BIOSCIENCE JOURNAL

INFLUENCE OF THE COLOR OF SEMI-FUNNEL TRAPS ON XYLOPHAGOUS COLEOPTERA CAPTURE EFFICIENCY IN FOREST FRAGMENTS

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How to cite: TREVISAN, H., SOUZA, T.S. and AMANCIO, J.M.S. Influence of the color of semi-funnel traps on xylophagous coleoptera capture efficiency in forest fragments. *Bioscience Journal*. 2021, **37**, e37034. https://doi.org/10.14393/BJ-v37n0a2021-53771

Abstract
Bark and ambrosia beetles, mainly the ones belonging to groups Scolytinae, Bostrichidae and Platypodinae, can kill trees from reforestation areas or native forests and damage the wood. Population monitoring and the identification of quarantine species are carried out by assembling ethanol-baited traps. The aims of the current study are to evaluate the influence of the color of ethanol-baited traps on the efficient capture of these insects, as well as to measure changes in colorimetric variables based on trap exposure in the field and to investigate whether these changes affect capture efficiency. Eight ethanolic traps (red, yellow, black and transparent traps - two of each color) were installed in a forest fragment in the first experimental stage – samples were collected on a weekly basis, for 11 months. New and used transparent traps were installed in the field in the second experimental stage - samples were collected for additional 11 months. A portable spectrophotometer was used to measure the colorimetric variables in these traps. The mean number of Scolytinae individuals (± SD) captured in transparent traps (48±50) was significantly higher than that of individuals captured in black (24±25), yellow (23±21) and red (22±21) traps. However, transparent traps subjected to field conditions were colonized by such as fungi, bacteria and mosses, which changed the transparent state of the traps into a darkened color and significantly affected their capture efficiency. The total number of 6,268 Scolytinae individuals were collected at this experimental stage: 4,977 of them were captured in new traps, whereas 1,291 were captured in the old ones. Based on the herein measured colorimetric variables, such color change got significantly intensified as transparent traps remained under field conditions. In conclusion, transparent traps were more efficient in capturing Scolytinae individuals than the black, yellow and red traps. In addition, the exposure to field conditions has progressively changed equipment color and decreased its capture efficiency.

Keywords: Bostrichidae. Coleoptera. Forest Entomology. Platypodinae. Population Dynamics. Scolytinae.

1. Introduction

Bark and ambrosia beetles belonging to groups Scolytinae, Platypodinae, and Bostrichidae colonize and build galleries in stressed trees, recently-felled timber, or in the case of family Bostrichidae, in wood subjected to drying processes. Xylomicetophagous species inoculate fungi in the stems or logs for feeding and reproduction purposes. Consequently, they depreciate the value of the timber, either due to stains resulting from the action of symbiotic fungi or to the incidence of galleries, which also favor the colonization of this substrate by secondary xylophagous fungi (Monteiro and Garlet 2016).

Population monitoring is the main stage of strategies focused on controlling these insects. Studies about the population level of these insects in wood-drying yards, or in reforestation systems, are often based on ethanol-baited impact traps (Lunz et al. 2010; Carvalho and Trevisan 2015; Silva et al. 2020).

Studies focused on improving the monitoring and control of bark and ambrosia beetles are expected to present projects to enable the manufacture of low-cost equipment, as well as efficient and practical models, or even to indicate the ideal conditions for the application of such equipment. It is worth highlighting several initiatives, such as projects suggesting the use of trap models, to explore the primary attractiveness of logs to Scolytinae (Flechtmann and Gaspareto 1997), the use of ethanol-baited traps (Berti-Filho and Flechtmann 1986; Rodríguez-González et al. 2017), the analysis of how the color and installation height of traps influence the capture of Scolytinae individuals (Strom and Goyer 2001; Chen et al. 2010), the use of recycled materials to manufacture such equipment (Moser and Browne 1978; Carvalho 1998; Murari et al. 2012; Carvalho and Trevisan 2015) and, finally, projects aimed at investigating the capture efficiency of different trap models (Carrano-Moreira et al. 1994; Flechtmann et al. 2000).

According to Steininger et al. (2010), commercial traps used to monitor bark and ambrosia beetles are quite expensive, whereas the ones produced with recycled material, such as the semi-funnel model, are effective and cheaper. Therefore, the trap described by Carvalho and Trevisan (2015) applies to this context and, since it is a recent project focused on this type of equipment, in comparison to similar ones, it is necessary to conduct studies aimed at improving its collection efficiency.

Based on the knowledge that the color of the traps can influence their ability to attract bark and ambrosia beetles (Strom and Goyer 2001; Chen et al. 2010), it is possible assuming that this variable can affect the capture efficiency of semi-funnel traps under field conditions, as well as inferring that the exposure of the equipment to these conditions can lead to significant changes in its original color and affect its capture efficiency.

In light of the foregoing, this study aimed to investigate whether semi-funnel traps manufactured in different colors (red, yellow, black, and translucent) present different efficiency in capturing beetles belonging to groups Scolytinae, Bostrichidae, and Platypodinae in a forest fragment. As well as to check whether the exposure of the equipment to field conditions leads to significant changes in its original color and whether these changes affect their capture efficiency.

2. Material and Methods

The experiment was carried out at the campus of Federal Rural University of Rio de Janeiro (UFRRJ), in a forest fragment of Atlantic Forest, characterized by secondary vegetation (22º75'S, 43º69'W, 33 meters altitude) located at the Forest Institute. Semi-funnel traps (Figure 1) were manufactured in compliance with guidelines set by Carvalho and Trevisan (2015).

The protection plate (Figure 1A), the interceptor panel (Figure 1B) and the collector funnel (Figure 1C) of the equipment, which derived from transparent polyethylene terephthalate (PET) bottle, were painted in red, yellow and black to enable analyzing the influence of color on insect attraction. With respect to the transparent trap, the natural color of the material used to manufacture it was herein adopted. A spray-type ink was used to paint the traps by following the instruction of letting the volatiles of the pigment fully dissipate for two weeks after the painting procedure in order to prevent them from interfering in the insect-attraction power of the bait used in the trap (Chen et al. 2010).

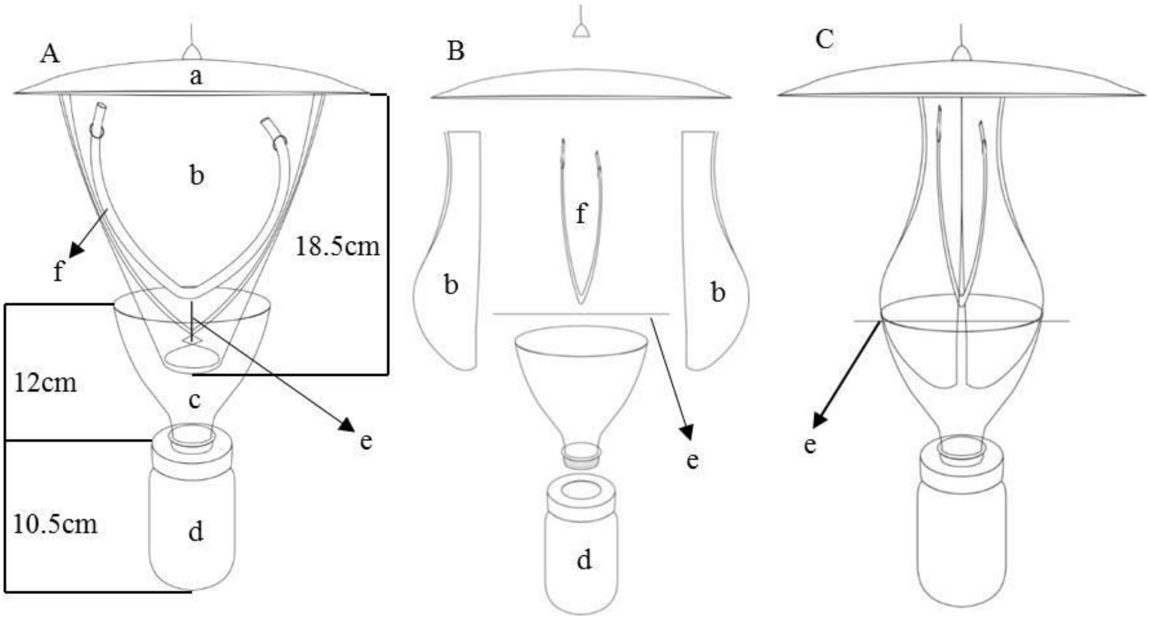

Figure 1. A – Front view: (a) Protection plate; (b) "Semi-funnel" interceptor panel; (c) Collector funnel; (d) Storage bottle; (f) Baitholder hose; (e) Fixing wire; B – Side view of parts: (b) Interceptor panel; (e) Fixing wire; (f) Baitholder hose; (d) Storage bottle; C – Side view of the installed trap: (e) Fixing shaft (rigid wire). Source: Carvalho and Trevisan (2015).

Based on Chen et al. (2010), two sets of traps in the four different colors were installed approximately 20 meters away from each other, and 1.5 meters above the ground, in an Atlantic Forest fragment. The equipment was baited with 100 ml of 96 GL alcohol because, according to Carvalho (1998), this substance is used to attract bark and ambrosia beetles.

Samples were collected weekly (from September 2015 to July 2016), when the bait was refilled. Captured individuals were taken to the Forest Entomology Laboratory of UFRRJ, where they were separated based on trap color and identified as Bostrichidae, Scolytinae, and Platypodinae, based on Casari and Ide (2012). Individuals belonging to other Insecta class taxa, who were captured in the traps, were also quantified.

The second experiment was carried out from August 2016 to June 2017; it only used traps manufactured with a material capable of enabling greater capture and quantified individuals belonging to the taxon prevailing in the first experiment. Therefore, the two traps made with transparent material - used in the first experiment - were reinstalled in the field, together with two transparent traps that had not been used before, to assess whether equipment exposure to field conditions had affected their efficiency in capturing Scolytinae.

Changes in the original color of the equipment exposed to field conditions were investigated based on the difference in colorimetric variables between new traps and the ones exposed to field conditions for 11 and 22 months. To do so, the interceptor panel (Figure 1B) was removed and opened over a sheet of white paper placed on a stand. A portable spectrophotometer (Konica Minolta; model CM 2600D) was used to measure the colorimetric variables under this condition, in compliance with procedures set by ISO 11.664-4: 2008 (International Organization for Standardization, 2008), based on three coordinates (L* = luminosity, a* = red shade, and b* = yellow shade). Measurements were based on the direct contact between the surface of the interceptor panel (at twenty equidistant points) and the lighting area of the apparatus.

Data were processed in the BioEstat 5.3 software (Ayres et al. 2007). The Lilliefors test was used to check data normality ($p < 0.05$). The Kruskal-Wallis test was used to investigate differences in the mean number of individuals belonging to the subfamily Scolytinae and another taxon of the Insecta class also captured and among the colorimetric variables ($p < 0.05$).

The Student-Newman-Keuls test was used to analyze the variance of mean ranks ($p < 0.05$). Data collected in the second experimental stage, which comprised comparisons between collections performed in the new and used traps, were analyzed through the Mann-Whitney test, at a 5% significance level. A line chart was used to analyze population fluctuations.

Means recorded for both experiments were calculated by adding the number of individuals collected in each trap, weekly, and by dividing it by the total number of collections.

3. Results and Discussion

A total of 9,394 insects were captured in collections performed in the forest fragment, weekly, from September 2015 to July 2016. Among them, 58% were Scolytinae, 40% belonged to other taxa, 1% was Bostrichidae, and 0.4% were Platypodinae.

The mean number of Scolytinae individuals captured in the transparent trap was significantly higher than that of individuals captured in the black, yellow, and red traps (Figure 2). Only 161 Bostrichidae and Platypodinae specimens were captured in traps of all colors throughout the monitoring period; thus, it was not possible conducting statistical analysis. However, transparent traps were more efficient than the others, since they captured 50% of Bostrichidae and Platypodinae individuals, whereas the black, yellow and red ones captured 15%, 20%, and 15%, respectively.

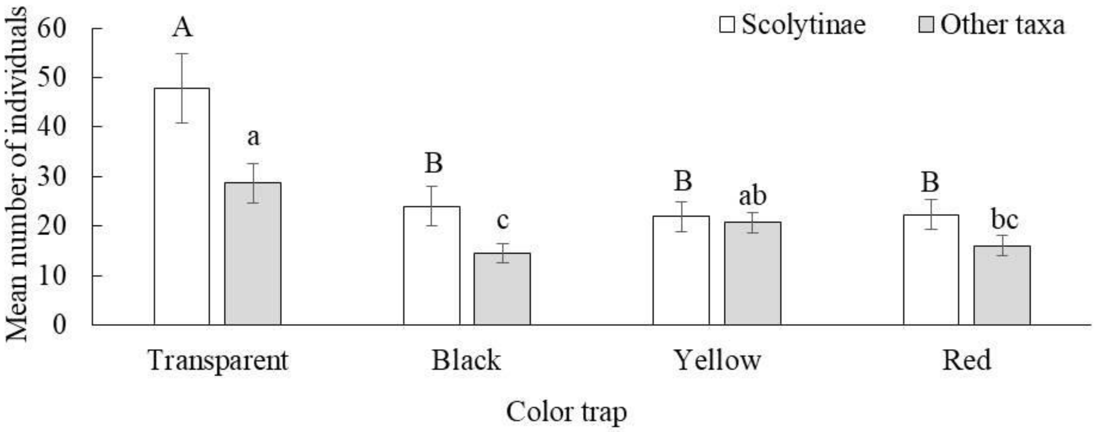

Figure 2. Mean number of Scolytinae and other taxa Insecta Class captured in the semi-funnel trap model manufactured in four different colors. Means followed by different capital (Scolytinae) and lowercase (Other taxa) letters statistically differed from each other (SNK - 5% significance).

Although the main aim of the current study was to analyze the incidence of Scolytinae, Bostrichidae, and Platypodinae individuals, it is worth emphasizing that the transparent traps were also more efficient in collecting individuals belonging to other Insecta Class. This outcome suggests that the adoption of this color to produce entomological traps can be an efficient strategy to capture other insect groups. Still, the performance of the yellow traps was statistically equal to that of the transparent ones in this specific case (Figure 2). It is worth emphasizing that different colors attract specific species; therefore, research focused on elucidating this issue should be conducted.

The current results comply with the study by Flechtmann et al. (1995), whose transparent traps captured more Scolytinae individuals than the yellow, red, green, black, brown, and white traps. According to the aforementioned study, the yellow color repelled Scolytinae specimens during the monitoring process conducted in a tropical pine-reforestation area. Strom and Goyer (2001) evaluated the influence of different trap colors (black, blue, brown, green, red, yellow, and white) on the capture of *Dendroctonus frontalis* (Coleoptera: Scolytinae) specimens. They concluded that the yellow traps were the least efficient ones, as well as that dark colors made the traps more attractive to these beetles; however, unlike the current study, they did not test transparent traps in their experiment.

According to Flechtmann et al. (2000), the black color is often used to manufacture commercial traps aimed at capturing Scolytinae specimens. This strategy is adopted due to reports that using dark colors (i.e., colors that do not contrast with the colors of forest environments) is an efficient strategy to capture Scolytinae specimens. However, transparent traps were not taken into consideration in these reports.

Thus, the results of the current experiment suggested that the higher insect-capturing efficiency of transparent traps, in comparison to the other colors, can be explained by their ability to blend into the environment – i.e., to not make evident contrast with the color of forest environments. Therefore, it is a reasonable understanding that black traps make more contrast with the environment than the transparent ones. Consequently, this characteristic may favor the capture of insects in transparent traps, since this material allows seeing the natural color of different substrates found in the environment, which may be associated with several barks and ambrosia beetle species.

On the other hand, traps painted with specific colors can emulate the shade of certain substrates; thus, they can be more attractive to species associated with substrates such as red fruits, for example. Accordingly, it is worth mentioning the case of Scolytinae *Hypothenemus hampei* (Ferrari), which is associated with coffee fruits and whose monitoring is often based on the adoption of red traps (Fernandes et al. 2014). According to Flechtmann et al. (1995), green ethanol-baited traps attracted more *Hypothenemus bolivianus* (Eggers) specimens, red traps attracted more *Hypothenemus eruditus* Westwood, white traps attracted more *Xylosandrus retusus* (Eichhoff), *Xyleborus spinulosus* (Blandford) and *Xyleborinus gracilis* (Eichhoff), black and red traps attracted more *Ambrosiodmus obliquus* (LeConte), and red and white traps attracted more *Cryptocarenus* sp. specimens.

However, the adoption of transparent traps in ecological studies aimed at collecting different Scolytinae species in native forests, or in reforestation areas, can be a strategy more efficient than the use of traps painted with specific colors. Accordingly, Steininger et al. (2010) tested the insect-capture efficiency of traps manufactured with the same material evaluated in the current study; they found that although the brown trap collected a slightly larger number of Scolytinae individuals, the transparent trap captured a larger number of species.

In addition, the superior capture efficiency of transparent traps was also observed throughout time, i.e., transparent traps captured a larger number of Scolytinae individuals than the other traps in 89% of the 47 weekly collections (Figure 3).

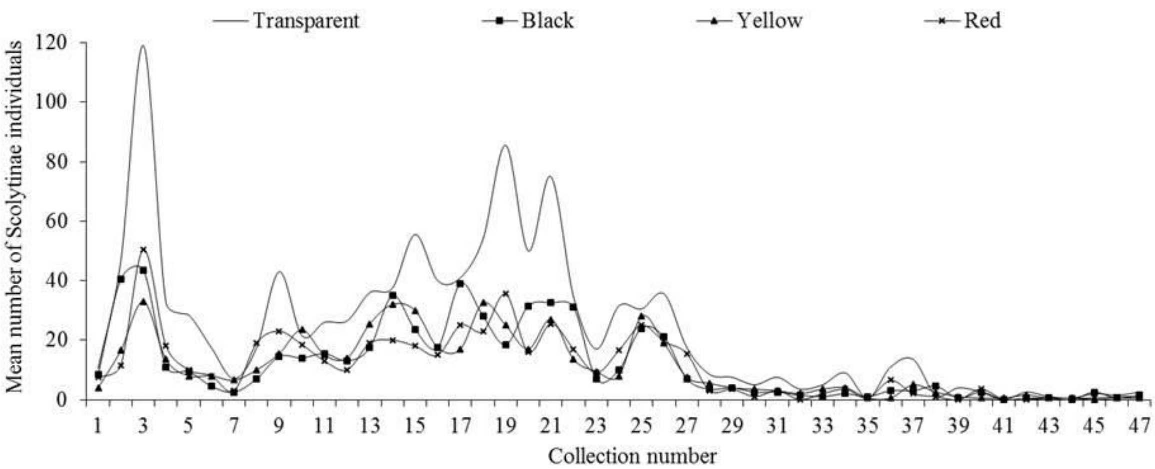

Figure 3. Fluctuation in the number of Scolytinae individuals captured in semi-funnel traps manufactured in four different colors.

All traps exposed to field conditions for 11 months were colonized by fungi, bacteria, and mosses, regardless of their color. The action of these organisms changed (darkened) the original color of the equipment and this condition intensified as organism colonization expanded overtime in the parts composing the trap. Thus, traps used in the first experimental stage were installed again in the field, along with new traps, to enable investigating whether the color change had affected their capture efficiency, mainly the efficiency of transparent traps, which were more efficient than the other colors tested in this experiment.

A total of 6,268 Scolytinae were collected at this experimental stage: 4,977 of them were captured in new traps, whereas 1,291 were captured in the old ones. It was possible observing that the old traps that have darkened by the action of organisms had their capture efficiency significantly affected in comparison to the new ones, which presented the original color (Figure 4). If one takes into consideration that the same sampling effort was adopted for the new and old traps in the current study, the difference in capture efficiency can be associated with the color change in the old traps due to organism colonization.

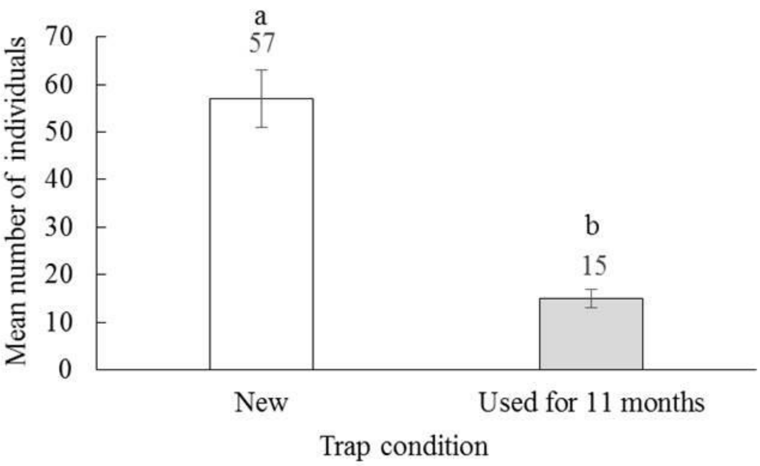

Figure 4. Mean number of Scolytinae individuals captured in semi-funnel traps under the following conditions: new and used for 11 months. Means followed by different (Scolytinae) letters statistically differed from each other (Mann-Whitney - 5% significance).

Thus, traps exposed to field conditions for longer periods-of-time presented significant changes in the colorimetric variables measured in the interceptor panel. Colorimetric variable b, which expressed the yellow shade, was the only one that did not present difference between traps exposed to field conditions for 11 and 22 months (Table 1).

Table 1. Mean values (± standard deviation) calculated for the colorimetric variables (L*=luminosity, a*=red shade and b*=yellow shade) of bark and ambrosia beetles -flight interceptor panels in the semi-funnel traps, under three different use conditions.

Trap condition	Colorimetric variables		
	L*	a*	b*
New	85.7 ± 9.4^{a}	-0.09 ± 0.8^{c}	-2.1 ± 1.3^{b}
Exposed in the field (11 months)	49.9 ± 20.3^{b}	1.2 ± 1.4^{b}	5.7 ± 3.4^{a}
Exposed in the field (22 months)	38.6 ± 16.2^{c}	2.5 ± 1.1^{a}	7.1 ± 1.9^{a}

Different letters between lines express statistical difference (SNK - 5% significance).

If one takes into consideration that these measurements were performed by placing a white sheet of paper behind the interceptor panel of the traps, it is possible to understand that the higher the L value, the more transparent the panel. It happened because higher L values indicated that the white color of the paper was more apparent to the spectrophotometer. Thus, traps exposed to field conditions for longer periods became significantly darker due to organism colonization (Table 1). This condition increased the contrast between traps and the environment; consequently, it impaired the ability of transparent traps to blend into the environment and to reflect different substrates, a fact that adversely affected their capture efficiency.

Therefore, since transparent traps were more efficient in capturing insects in the two experimental stages (Figures 2 and 4), it is possible to assume that the transparent material used to manufacture them increased their capture efficiency. In addition, it is possible saying that traps exposed to field conditions had their efficiency decreased due to significant color changes, with emphasis on the reduced translucency of the interceptor panels, whose color acquired a different shade from that of the original material used in the manufacturing process.

4. Conclusions

Transparent traps were more efficient in capturing Scolytinae individuals than the black, yellow, and red traps.

Parts composing transparent traps have darkened under exposure to field conditions, a fact that has negatively affected their efficiency in capturing Scolytinae individuals. The darkening process has intensified as time traps remained exposed to natural weathering got longer. It is recommended to clean the traps with water as they get dark to preserve their capture efficiency.

Authors' Contributions: TREVISAN, H.: conception and design, drafting the article, critical review of important intellectual content; SOUZA, T.S.: conception and design, critical review of important intellectual content; AMANCIO, J.M.S.: conception and design, drafting the article. All authors have read and approved the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Ethics Approval: Not applicable.

Acknowledgments: Not applicable.

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Received: 13 April 2020 | **Accepted:** 20 August 2020 | **Published:** 28 June 2021