) para el monitoreo de *Chrysobothris* fue pegamento transparente en una trampa de plástico púrpura doblada en forma de prisma triangular con el ancho de los paneles (3,8 cm) y su altura (1 m) similares a un tronco de árbol joven. Nuestro diseño de trampa ayudará en las estrategias de manejo de plagas de *Chrysobothris* en los viveros de árboles al aumentar la tasa de éxito de captura y llegar a un mejor monitoreo general de las poblaciones de *Chrysobothris* en la producción en viveros.

Palabras Clave: escarabajos; barrenadores de cabeza plana; escarabajos joya; monitoreo de plagas; señales visuales

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