



**GABRIELA COSTA PINHEIRO**

**INTERCEPT FLIGHT TRAP DESIGNS TO CAPTURE  
SCOLYTINAE, PLATYPODINAE, CERAMBYCIDAE,  
BOSTRICHIDAE AND CLERIDAE**

**LAVRAS-MG  
2022**

**GABRIELA COSTA PINHEIRO**

**INTERCEPT FLIGHT TRAP DESIGNS TO CAPTURE SCOLYTINAE,  
PLATYPODINAE, CERAMBYCIDAE, BOSTRICHIDAE AND CLERIDAE**

Dissertação de Mestrado apresentada a Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Entomologia, área de concentração em Entomologia, na linha de pesquisa em Controle Biológico e Manejo Integrado de Pragas, para a obtenção do título de Mestre.

Prof. Dr. Ronald Zanetti Bonetti Filho

Orientador

Prof. Dr. Carlos Alberto Hector Flechtmann

Coorientador

**LAVRAS-MG  
2022**

**Ficha catalográfica elaborada pelo Sistema de Geração de Ficha Catalográfica da Biblioteca Universitária da UFLA, com dados informados pelo(a) próprio(a) autor(a).**

Pinheiro, Gabriela Costa.

Intercept flight trap designs to capture Scolytinae, Platypodinae, Cerambycidae, Bostrichidae and Cleridae / Gabriela Costa Pinheiro. - 2022.

51 p.

Orientador(a): Ronald Zanetti Bonetti Filho.

Coorientador(a): Carlos Alberto Hector Flechtmann.

Dissertação (mestrado acadêmico) - Universidade Federal de Lavras, 2022.

Bibliografia.

1. eficiência de armadilha. 2. dispersão. 3. besouro da ambrosia. I. Bonetti Filho, Ronald Zanetti. II. Flechtmann, Carlos Alberto Hector. III. Título.

**GABRIELA COSTA PINHEIRO**

**INTERCEPT FLIGHT TRAP DESIGNS TO CAPTURE SCOLYTINAE,  
PLATYPODINAE, CERAMBYCIDAE, BOSTRICHIDAE AND CLERIDAE**

**MODELOS DE ARMADILHA DE INTERCEPÇÃO DE VOO PARA CAPTURA DE  
SCOLYTINAE, PLATYPODINAE, CERAMBYCIDAE, BOSTRICHIDAE E  
CLERIDAE**

Dissertação de Mestrado apresentada a Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Entomologia, área de concentração em Entomologia, na linha de pesquisa em Controle Biológico e Manejo Integrado de Pragas, para a obtenção do título de Mestre.

APROVADA em 14 de fevereiro de 2022.

Prof. Dr. Ronald Zanetti Bonetti Filho	UFLA
Prof. Dr. Khalid Haddi	UFLA
Prof. Dr. Adriano Arrué Melo	UFMS
Prof. Dr. Otávio Peres Filho	UFMT

Prof. Dr. Ronald Zanetti Bonetti Filho

Orientador

Prof. Dr. Carlos Alberto Hector Flechtmann

Coorientador

**LAVRAS-MG  
2022**

## AGRADECIMENTOS

À Universidade Federal de Lavras (UFLA).

À Universidade Estadual Paulista “Júlio de Mesquita Filho”, campus de Ilha Solteira (UNESP).

Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), pelo financiamento do projeto.

Ao meu orientador Prof. Dr. Ronald Zanetti Bonetti Filho pela parceria, contribuições e solicitude.

Ao meu coorientador Prof. Dr. Carlos Alberto Hector Flechtmann pela dedicação, contribuição e ensinamentos.

Aos funcionários da Fazenda de Ensino Pesquisa e Extensão da UNESP Ilha Solteira pelo suporte ao desenvolvimento do projeto.

Ao José Antônio pelo transporte, ajuda com as coletas em campo, e ensinamentos.

À Silvia Tanabe, pela ajuda na identificação dos insetos.

Aos meus colegas do Laboratório de Entomologia da UNESP Ilha Solteira, por todo apoio e parceria, e aos do Laboratório de Entomologia Florestal da UFLA pela receptividade.

Aos amigos e família pelo apoio e por rezarem por mim para Deus preparar o melhor caminho.

## RESUMO

Os besouros das subfamílias Scolytinae e Platypodinae (Curculionidae), Cerambycidae e Bostrichidae (Coleoptera) apresentam alta diversidade e, em muitos casos, altos danos às plantas hospedeiras que atacam. As espécies são monitoradas com armadilhas de interceptação de voo iscadas com etanol, cujo modelo afeta a eficiência de coleta das espécies. O objetivo desse estudo foi analisar a influência do número de aletas e aberturas na armadilha de interceptação de voo tradicionalmente usada no Brasil, feita de garrafa de refrigerante de dois litros, iscada com etanol 96% para coletar esses besouros e seus predadores Cleridae (Coleoptera). As armadilhas tinham um, três ou quatro aletas, presença/ausência de orifício no centro das aletas, e presença/ausência de abertura superior na armadilha. O número de aletas influenciou na coleta desses besouros. As armadilhas com três aletas e sem orifícios coletaram a maioria dos besouros. O orifício central e superior não influenciou na coleta deles, talvez devido a condições climáticas desfavoráveis para o voo dos besouros e para dispersar o etanol. A maior taxa de volatilização do etanol não é suficiente para aumentar a coleta desses besouros, pois a eficiência do monitoramento depende de um conjunto de fatores.

**Palavras-chave:** besouro da ambrosia, eficiência de armadilha, dispersão.

## ABSTRACT

Beetles Scolytinae and Platypodinae (Curculionidae), Cerambycidae e Bostrichidae (Coleoptera) present a high diversity, and they can, in many cases, inflict a high damage to the host plants they attack. The beetles number of these species are monitored with ethanol-baited flight intercept traps, and its design affects the efficiency of collect of the species. The aim of this study was to analyze the influence of the number of vanes and openings in flight intercept traps traditionally used in Brazil, made from two-liter soda bottles, baited with 96% ethanol to collect these beetles and your predator Cleridae (Coleoptera). The traps had one, three or four vanes, presence/absence of a central vane hole; and presence/absence of an upper opening at its top. The number of vanes influenced in the capture of these beetles, because the traps with three vanes with absence of both holes collected the most of these beetles. The central and upper hole did not influence the collect them in this study, perhaps due to unfavorable climate conditions for the flight of these beetles and to disperse the ethanol. The efficiency of the monitoring depends on a set of factors. A single factor, such as the highest ethanol release rate is not enough for highest beetle catches.

**Keywords:** ambrosia beetle, trap efficiency, dispersion.

## SUMÁRIO

<b>PRIMEIRA PARTE.....</b>	<b>8</b>
<b>1 INTRODUÇÃO (SEÇÃO PRIMÁRIA) .....</b>	<b>8</b>
<b>2 REFERENCIAL TEÓRICO (SEÇÃO PRIMÁRIA) .....</b>	<b>10</b>
<b>2.1 Scolytinae e Platypodinae (Curculionidae).....</b>	<b>10</b>
<b>2.2 Cerambycidae.....</b>	<b>12</b>
<b>2.3 Bostrichidae.....</b>	<b>12</b>
<b>2.4 Cleridae.....</b>	<b>13</b>
<b>2.5 Monitoramento.....</b>	<b>14</b>
<b>REFERÊNCIAS.....</b>	<b>16</b>
<b>SEGUNDA PARTE - ARTIGOS.....</b>	<b>22</b>
<b>ARTIGO 1 - Flight intercept trap designs to capture Scolytinae, Platypodinae, Cerambycidae, Bostrichidae and Cleridae.....</b>	<b>23</b>

## PRIMEIRA PARTE

### 1 INTRODUÇÃO

Besouros das subfamílias Scolytinae e Platypodinae (Curculionidae) em sua maioria são pragas secundárias, que atacam plantas estressadas ou enfraquecidas, causando a depreciação da madeira pelos orifícios e galerias, e algumas espécies são primárias, atacando plantas saudáveis e ocasionalmente matando-as (BEAVER, 1988; KIRKENDALL; BIEDERMANN; JORDAL, 2015). Algumas espécies de Scolytinae e todas de Platypodinae são conhecidos como besouros da ambrosia por se alimentarem de fungos que introduzem em suas galerias no hospedeiro, podendo ser vetores de doenças a plantas hospedeiras (KIRKENDALL; BIEDERMANN; JORDAL, 2015).

Além de pragas, essas brocas aceleram o processo de reciclagem de matéria orgânica ao ambiente, por acelerarem a decomposição das plantas atacadas ( MOREHOUSE; JOHNS; KAYE, 2008), assim como Cerambycidae e Bostrichidae que também são pragas secundárias, com algumas espécies capazes de causar danos econômicos às florestas cultivadas (FREDIANI, 1961; EVANS; MORAAL; PAJARES, 2007; LIU; SCHÖNITZER; YANG, 2008). Embora não se alimentem de fungos simbióticos, eles podem transportar fitopatógenos para plantas hospedeiras (LINSLEY, 1959; LIU; SCHÖNITZER; YANG, 2008; BOONE, 2019). Os Cleridae são predadores de Scolytinae, Platypodinae, Cerambycidae e Bostrichidae tanto em fase adulta quanto larval (LEAVENGOOD, 2008; CLARKE; MENARD, 2006).

O monitoramento é essencial para acompanhar o tamanho da população desses besouros (BOUGET et al., 2009) e para saber quando aplicar um tratamento (OLIVER; MANNION, 2001), já que são de difícil controle por se hospedarem no interior da madeira (BEAVER, 1988). A maioria dos países usa armadilhas para monitoramento, mas elas podem ser usadas para controle em massa (GALKO et al., 2016), coletando grande quantidade de insetos pragas e, reduzindo de 70 a 100% sua infestação (NIEMEYER, 1997).

Armadilhas de intercepção de voo são eficientes na coleta de Scolytinae, Platypodinae, Cerambycidae, Bostrichidae e Cleridae (FILHO; FLECHTMANN, 1986), além de ser uma ferramenta simples e barata de monitoramento (STEININGER, 2015). Há vários fatores que influenciam a eficiência do monitoramento dessas armadilhas, como o modelo e o atrativo para coleta dos besouros com armadilhas (FLECHTMANN et al., 1995).

Há vários tipos de armadilhas de interceptação de voo. A ESALQ-84 é a mais usada e eficiente na coleta de Scolytinae, Platypodinae, Cerambycidae, Bostrichidae e Cleridae no Brasil. Elas podem apresentar modificações com diferentes números de aletas (FILHO; FLECHTMANN, 1986; FLECHTMANN; OTTATI; BERISFORD, 2000). Armadilha com mais de uma aleta pode coletar o inseto em mais de uma direção de voo (SAFRANYIK; SHORE; LINTON, 2004), o que é importante porque o voo desses besouros é direcional ao volátil atrativo (KELSEY; JOSEPH, 1998), que pode ser espalhado em qualquer direção do vento (DAVID et al., 1982; ELKINTON et al., 1987).

O número mais adequado de aletas na armadilha para captura de coleobrocas é internacionalmente controverso (BOUGET et al., 2009; GROOT; NOTT, 2001; MOREWOOD et al., 2002; MCINTOSH et al., 2001; SAFRANYIK; SHORE; LINTON, 2004; BARRERA et al., 2008; GRAHAM et al., 2012; GALKO et al., 2016; KENDRA et al., 2020). Além disso, influência de vários fatores na eficiência da armadilha, inclusive o ambiente da área amostral, faz necessário determinar o melhor modelo para as condições brasileiras.

O atrativo é outro fator que aprimora a eficiência do monitoramento, sendo o etanol o mais empregado (GORZLANCYK, 2013). No entanto, a atratividade do etanol é variável conforme sua taxa de liberação (SAMANIEGO; GARA, 1970; REDING et al., 2011), a qual é dependente das variações climáticas (RANGER et al., 2011) e da densidade da floresta, uma vez que ambientes mais fechados desfavorecem a liberação, ao contrário de florestas abertas (SVERDRUP-THYGESON; BIRKEMOE, 2009; MILLER et al., 2015).

O tipo de armadilha pode alterar a taxa de liberação do etanol, uma vez que podem permitir sua maior dispersão (GALKO et al., 2014; PENG; WILLIAMS, 1991; BURBANO et al., 2012), com maior fluxo de ar nela (SAFRANYIK; SHORE; LINTON, 2004), podendo ser mais eficiente, atraindo maior número de besouros (FLECHTMANN; OTTATI; BERISFORD, 2000).

Portanto, o objetivo desse estudo foi analisar a influência da combinação do número de aletas e aberturas na armadilha de interceptação de voo na captura de besouros Scolytinae, Platypodinae (Curculionidae), Cerambycidae e Bostrichidae e seus predadores Cleridae (Coleoptera). Espera-se que a presença de orifícios no centro das aletas e/ou na parte superior da armadilha permita maior liberação da isca e conseqüentemente maior captura que armadilhas sem orifícios com o mesmo número de aletas, com objetivo de analisar a taxa de captura dos besouros em função da presença/ausência de orifícios na parte central das aletas e da presença/ausência de tampa na parte superior da armadilha.

Outra hipótese foi que quanto mais aletas, maior a área de interceptação de voo e em várias direções, aumentando a quantidade de besouros capturados, com objetivo de analisar a taxa de captura dos besouros em função do número de aletas nas armadilhas. Além de determinar a melhor combinação do número de aletas e ausência ou presença de orifício nas armadilhas, contribuindo assim na eficiência de programas de monitoramento e controle massal destas pragas.

## 2 REFERENCIAL TEÓRICO

### 2.1 Scolytinae e Platypodinae (Curculionidae)

Há cerca de 6000 espécies de Scolytinae e 1400 de Platypodinae descritas (KIRKENDALL; BIEDERMANN; JORDAL, 2015). Esses besouros de tonalidade marrom amarelado ou avermelhado a preto possuem de 0,5 mm a 4 mm de comprimento, com aparato bucal mastigador, utilizado para alimentação e para escavar galerias (KIRKENDALL; BIEDERMANN; JORDAL, 2015). Os besouros perfuram a madeira para construção de galerias na planta hospedeira, onde abrigam sua ninhada (BEAVER, 1988), esse comportamento desvaloriza a madeira para fins comerciais (BEAVER, 1988).

Alguns exemplos de espécies pragas são *Xylosandrus germanus* e *Xylosandrus crassiusculus*, importantes em viveiros e pomares (MILLER et al., 2015). *Hypothenemus hampei* é uma das principais pragas do café (DAMON, 2000). *Hypothenemus obscurus* causa sérios danos em macadâmia (JONES; BURNAM-LARISH; CAPRIO, 1992). Há ainda espécies que introduzem fungo simbiótico na planta hospedeira, a qual pode ser patógeno a ela, com potencial para matá-la (HARRINGTON; AGHAYEVA; FRAEDRICH, 2010; HULCR; DUNN, 2011). Como exemplo está *Xyleborus glabratus* e *Xyleborus volvulus* que introduz fungo causador da doença da murcha do louro no seu hospedeiro (HARRINGTON; FRAEDRICH, 2010; CASTREJON et al., 2018).

As espécies com potencial de causarem dano econômico por atacarem plantas saudáveis são chamadas de espécies primárias, e há as espécies secundárias, que compõem a maioria das espécies, e atacam plantas doentes ou estressadas (WOOD, 1982). Essas espécies secundárias também apresentam importância ecológica (WOOD, 1982), devido a ajuda na decomposição da madeira ao construírem suas galerias, e na reciclagem de nutrientes no caso de espécies que se alimentam da madeira (MOREHOUSE; JOHNS; KAYE, 2008).

Todos os Platypodinae e algumas espécies de Scolytinae se alimentam de fungos simbióticos que introduzem na planta hospedeira (HARRINGTON et al., 2010; HULCR;

DUNN, 2011). Além de alimento o fungo ajuda o besouro a quebrar a resistência da planta hospedeira para colonização, e em benefício do fungo ele é transportado e disseminado na planta hospedeira (HULCR; DUNN, 2011).

As espécies possuem diferentes hábitos alimentares, espécies xilomicetófagas se alimentam de fungo simbiótico e são popularmente conhecidas como besouros da ambrosia (WOOD, 1982), enquanto as espécies fleófagas, que se alimentam do floema da madeira são popularmente conhecidas como besouros da casca, espécies xilófagas se alimentam do xilema da madeira, e mielófagas da medula de pequenos ramos (WOOD, 1982), espécies herbípagas se alimentam de plantas herbáceas, e espermófagas de sementes e parte do endocarpo de frutos (WOOD, 1982).

Os besouros da casca são monófagos, possuem hospedeiro específico, uma vez que se alimentam da madeira, enquanto os besouros da ambrosia são polípagos, uma vez que se alimentam do fungo simbiótico introduzido na planta que é pouco seletivo ao hospedeiro (ATKINSON; MARTINEZ, 1986), embora exija hospedeiro com certa umidade para sobrevivência do fungo (ELLIOTT; MADDEN; BASHFORD, 1983).

A seleção hospedeira ocorre através de atração primária, devido a liberação de caimônio, volátil liberado pelas plantas hospedeiras, e através de atração secundária, devido a liberação de feromônio de agregação, volátil liberado pelo besouro para atrair outros indivíduos para colonização em massa da planta hospedeira (FLECHTMANN et al., 1995).

Entre os caimônios o etanol é eficiente para atração primária da maioria das espécies de Scolytinae e Platypodinae (KIMMERER; KOZLOWSKI, 1982; MOECK, 1971; MONTGOMERY; WARGO, 1983), porque a maioria são espécies secundárias, que hospedam plantas enfraquecidas ou doentes (WOOD, 1982), estas produzem etanol devido ao processo anaeróbico realizado como medida de sobrevivência a condição de estresse, e quanto mais estressada maior a produção de etanol (KIMMERER; KOZLOWSKI, 1982; KELSEY; JOSEPH, 1998).

A taxa de liberação do etanol influencia na sua atratividade aos besouros (KLIMETZEK et al., 1986), sendo algumas espécies mais atraídas por altas taxas de liberação de etanol (KLIMETZEK et al., 1986), e outras por baixas taxas de liberação, sendo a alta taxa de volatilização repelente a essas espécies (GORZLANCYK et al., 2013). A atratividade do besouro a taxa de liberação do etanol está correlacionada com sua preferência ao estado fisiológico do hospedeiro (KELSEY; WESTLIND, 2017; KIMMERER; KOZLOWSKI, 1982), uma vez que quanto mais debilitada a planta maior será a sua liberação de etanol (KIMMERER; KOZLOWSKI, 1982; KELSEY; JOSEPH, 1998), está também correlacionada

com condições climáticas e estrutura da planta (RANGER et al., 2011), e com a densidade de cobertura florestal (ARISTOPHANOUS, 2010; MILLER et al., 2015).

## 2.2 Cerambycidae

Há cerca de sete subfamílias e 20.000 espécies descritas, eles apresentam tamanhos variados, tendo a maioria aproximadamente 2 mm a 60mm, com alguns alcançando até 170 mm, alguns com mandíbulas muito grandes (LINSLEY, 1959), e antenas muito longas (EVANS; MORAAL; PAJARES, 2007). Os que se hospedam em madeira são a maioria achatados e de hábito noturno ou crepuscular e por isso são castanhos ou pretos, enquanto as espécies diurnas a maioria são brilhantes e coloridos (LINSLEY, 1959).

Algumas espécies são monófagas, outras são oligófagas enquanto outras são polífagas, também há uma variedade quanto a atratividade para condição do hospedeiro, com algumas espécies preferindo madeira saudável, enquanto outros preferem enfraquecida ou em decomposição ( ALLISON; BORDEN; SEYBOLD, 2004; EVANS; MORAAL; PAJARES, 2007), este último grupo é de importância ecológica, pela ajuda no processo de decomposição da madeira e reciclagem de nutrientes (LINSLEY, 1959; EVANS; MORAAL; PAJARES, 2007).

As espécies que atacam árvores e arbustos vivos são capazes de matar a planta devido a construção de extensas galerias de alimentação da larva (EVANS; MORAAL; PAJARES, 2007). Além de desvalorizar a madeira com presença de orifícios e as vezes de manchas oriundas de fungos que aproveitam a perfuração da madeira para se alojarem, as vezes transportados pelos Cerambycidae (ALLISON; BORDEN; SEYBOLD, 2004). Os Cerambycidae podem carregar microrganismos fitopatogênicos simbióticos para quebrar as defesas da planta e ajudá-lo a colonizá-la (LINSLEY, 1959; BOONE, 2019). O gênero *Monochamus* é vetor do nematóide *Bursaphelenchus xylophilus* da madeira do pinheiro, causador da doença murcha do pinheiro, que já matou muitas árvores na Ásia (BOONE, 2019).

A seleção hospedeira ocorre através de atrativos liberados pelas plantas hospedeiras, entre eles são de grande destaque monoterpenos e etanol liberados por plantas enfraquecidas, recém cortada ou em decomposição, além de feromônios sexuais e de agregação (ALLISON; BORDEN; SEYBOLD, 2004).

## 2.3 Bostrichidae

Há cerca de nove subfamílias e 580 espécies descritas, com tamanho de aproximadamente 2 a 16 mm, marrom amarelado ou avermelhado a preto (PARK, 2015), de hábito noturno atraídos pela luz (LIU; SCHÖNITZER; YANG, 2008).

A maioria são polípagos, mas algumas espécies demonstram especificidade ao hospedeiro (LIU; SCHÖNITZER; YANG, 2008). Os Bostrichidae habitam cereais armazenados, madeira morta, viva e bambus (LIU; SCHÖNITZER; YANG, 2008). Eles selecionam um hospedeiro para alimentação de maturação, o que pode ser plantas vivas, sob estresse ou enfraquecidas, e podem levar essas plantas a morte com a construção de suas galerias e alimentação da madeira. Além de procurarem outro hospedeiro para reprodução, este último normalmente são caules e galhos caídos (FREDIANI, 1961; LIU; SCHÖNITZER; YANG, 2008), o que ajuda a acelerar a decomposição da madeira e a reciclagem de nutrientes (CURKOVIC, 2018).

Eles podem passar mais de uma geração no mesmo hospedeiro de reprodução se as condições climáticas para voo não forem adequadas para saída do hospedeiro inicial (BEESON; BATHIA, 1936). A procura do novo hospedeiro envolve voláteis atrativos como os emitidos pelas plantas hospedeiras, entre eles o etanol que indica o estado fitossanitário de estresse da planta, atrativo também aos Bostrichidae (EDDE; TOEWS; PHILLIPS, 2011; MILLER et al., 2015).

## **2.4 Cleridae**

Há cerca de 4000 espécies descritas (GERSTMEIER; HALPERIN; CHEKATUNOV, 1999), com tamanho de aproximadamente 5 a 30 mm de comprimento, a coloração de brilhantes a quase pretos (BURK, 2015). Como hábito alimentar a maioria são predadores de Scolytinae, Platypodinae, Bostrichidae e Cerambycidae tanto em fase adulta quanto larval (LEAVENGOOD, 2008; CLARKE; MENARD, 2006), algumas espécies se alimentam de pólen, outras de madeira e outras de produtos cárneos armazenados (BURK, 2015).

As espécies predadoras na fase larval comem preferencialmente os ovos e larvas de primeiro instar das suas presas, que por serem muito pequenos não apresenta boa perfuração e locomoção na madeira, enquanto os adultos se alimentam tanto da fase larval quanto da adulta das suas presas (REID, 1957; REEVE, 1997).

Os predadores seguem suas presas, então obtém os mesmos requisitos para voo e se atraem pelos mesmos voláteis que suas presas (HARWOOD; RUDINSKY, 1995), pelos feromônios de agregação das presas e pelos voláteis emitidos pelos seus hospedeiros (REEVE, 1997).

## **2.5 Monitoramento**

Os besouros são coletados durante o voo, atividade essencial para encontrar um novo hospedeiro, e único momento que estão expostos as causas de mortalidade, como esgotamento energético, desidratação e predação (WOOD, 1982). As condições climáticas favoráveis ao voo são essenciais para a distribuição dos besouros, uma vez que em baixa umidade relativa e precipitação pluvial aumenta sua taxa de desidratação, assim como em elevadas temperaturas (JONES et al., 2019), e a velocidade do vento determina a distância do voo do besouro e sua direção (SAFRANYIK et al., 1989; JONES et al., 2019), na ausência de vento o besouro voa aleatoriamente até localizar o atrativo (WOOD, 1982; SALOM; MCLEAN, 1991), em baixas velocidades do vento o besouro voa contra ele em direção a fonte atrativa, mas em altas velocidades os besouros são arrastados pelo vento não conseguindo se direcionar para a fonte atrativa (SEYBERT; GARA, 1970; MEYER; NORRIS, 1973).

As armadilhas de intercepção de voo iscadas com atrativo são utilizadas para monitoramento da população desses besouros (BOUGET et al., 2009), uma vez que o melhor método de controle é o preventivo, já que ao se instalarem na planta causam prejuízo, e não há mais viabilidade de controle (BEAVER, 1988). A coleta das armadilhas informa quando e onde a população pode causar dano econômico (BOUGET et al., 2009), para poder isolar da área a planta foco da população para impedir que eles atinjam as outras plantas na proximidade (NIEMEYER, 1997). Além de estudar o comportamento da riqueza e abundância de espécies no ambiente para fins ecológicos e de aprimoramento da eficiência do monitoramento (BYERS, 1989; CARVALHO; TREVISAN, 2015)

Há vários fatores que influenciam na eficiência do monitoramento, entre eles o atrativo e o tipo de armadilha são os principais fatores (FLECHTMANN et al., 1995). Além deles ainda há o número de armadilhas por área, a distância entre elas, a frequência de coletas (FLECHTMANN et al., 1995), a altura (HANULA; ULYSHEN; HORN, 2011) e localização (SAFRANYIK; SHORE; LINTON, 2004). Entre os tipos de armadilhas o que influencia na coleta dos besouros é a forma e tamanho da área de intercepção de voo, a capacidade de retenção dos insetos e o fluxo de ar na armadilha (SAFRANYIK; SHORE; LINTON, 2004).

Além da eficiência de coleta dos besouros, precisa ponderar o custo, durabilidade, e facilidade de coleta e manutenção das armadilhas (GRAHAM et al., 2012).

Entre os tipos de armadilhas, as com mais de uma aleta pode capturar os insetos independente da sua direção de voo (SAFRANYIK; SHORE; LINTON, 2004), e como o voo dos Scolytinae é direcional ao volátil atrativo liberado pelo possível hospedeiro (KELSEY; JOSEPH, 1998), não conhecendo a localização do possível hospedeiro é importante considerar várias direções de captura (BROCKERHOFF, 2006), além da constante mudança da direção do vento dentro da floresta, o que espalha o atrativo para várias direções (FARES, 1980).

Armadilhas com uma aleta se mostrou mais eficiente do que com quatro aletas (SAFRANYIK; SHORE; LINTON, 2004), talvez porque embora os dois modelos apresentassem a mesma área, as de única aleta apresentam toda sua área para intercepção de voo (ângulo de  $0^\circ$ ) enquanto as de aletas cruzadas apresentam área compacta pelas aletas, formando ângulo de  $90^\circ$  entre cada aleta e perdendo espaço para intercepção de voo (BOUGET et al., 2008). No entanto Groot e Nott (2001) obteve diferença entre espécies de Cerambycidae, sendo aletas cruzadas mais eficientes para determinada espécie, e indiferente para outra espécie, por isso a escolha da armadilha depende do grupo alvo a ser capturado.

Quanto mais aletas maior a área de intercepção de voo da armadilha e maior a eficiência de captura (OKLAND, 1996; GALKO et al., 2016). Embora a ESALQ-84, armadilha de intercepção de voo frequentemente usada no Brasil (FLECHTMANN; OTTATI; BERISFORD, 2000) apresente pequena área de intercepção de voo, ela mostrou ser mais eficiente na captura de Scolytinae por unidade de área que outras armadilhas com grande área de intercepção frequentemente usadas em outros países (FLECHTMANN; OTTATI; BERISFORD, 2000).

O tipo de armadilha pode alterar a taxa de liberação do etanol, uma vez que podem permitir sua maior dispersão (GALKO et al., 2014; PENG; WILLIAMS, 1991; BURBANO et al., 2012), com maior fluxo de ar nela (SAFRANYIK; SHORE; LINTON, 2004), através de aberturas que podem mudar a pluma do atrativo a tornando mais longa e dispersa (LEWIS; MACAULAY, 1976), podendo ser mais eficiente, atraindo maior número de besouros (FLECHTMANN; OTTATI; BERISFORD, 2000).

## REFERÊNCIAS

- ALLISON, J. D.; BORDEN, J. H.; SEYBOLD, S. J. A review of the chemical ecology of the Cerambycidae (Coleoptera). **Chemoecology**, Basel, v. 14, n. 3-4, p. 123–150, 2004.
- ARISTOPHANOUS, M. Does your preservative preserve? A comparison of the efficacy of some pitfall trap solutions in preserving the internal reproductive organs of dung beetles. **ZooKeys**, Sofia, v. 34, n. 196, p. 1- 16, 2010.
- ATKINSON, T. H.; EQUIHUA-MARTINEZ, A. Biology of bark and ambrosia beetles (Coleoptera: Scolytidae and Platypodidae) of a tropical rain forest in Southeastern Mexico with an annotated checklist of species. **Annals of the Entomological Society of America**, College Park, v. 79, n. 3, p. 414–423, 1986.
- BARRERA, J. F. et al. La trampa de una ventana (Ecoiapar) captura más broca del café *Hypothenemus hampei* que la trampa de tres ventanas (Etotap). **Entomología Mexicana**, Chiapas, v. 7, p. 619–624, 2008.
- BEAVER, R. A. Biological studies on ambrosia beetles of the Seychelles (Col., Scolytidae and Platypodidae). **Journal of Applied Entomology**, Berlin, v. 105, n. 1–5, p. 62–73, 1988.
- BEESON, C.F.C.; BHATIA, B. M. On the biology of the Bostrychidae (Coleoptera). **Indian Forest Records (N.S.) Entomology**, Dehradun, v. 2, n. 12, p. 223–323, 1936.
- BERTI FILHO, E.; FLECHTMANN, C. A. H. A model of ethanol trap to collect Scolytidae and Platypodidae (Insecta, Coleoptera). **Instituto de Pesquisas e Estudos Florestais**, Piracicaba, v. 34, p. 53-56, 1986.
- BOONE, C. K. et al. *Monochamus* species from different continents can be effectively detected with the same trapping protocol. **Journal of pest science**, Berlin, v. 92, n. 1, p. 3-11, 2019.
- BOUGET, C. et al. Sampling Saproxylic beetles with window flight traps: Methodological insights. **Revue d'Ecologie (La Terre et la Vie)**, Paris, v. 10, p. 21-32, 2008.
- BOUGET, C. et al. Evaluation of window flight traps for effectiveness at monitoring dead wood-associated beetles: The effect of ethanol lure under contrasting environmental conditions. **Agricultural and Forest Entomology**, St Albans, v. 11, n. 2, p. 143–152, 2009.
- BROCKERHOFF, E. G. et al. Nationwide survey for invasive wood-boring and bark beetles (Coleoptera) using traps baited with pheromones and kairomones. **Forest Ecology and Management**, Amsterdam, v. 228, n. 1–3, p. 234–240, 2006.
- BURBANO, E. G. et al. Efficacy of traps, lures, and repellents for *Xylosandrus compactus* (Coleoptera: Curculionidae) and other ambrosia beetles on *Coffea arabica* plantations and *Acacia koa* nurseries in Hawaii. **Environmental Entomology**, College Park, v. 41, n. 1, p. 133–140, 2012.
- BURKE, A.; CHABOO, C. S. Beetles (Coleoptera) of Peru: A survey of the families. Cleridae Latreille, 1802. **Journal of the Kansas Entomological Society**, Lawrence, v. 88, n.

2, p. 260-266, 2015.

BYERS, J.A. Chemical ecology of bark beetles. **Experientia**, Berlin, v. 45, n. 3, p. 271-283, 1989.

CARVALHO, A. G. D.; TREVISAN, H. Novo modelo de armadilha para captura de Scolytinae e Platypodinae (Insecta, Coleoptera). **Floresta e Ambiente**, Rio de Janeiro, v. 22, p. 575-578, 2015.

CASTREJÓN-ANTONIO, J. E. et al. Infestation of *Xyleborus volvulus* (Fabricius) (Coleoptera: Curculionidae: Scolytinae) in *Mangifera indica* L. (*Mangifera*: Anacardiaceae) in Manzanillo, Colima. **Florida Entomologist**, Hillsborough, v.101, n. 4, p. 676-679, 2018.

CLARKE, S. R.; MENARD, R. D. Predation of an ambrosia beetle (Coleoptera: Platypodidae) by a checkered beetle (Coleoptera: Cleridae) congregating on pines containing brood adult southern pine beetles (Coleoptera: Curculionidae). **Journal of Entomological Science**, Tifton, v. 41, n. 3, p. 1-257, 2006.

CURKOVIC, T. et al. Effect of infestation by *Micrapate scabrata* (Erichson, 1847) (Coleoptera: Bostrichidae) on wood degradation and its impacts on some soil chemistry properties. **Gayana**, Concepción, v. 82, n. 1, p. 1-7, 2018.

DAMON, A. A review of the biology and control of the coffee berry borer, *Hypothenemus hampei* (Coleoptera: Scolytidae). **Bulletin of entomological research**, Brisbane, v. 90, n. 6, p. 453-465, 2000.

DAVID, C. T. et al. A reappraisal of insect flight towards a distant point source of wind-borne odor. **Journal of Chemical Ecology**, Lund, v. 8, n. 9, p. 1207-1215, 1982.

EDDE, P. A.; TOEWS, M. D.; PHILLIPS, T. W. Effects of various semiochemicals on the responses of *Rhyzopertha dominica* to pheromone traps in the field. **Annals of the Entomological Society of America**, College Park, v. 104, n. 6, p. 1297-1302, 2011.

ELLIOTT, H. J.; MADDEN, J. L.; BASHFORD, R. The association of ethanol in the attack behaviour of the mountain pinhole borer *Platypus subgranosus* Schedl (Coleoptera: Curculionidae: Platypodinae). **Austral Entomology**, Melbourne, v. 22, n. 1, p. 299- 302, 1983.

ELKINTON, J.S. et al. Pheromone puff trajectory and upwind flight of male gypsy moths in a forest. **Physiological Entomology**, London, v. 12, n. 4, p. 399-406, 1987.

EVANS, H. F.; MORAAL, L. G.; PAJARES, J.A. Biology, ecology and economic importance of Buprestidae and Cerambycidae. In: **Bark and Wood Boring Insects in Living Trees in Europe, a Synthesis**, Berlin, Springer, p. 447-474, 2007.

FARES, Y.; CHARLES, P. J. H.; MAGNUSON, C.E. Pheromone dispersion in forests. **Journal of Theoretical Biology**, Amsterdam, v. 84, n. 2, p. 335-359, 1980.

FLECHTMANN, C. A. H. et al. **Manual de pragas em florestas: Scolytidae em reflorestamento com pinheiros tropicais**. IPEF, Piracicaba, v. 4, 1995.

- FLECHTMANN, C. A. H.; OTTATI, A. L. T.; BERISFORD, C. W. Comparison of four trap types for Ambrosia Beetles (Coleoptera, Scolytidae) in Brazilian *Eucalyptus* stands. **Journal of Economic Entomology**, Lanham, v. 93, n. 6, p. 1701–1707, 2000.
- FREDIANI, D. Ricerche morfo-biologiche sul *Synoxylon perforans* Schrk (Coleoptera Bostrichidae). **Bollettino del laboratorio di entomologia agraria**, v. 19, p. 1–52, 1961.
- GALKO, J. et al. Attraction of ambrosia beetles to ethanol baited traps in a Slovakian oak forest. **Biologia**, Berlin, v. 69, n. 10, p. 1376-1383, 2014.
- GALKO, J. et al. Effectiveness of pheromone traps for the European spruce bark beetle: a comparative study of four commercial products and two new models. **Forestry Journal**, Basel, v. 62, n. 4, p. 207–215, 2016.
- GERSTMEIER, R.; HALPERINAND, J.; CHEKATUNOV, V. An Annotated List of Cleridae and Thanerocleridae (Coleoptera) of Israel. **Phytoparasitica**, Berlin, v. 27, n. 1, p. 27-33, 1999.
- GORZLANCYK, A. **Visual, acoustic, and volatile cues to improve performance of trapping ambrosia beetles (Coleoptera: Curculionidae)**. Thesis of Master, Auburn University, 73 p., 2013.
- GRAHAM, E. E. et al. A comparison of trap type and height for capturing Cerambycidae beetles (Coleoptera). **Journal of Economic Entomology**, Lanham, v. 105, n. 3, p. 837–846, 2012.
- GROOT, P.; NOTT, R. Evaluation of traps of six different designs to capture pine sawyer beetles (Coleoptera: Cerambycidae). **Agricultural and Forest Entomology**, St Albans, v. 3, n. 2, p. 107–111, 2001.
- HANULA, J. L.; ULYSHEN, M. D.; HORN, S. Effect of trap type, trap position, time of year, and beetle density on captures of the redbay ambrosia beetle (Coleoptera: Curculionidae: Scolytinae). **Journal of Economic Entomology**, Lanham, v. 104, n. 2, p. 501–508, 2011.
- HARRINGTON, T. C.; AGHAYEVA, D. N.; FRAEDRICH, S. W. New combinations in *Raffaelea*, *Ambrosiella*, and *Hyalorhinocladiella*, and four new species from the redbay ambrosia beetle, *Xyleborus glabratus*. **Mycotaxon**, v. 111, p. 337-361, 2010.
- HARRINGTON, T. C.; FRAEDRICH, S. W. Quantification of propagules of the laurel wilt fungus and other mycangial fungi from the redbay ambrosia beetle, *Xyleborus glabratus*. **Phytopathology**, Northwood, v. 100, n. 10, p. 1118-1123, 2010.
- HARWOOD, W. G. **The flight and olfactory behavior of checkered beetles (Coleoptera: Cleridae) predatory on the Douglas-fir beetle**. Thesis of Master, Corvallis Oregon: Oregon State University, 36 p., 1966.
- HULCR, J.; DUNN, R. R. The sudden emergence of pathogenicity in insect–fungus symbioses threatens naive forest ecosystems. **Proceeding of the Royal Society B: Biological Sciences**, London, v. 278, n. 1720, p. 2866-2873, 2011.

JONES, V. P.; BURNAM-LARISH, L. L.; CAPRIO, L. C. Effect of harvest interval and cultivar on damage to macadamia nuts caused by *Hypothenemus obscurus* (Coleoptera: Scolytidae). **Journal of economic entomology**, Lanham, v. 85, n. 5, p. 1878-1883, 1992.

JONES, K. L. et al. Factors influencing dispersal by flight in bark beetles (Coleoptera: Curculionidae: Scolytinae): from genes to landscapes. **Canadian Journal of Forest Research**, Ottawa, v. 49, n. 9, p. 1024-1041, 2019.

KELSEY, R. G.; JOSEPH, G. Ethanol in Douglas-fir with black-stain root disease (*Leptographium wageneri*). **Canadian Journal of Forest Research**, Ottawa, v. 28, n. 8, p. 1207–1212, 1998.

KELSEY, R. G.; WESTLIND, D. J. Physiological stress and ethanol accumulation in tree stems and woody tissues at sublethal temperatures from fire. **Bioscience**, Herndon, v. 67, n. 5, p. 443-451, 2017.

KENDRA, P. E. et al. Comparison of trap designs for detection of *Euwallacea nr. fornicatus* and other Scolytinae (Coleoptera: Curculionidae) that vector fungal pathogens of avocado trees in Florida. **Journal of Economic Entomology**, Lanham, v. 113, n. 2, p. 980–987, 2020.

KIMMERER, T. W.; KOZLOWSKI, T. T. Ethylene, ethane, acetaldehyde, and ethanol production by plants under stress. **Plant Physiology**, Rockville, v. 69, n. 4, p. 840-847, 1982.

KIRKENDALL, L. R.; BIEDERMANN, P. H. W.; JORDAL, B. H. Evolution and diversity of bark and ambrosia beetles. In: **Bark Beetles**. [s.l.] Elsevier, p. 85–156, 2015.

KLIMETZEK, D. *et al.* Dosage response to ethanol mediates host selection by secondary bark beetles. **Naturwissenschaften**, Freiburg, v. 73, n. 5, p. 270- 272, 1986.

LEAVENGOOD, J. M. **The checkered beetles (Coleoptera: Cleridae) of Florida**. Thesis of Doctorage, University of Florida, 206 p., 2008.

LEWIS, T.; MACAULAY, E. D. M. Design and elevation of sex-attractant traps for pea moth, *Cydia nigricana* (Steph.) and the effect of plume shape on catches. **Ecological Entomology**, St Albans, v. 1, n. 3, p. 175-187, 1976.

LINSLEY, E. G. Ecology of Cerambycidae. **Annual review of entomology**, San Francisco, v. 4, n. 1, p. 99-138, 1959.

LIU, L.-Y.; SCHÖNITZER, K.; YANG, J.-T. A review of the literature on the life history of Bostrichidae (Coleoptera). **Mitteilungen der Münchner Entomologischen Gesellschaft**, München, v. 98, p. 91–97, 2008.

MCINTOSH, R. L. et al. Comparative efficacy of five types of trap for woodborers in the Cerambycidae, Buprestidae and Siricidae. **Agricultural and Forest Entomology**, St Albans, v. 3, n. 2, p. 113-120, 2001.

MEYER, H.J.; NORRIS, D.M. A mathematical relation to describe the influence of wind on the initial flight dispersal of *Scolytus multistriatus* (Coleoptera: Scolytidae). **Annals of the**

**Entomological Society of America**, College Park, v. 66, n. 3, p. 505-508, 1973.

MILLER, D. R. et al. Variation in effects of conophthorin on catches of Ambrosia Beetles (Coleoptera: Curculionidae: Scolytinae) in ethanol-baited traps in the United States. **Journal of Economic Entomology**, Lanham, v. 108, n. 1, p. 183–191, 2015.

MOECK, H. A. Ethanol as the primary attractant for the ambrosia beetle *Trypodendron lineatum* (Coleoptera: Scolytidae). **Canadian Entomologist**, Ottawa, v. 102, n. 8, p. 985-994, 1970.

MONTGOMERY, M. E.; WARGO, P. M. Ethanol and other host-derived volatiles as attractants to beetles that bore into hardwoods. **Journal of Chemical Ecology**, Lund, v. 9, n. 2, p. 181- 190, 1983.

MOREHOUSE, K. et al. Carbon and nitrogen cycling immediately following bark beetle outbreaks in southwestern ponderosa pine forests. **Forest Ecology and Management**, Amsterdam, v. 255, n. 7, p. 2698–2708, 2008.

MOREWOOD, W. D. et al. An improved trap for large wood-boring insects, with special reference to *Monochamus scutellatus* (Coleoptera: Cerambycidae). **Canadian Journal of Forest Research**, Ottawa, v. 32, n. 3, p. 519–525, 2002.

NIEMEYER, H. Integrated bark beetle control : experiences and problems in Northern Germany. **General Technical Reports - USDA Forest Service**, v. 236, n. Kremser 1982, p. 80–86, 1997.

OKLAND, B. A comparison of three methods of trapping saproxylic beetles. **European Journal of Entomology**, Ceske Budejovice, v. 93, n. 1, p. 195–209, 1996.

OLIVER, J. B.; MANNION, C. M. Ambrosia Beetle (Coleoptera: Scolytidae) species attacking chestnut and captured in ethanol-baited traps in Middle Tennessee. **Environmental Entomology**, College Park, v. 30, n. 5, p. 909–918, 2001.

PARK, S.; LEE, S.; HONG, K. J. Review of the family Bostrichidae (Coleoptera) of Korea. **Journal of Asia-Pacific Biodiversity**, v. 8, n. 4, p. 298-304, 2015.

PENG, C.; WILLIAMS, R. N. Effect of trap design , trap height, and habitat on the capture of sap beetles (Coleoptera : Nitidulidae ) using whole- wheat bread dough. **Journal of Economic Entomology**, Lanham, v. 84, n. 5, p. 1515–1519, 1991.

RANGER, C. M. et al. Species dependent influence of  $\alpha$ -pinene on attraction of Ambrosia Beetles (Coleoptera: Curculionidae: Scolytinae) to ethanol-baited traps in nursery agroecosystems. **Journal of Economic Entomology**, Lanham, v. 104, n. 2, p. 574–579, 2011.

REEVE, J. D. Predation and bark beetle dynamics. **Oecologia**, Berlin, v. 112, n. 1, p. 48-54, 1997.

REDING, M. E. et al. Optimizing ethanol-baited traps for monitoring damaging ambrosia beetles (Coleoptera: Curculionidae, Scolytinae) in ornamental nurseries. **Journal of Economic Entomology**, Lanham, v. 104, n. 6, p. 2017–2024, 2011.

REID, R. W. The Bark Beetle Complex Associated with Lodgepole Pine Slash in Alberta: Part III—Notes on the Biologies of Several Predators with Special Reference to *Enoclerus sphegeus* Fab. (Coleoptera: Cleridae) and Two Species of Mites. **The Canadian Entomologist**, Ottawa, v. 89, n. 3, p. 111-120, 1957.

SAFRANYIK, L. et al. An empirical approach to modeling the local dispersal of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) (Col., Scolytidae) in relation to sources of attraction, wind direction and speed. **Journal of Applied Entomology**, Berlin, v. 108, n. 1-5, p. 498-511, 1989.

SAFRANYIK, L.; SHORE, T. L.; LINTON, D. A. Measuring trap efficiency for bark beetles (Col., Scolytidae). **Journal of Applied Entomology**, Berlin, v. 128, n. 5, p. 337–341, 2004.

SALOM, S. M.; MCLEAN, J. A. Flight behavior of Scolytid beetle in response to semiochemicals at different wind speeds. **Journal of Chemical Ecology**, Lund, v. 17, n. 3, p. 647-661, 1991.

SEYBERT, J. P.; GARA, R. I. Notes on flight and host-selection behavior of the pine engraver, *Ips pini* (Coleoptera: Scolytidae). **Annals of the Entomological Society of America**, College Park, v. 63, n. 4, p. 947-950, 1970.

SAMANIEGO, A.; GARA, R. Estudios sobre la actividad de vuelo y selección de huéspedes por *Xyleborus* spp. y *Piatypus* spp. (Coleóptera: Scolytidae y Platypodidae). **Turrialba**, v. 20, n. 4, p. 471–477, 1970.

STEININGER, M. S. et al. Simple and efficient trap for bark and ambrosia beetles (Coleoptera: Curculionidae) to facilitate invasive species monitoring and citizen involvement. **Journal of Economic Entomology**, Lanham, v. 108, n. 3, p. 1115–1123, 2015.

SVERDRUP-THYGESON, A.; BIRKEMOE, T. What window traps can tell us: effect of placement, forest openness and beetle reproduction in retention trees. **Journal of Insect Conservation**, Berlin, v. 13, n. 2, p. 183–191, 2009.

WOOD, D. L. The role of pheromones, kairomones, and allomones in the host selection and colonization behavior of bark beetles. **Annual Reviews in Control**, Laxenburg, v. 27, n. 1, p. 411-446, 1982.

**SEGUNDA PARTE – ARTIGOS****ARTIGO 1 – Flight intercept trap designs to capture Scolytinae, Platypodinae, Cerambycidae, Bostrichidae and Cleridae**Gabriela Costa Pinheiro<sup>1</sup>Carlos Alberto Hector Flechtmann<sup>2</sup>Ronald Zanetti Bonetti Filho<sup>3</sup>**Normas da revista *Annals of Forest Research* (versão preliminar em inglês)**

<sup>1</sup> Mestranda em Entomologia da Universidade Federal de Lavras, Lavras, MG.

<sup>2</sup> Professor/Coorientador da Universidade Estadual Paulista “Júlio de Mesquita Filho”, Ilha Solteira, SP.

<sup>3</sup> Professor/Orientador do Programa de Pós-Graduação em Entomologia da Universidade Federal de Lavras, Lavras, MG.

## ABSTRACT

Beetles of the subfamilies Scolytinae and Platypodinae (Coleoptera, Curculionidae) present a high diversity, and in many cases inflict a high damage to the host plants they attack. A number of these species are monitored with ethanol-baited flight intercept traps, and the design of the trap affects its efficiency. The aim of this study was to analyze the influence of the number of vanes and openings in flight intercept traps traditionally used in Brazil, made from two-liter soda bottles, baited with 96% ethanol to capture Scolytinae and Platypodinae. The traps had one, three or four vanes, presence/absence of a central vane hole; and presence/absence of an upper opening at its top. The number of vanes influenced in the capture of these beetles. The traps with three vanes with absence of both holes captured the most Scolytinae and Platypodinae beetles, in addition to Bostrichidae, Cerambycidae and their Cleridae predators. The central and upper hole did not influence the capture of these beetles in this study, perhaps due to unfavorable climate conditions for the flight of these beetles and to disperse the ethanol. The efficiency of the monitoring depends on a set of factors. A single factor, such as the highest ethanol release rate is not enough for highest beetle catches.

**Keywords:** ambrosia beetle, trap efficiency, dispersion.

## 1. Introduction

Scolytinae and Platypodinae wood boring beetles are responsible for substantial losses to wood industry by drilling and building galleries in planted trees. Additionally, they may inflict damage to stems of herbaceous plants, leaf petioles, fruits and seeds (Kirkendall et al. 2015). All Platypodinae and the majority of the Scolytinae are ambrosia beetles, as they introduce and cultivate a fungus in their host plants for feeding purposes; however sometimes these fungi may be pathogenic to their host plants, and may even kill them (Harrington et al. 2010, Hulcr & Dunn 2011).

These beetles fly in search of a new host, and most of them look for stressed hosts, since they have less defenses against beetle attacks (Byers 1989). These weakened plants release ethanol, a volatile used by these beetles as an olfactory cue to help them find their host during flight (Ranger et al. 2011). The flight is influenced by factors such as temperature, humidity, luminosity, wind speed and rainfall (Safranyik et al. 1989, Flechtmann 1995, Jones et al. 2019). Under ideal flight conditions this activity is shortened, reducing exposure to mortality factors (Wood 1982). Between these factors the wind speed has highest importance because influences the beetles' flight and the dispersion of the attractive (Safranyik et al. 1989, Jones et al. 2019). At a low wind speed, under of 1m/s the beetles fly against the wind towards to the attractive volatile, but at a high wind speed they are blown by it, and cannot turn towards the attractive source (Seybert & Gara 1970, Meyer & Norris 1973). In the absence of wind, the beetle flies without direction even if close to the attractive source (Salom & McLean 1991). The wind direction is another factor that influences the beetle's flight; when there is a frequent change of wind direction, which is usually what happens inside forests, it influences the dispersion of the attractive volatile and the flight direction of the beetles (Fares 1980, Blatt et al. 2017), because the beetle loses the attractive plume and ends up depleting its energy reserves before reaching the attractive source (David et al. 1982, Elkinton et al. 1987).

There is no efficient control method after a tree is colonized by these beetles (Reding & Ranger 2019), and one of the best options would be the employment of preventive measures, where monitoring is one of them (Bouget 2009, Reding et al. 2010, Hanula et al. 2011, Reding 2013). Monitoring can be done through flight intercept traps, which are usually efficient in capturing Scolytinae and Platypodinae (Berti Filho & Flechtmann 1986, Hulcr 2008, Hanula 2011, Miller 2020). In Brazil, the most used trap to capture of these beetles is the ESALQ-84 (and its modifications), which is able to correctly determine abundance and richness of species (Berti Filho & Flechtmann 1986, Flechtmann, Ottati, Berisford 2000, Nascimento, Zuniga, Carvalho 2019, Trevisan, Souza, Amancio 2021), by alerting when and where they start infestations when colonizing plants (Bouget 2009), and when invasive species enters in the country (Clark et al. 2001, Rassati et al. 2012, 2014).

The efficiency of forest pest monitoring through baited flight intercept traps can be influenced by many factors, mainly the trap design and the attractive bait (Flechtmann 1995, Sweeney et al. 2006, Rassati et al. 2014, Allison & Redak 2017). The design of the trap can change the bait release rate of

the trap, since it can allow for a greater dispersion of the bait (Lewis & Macaulay 1976, Flechtmann, Ottati, Berisford 2000, Burbano et al. 2012). The architecture of the trap can favor a greater flow of air going through it (Safranyik et al. 2004), and this can be potentiated through openings in the traps, which create a long plume and propitiate a higher lure range, as pheromone (E,E)-8,10-dodecadienyl acetate 0.1 mg per trap to capture pea moth (Lewis & Macaulay 1976).

Another factor that changes the trap design and influences in the monitoring is the number of vanes in a flight intercept trap. The more vanes the greater is the area to capture beetles (Bouget et al. 2008), and more vanes allow for catches of beetles flying in from different directions, which is advantageous in monitoring them (Safranyik et al. 2004), because the flight of beetle is directional to the attractant volatile released by the host, which can be in any direction (Kelsey & Joseph 1998), and disperse according to the wind direction.

Thus, considering the importance of an adequate trap design to monitor Scolytinae, Platypodinae beetles, in addition to Bostrichidae, Cerambycidae and their Cleridae predators, wood boring beetles, we were interested in studying the best combination of (1) number of vanes and (2) presence of holes in the traps, to captures the highest number of beetles. Considering that the number of vanes and holes could influence in the rate of ethanol release, we also measured its release rate among treatments. We also measured wind speed and wind direction, due to the fact that these variables interfere with the ability of beetles to locate an attractive source.

## **2. Material and Methods**

### **2.1. Study site**

The study site was a 14-ha Cerrado fragment physiognomy cerradão, in advanced stage of regeneration (20°23'2.70''S 51°24'46.20''W) in Selvíria, state of Mato Grosso do Sul, Brazil, and owned by the Universidade Estadual Paulista (UNESP).

### **2.2. Trap**

The traps used were made out of two-liter translucent soft drink bottles (modified from Berti Filho & Flechtmann 1986), with the following combinations: (1) no hole in the center of the vane (2.5 cm<sup>2</sup>), combined with presence or not of the upper hole (2.5 cm<sup>2</sup>) in the bottle, and presence of hole in the center of the vane without upper hole, with (2) one (170 cm<sup>2</sup> flight intercept area), three (255 cm<sup>2</sup> flight intercept area) or four vanes (340 cm<sup>2</sup> flight intercept area), resulting in a total of nine treatments (Figure 1, Supplementary Figure 1). The traps with a central hole have a smaller flight intercept area, 160 cm<sup>2</sup> for one-, 245 cm<sup>2</sup> for three-, and 330 cm<sup>2</sup> for four-vane traps.

Traps were placed in transects, 1.5 m from the ground, 25 m apart from each other, and 50 m from the fragment border, where a transect was composed of nine traps, each corresponding to one of the nine combinations mentioned above. There were four transects, totaling 36 traps. The lure was 96% pure ethanol, applied 30 ml in the dispensers placed in the center of the vanes. The trap collector in the bottom of each trap had salt, detergent and water to break the surface tension of the water (preventing beetle's escapes) and conserve collected insects. Trapping, refilling of the ethanol, water, salt and detergent of the traps was weekly, for 59 weeks, from July 2020 to August 2021. The content of the trap was collected with a sieve (1mm diameter) that filters the liquid from the trap collector and placed the solid content in pots identified by trap designs.

Scolytinae, Platypodinae, Bostrichidae, Cleridae and Cerambycidae species were determined, based on the reference collection from MEFES (Museu de Entomologia da FEIS, UNESP – Ilha Solteira, state of São Paulo, Brazil), where voucher specimens were deposited.

### **2.3. Ethanol release rate**

To measure the release rate in each ethanol-baited flight intercept trap design, the sets of dispensers (38.88 cm<sup>2</sup>, by glass, with lid by eraser (0.78 cm<sup>2</sup>) bored in the middle with a cotton swab filled with string) plus ethanol in all traps from one transect, identified by each trap design were weighed and placed in the field. The next week these sets were taken to the lab and weighed to determine gravimetrically how much ethanol per trap type was released, and so successively for another transect. This was done for 10 weeks from November 2020 until January 2021, period with more rainfall, and for another 10 weeks from April until June 2021, period with less rainfall (Supplementary Figure 2).

### **2.4. Wind direction and wind speed**

An anemometer sensitive enough to measure wind speeds below 1 m/s was built and assess wind direction inside the forest, because the anemometers available in the market to measure low wind speed are very expensive. A 15-cm diameter circle on the smoother part of a 40 cm x 40 cm 3-mm thick masonite board was drew. On this circle, the cardinal positions north, south, east and west, and also the intercardinal points northeast, southeast, northwest and southwest were marked. The board was set on top of a tripod 1.5 m high (same height of the lure), had its north mark oriented north with a compass and leveled the board with a two-way bubble level (Supplementary Figure 3). A 5-mm diameter polystyrene ball with a smooth surface and weighing on average 0.9 mm was placed on the center of the circle, in order to measure wind speed and determine wind direction. The ball trajectory until it crossed the circle border was recorded with a cellular phone. The time spent for the wind-

blown ball to transverse the circle line was calculated on a computer, hence obtaining wind speed, and we annotated its direction frequency. Wind speed was not constant throughout measurements. Thus, if after placing the ball in the circle center it did not move within three minutes, a wind speed of zero was registered. Observations were discarded in cases the ball stopped moving in the middle of its course, or if its route was inconsistent, without a clear direction.

The anemometer was placed near each of traps placed inside the fragment, and in each position five measurements were taken, from July 2021 to August 2021, at approximately the same time in the mornings and also in the afternoons of beetle trapping collecting dates. Measurements of wind speed and direction outside the forest, and temperature, rainfall and humidity data were obtained from a meteorological station distant 430 m from the study area (20°22'45.36"S 51°24'38.84"W).

## 2.5. Experimental design and analyses

The experiment was in a randomized complete block design. We used the most abundantly trapped beetle species in the trap comparison analyses. Beetle catches were transformed into  $\sqrt{x + 0,5}$  to remove heterocedasticity (Phillips 1990). Beetle catches, ethanol release rates among trap types, wind speed and wind direction between day periods and localities were compared using generalized linear models (Proc GLM) and treatment means were separated by the Tukey test (SAS Institute 1990).

## 3. Results

### 3.1. Collected species

The traps captured not only Scolytinae and Platypodinae, but also Bostrichidae, Cerambycidae, and Cleridae beetles, the latter composed of species that usually predate on all other beetle groups, and were also included in the analyses. We collected 5276 specimens, in 58 species of Scolytinae, 3 of Platypodinae, 8 of Bostrichidae, 12 of Cleridae and 46 of Cerambycidae. Included in the analyses were *Ambrosiodmus opimus* (Wood), *Cryptocarenum diadematus* Eggers, *Cryptocarenum heveae* (Hagedorn), *Cryptocarenum seriatus* Eggers, *Hypothenemus eruditus* Westwood, *Hypothenemus javanus* (Eggers), *Hypothenemus obscurus* (Fabricius), *Hypothenemus subsulcatus* Atkinson & Flechtmann, *Hypothenemus suspectus* Wood, *Premnobius cavipennis* Eichhoff, *Sampsonius dampfi* Schedl, *Xyleborus affinis* Eichhoff, *Xyleborus ferrugineus* (Fabricius), and *Xyleborus spinulosus* Blandford in Scolytinae. *Micrapate brasiliensis* (Lesne 1899), *Xyloperthella picea* (Olivier), and *Xylopsocus capucinus* (Fabricius) in Bostrichidae. *Aerenea brunnea* Thomson, *Carphina elliptica* (Germar), *Compsa quadriguttata* (White), *Compsibidion vanum* (Thomson),

*Neoclytus pusillus* Laporte & Gory, and *Oreodera aerumnosa* Erichson in Cerambycidae. And *Megaphloeus mucoreus* (Klug) in Cleridae. None of the species from Platypodinae were abundant enough to be included in the analyses, as a result of the environmental condition that interfered with the number of insects collected (Supplementary Table 1).

### 3.2. All trap designs

*Hypothenemus obscurus* and the sum of all Scolytinae were significantly trapped in traps with three vanes without central hole and with upper hole, *X. picea* and the sum of all Bostrichidae in traps with three vanes with no central hole and no upper hole, *M. mucoreus* in traps with three vanes with central hole and without upper hole, while *X. affinis*, *C. quadriguttata* and the sum of all Cerambycidae had higher catches in traps with one vane no central hole and without upper hole. For all other analyzed species, there were no significantly different catches among trap designs ( $p > 0.005$ ), (Table 1).

### 3.3. Number of vanes

One-vane traps trapped significantly more *P. cavipennis* and *X. affinis*, *M. mucoreus* and the sum of all Cleridae in three-vane traps, while *C. quadriguttata* and the sum of all Cerambycidae traps with one and three vanes trapped significantly more specimens. For all other analyzed species, there were no significant differences among catches ( $p > 0.05$ ), (Table 2).

### 3.4. Presence/absence of the central and upper hole

In this situation, *X. affinis*, *X. picea*, *C. quadriguttata* and the sums of Bostrichidae and Cerambycidae were significantly more caught in traps where the central hole was absent, and the sum of Scolytidae in traps where it was present, while for all other species there were no significantly differences among catches ( $p > 0.005$ ). When now combining traps based on the presence/absence of the upper hole, *A. opimus*, *H. obscurus*, *Hypothenemus subsulcatus*, *Hypothenemus suspectus* and the sum of all Scolytinae were captured in significantly higher numbers in traps with the upper hole present, and for all other species no significantly different differences were observed ( $p > 0.05$ ), (Table 2).

### 3.5. Presence/absence of the central and upper hole based on vane numbers

In traps where the central hole was present, only for *C. quadriguttata* ( $F_{70, 1321} = 9.16$ ,  $p = 0.0001$ ), the sum of all Cerambycidae ( $F_{67, 628} = 4.35$ ,  $p = 0.0133$ ), *M. mucoreus* ( $F_{67, 628} = 16.40$ ,  $p <$

0.0001) and the sum of all Cleridae ( $F_{67, 628} = 17.22$ ,  $p < 0.0001$ ) there were statistically significant differences among trappings based on vane numbers, where three-vane traps caught more specimens. Now when comparing catches in traps where the central hole was absent, only for *H. obscurus* ( $F_{70, 1321} = 6.97$ ,  $p = 0.0010$ ) and the sum of Scolytinae ( $F_{70, 1321} = 10.68$ ,  $p < 0.0001$ ) statistically significant differences were observed, and again three-vane traps caught more specimens (Supplementary Table 2).

When only traps with the upper hole were present were compared, *H. eruditus* ( $F_{67, 628} = 3.76$ ,  $p = 0.0239$ ), *H. obscurus* ( $F_{67, 628} = 6.65$ ,  $p = 0.0014$ ), *X. affinis* ( $F_{67, 628} = 3.70$ ,  $p = 0.0253$ ) and the sum of Scolytinae ( $F_{67, 628} = 11.67$ ,  $p < 0.0001$ ) were significantly more trapped in three-vane traps, while for all other species there were no statistically significant differences among traps. In traps where the upper hole was absent, significant differences were observed only in *M. mucoreus* ( $F_{70, 1321} = 15.14$ ,  $p < 0.0001$ ) and the sum of Cleridae ( $F_{70, 1321} = 15.83$ ,  $p < 0.0001$ ), which were more trapped in three-vane traps, and in *C. quadriguttata* ( $F_{70, 1321} = 10.98$ ,  $p < 0.0001$ ) and the sum of Cerambycidae ( $F_{70, 1321} = 15.14$ ,  $p < 0.0001$ ), more caught in one- and three-vane traps (Supplementary Table 3).

### 3.6. Ethanol release rate

The release rate of ethanol from of the dispensers was significantly higher in one-vane traps where the upper hole was absent, regardless of the presence of the central hole (Table 3). When only number of vanes was considered, one-vane traps released significantly more ethanol ( $F_{29, 150} = 5.64$ ,  $p = 0.0044$ ) than 3- or 4-vane traps, whose release rates did not differ between each other ( $p > 0.5$ ). Now when only the central hole was considered, there were no significant differences between traps with the presence or absence of it ( $F_{28, 151} = 0.98$ ,  $p = 0.3245$ ), while when only the upper hole was considered, traps without it released significantly more ethanol than traps with it ( $F_{28, 151} = 4.34$ ,  $p = 0.0390$ ). When the central hole was present in traps, 1- and 4-vane traps had significantly higher ethanol release as compared to 3-vane traps, while when this hole was absent in traps, there were no significant differences in ethanol release rates among 1-, 3- and 4-vane traps. When the upper hole alone was considered, when it was present there were no differences in ethanol release rates among traps, but when it was absent, 1-vane traps had a significantly higher release rate as compared to 3- and 4-vane traps (Table 4).

The observed rainy and dry seasons roughly matched the periods in the region where rainfall (or lack of it) is observed. However, it rained substantially lower than in normal periods (Alvares et al. 2013), (Supplementary Figure 2).

### 3.7. Wind direction and wind speed

Wind speed was always significantly higher in the pasture area, where the meteorological station was located, then inside the cerradão fragment, whether measured in the morning, afternoon or full day (Supplementary Table 4). In both fragment and pasture wind speed was significantly higher in the morning than in the afternoon (Supplementary Table 5).

The predominant wind direction was south-southeast, and statistically the same, between pasture and inside the fragment, regardless of the time period when it was measured (Supplementary Table 4). Although in the pasture area the direction was more frequent in the south-southeast direction, inside the cerradão fragment wind direction was more spread out towards other directions (Figure 2). In the cerradão fragment the direction was significantly the same when both morning and afternoon periods were compared, while in the pasture it was statistically different, but always south-southeast (Supplementary Table 5).

#### 4. Discussion

Regarding ethanol release, one would initially expect that since traps with a central hole (where the dispenser was placed at) allow for the wind to go through this opening, its presence would allow for a higher release rate than in traps without this opening. Another opening some traps had were on its upper part, and the natural upward convection process expected to occur would arrest ethanol molecules towards the top (Flechtmann & Gaspareto 1997), also allowing for a higher release as compared to traps without the upper hole. When we consider the number of vanes, it is reasonable to grant that the presence of three or four vanes would create a more "nested" and closed microenvironment in the space among the vanes, which would work as an impediment, an obstacle for a more free air flow than in one-vane traps. Hence, it is plausible to expect a higher ethanol release rate in traps with one vane as compared to the models with three or four vanes.

Our results showed that the highest ethanol release rates were observed in one-vane traps, whether considering all trap models (Table 3) or when just number of vanes was considered (see Results). These results were in agreement with our hypotheses.

An unexpected result was related to the comparison of ethanol release between traps with or without the upper hole, where traps with no top opening released significantly more ethanol than traps without it (see Results). Results of analyses (not shown in Results) indicate that only in one-vane traps these significant differences were observed ( $F_{1,151} = 4.34$ ;  $p = 0.0390$ ), and that they were statistically the same in three- and four-vane traps ( $p > 0.05$ ). Half of the traps with no top opening had a central hole, and the design of one-vane traps do not allow for air to be trapped between vanes, allowing for a greater air flow and concomitant larger ethanol release. And in traps where only the upper hole was present, perhaps first the headspace above the dispenser had to be saturated with ethanol and then released at a slower rate than through traps with the central opening, thus explaining these results. This

might be also the explanation for why there were no differences among release rates in traps with the upper hole in traps with different number of vanes (Table 4).

When the central hole factor was analyzed, there were no significant differences among traps (hole present vs. absent; see Results), which was also not expected beforehand. Wind speed inside the fragment was low (Supplementary Table 4), and it might as well be that it was not strong enough to break the barrier of stagnant air between vanes possibly created by them in the case at least of traps with three and four vanes (two-thirds of the tested traps). Additionally, traps with central hole present did not bear the upper hole - hence no ascending convection - helping probably in maintaining the resistance of that stagnant air against wind passage. These two factors combined might have led to no significant differences between those treatments. When the comparisons were broken down to release rate among the number of vanes in traps, when no central hole was present, no significance among traps was found (Table 4), which pretty much fits in our interpretation of the results, made above. However, when this opening was present, the highest release was observed in both one- and four-vane traps (Table 4). Considering the 'air trapping factor' mentioned above in one-vane traps, one would expect a higher release rate in this trap, but there is no good explanation for why this was statistically equal for four-vane traps.

Overall, three-vane traps trapped significantly more beetles (Table 1), despite the fact that one-vane traps showed the highest ethanol release rate (Table 3). Traps with three or four vanes are able to trap beetles flying in from all directions (Groot & Nott 2001, Safranyik et al. 2004, Bouget et al. 2008), which is not true with one-vane traps. This is an indication that, despite with a lower ethanol release rate, three-vane traps compensate for that with a higher efficiency in trapping incoming beetles. However, for *P. cavipennis* and *X. affinis*, when only number of vanes was considered, these were more trapped in one-vane traps (Table 2). Those species attack usually stressed trees (Beaver 1988, Roeper et al. 2015, Martínez et al. 2019), which typically release larger amounts of ethanol than healthy trees (Kimmerer & Kozłowski 1982, Kelsey & Westlind 2017). It is reasonable to assume that these species were responding to a higher ethanol release, provided by the one-vane traps (see Results), as discussed above.

The only statistical differences in trappings while comparing presence/absence of the upper hole were observed when it was present (Table 2). This seems to make sense because with the upper hole absent, the only possible path for the ethanol to be released to the environment would be via the area where the vanes are placed. Additionally, the top opening was distant at least 10 cm from where the upper part of the vanes - responsible for the trappings (by beetles crashing into them) - was. Hence, while traps with the upper hole released significantly less ethanol (see Results), attracted beetles would not be trapped because they are far from the upper hole release point. When these analyses were broken down by number of vanes, more species were significantly trapped in three-vane traps and upper hole present or absent (Supplementary Table 3), corroborating our hypotheses stated before.

Higher rate of capture of individuals and species occurred with traps with the central hole absent, different from what we expected (Table 2). We did not identify a reasonable explanation for these results. Similar to results observed in traps with the presence/absence of the upper hole, when analyses were broken down by the number of vanes, more species were significantly trapped in three-vane traps and central hole present or absent (Supplementary Table 2), confirming the efficacy of three-vane traps once again.

The wind speed was significantly higher in the pasture, where there are no physical obstacles for its passage, than inside the fragment, where trees and bushes partially obstruct its path, slowing it down (Supplementary Table 4). In the neotropics, the wind speed inside forests seems to be characteristically low, and occasionally reaching values as low as or even lower as those found in our experiment (Baynton et al. 1965, Kruijt et al. 2000, Santana et al. 2017, 2021, Crall et al. 2020). While on average the prevailing wind direction was statistically the same in both pasture and the fragment (Supplementary Table 4), in the pasture the largest portion of the wind blew always in the same average direction (Figure 2). However, wind direction inside the fragment was not that clear-cut, with a much wider range of directions, that influenced in our study (Figure 2).

One factor that most likely influenced, in a negative way, the results of our experiment, was the low number of beetles trapped. When we compare results of similar traps (one vane and no openings) used in this experiment with those from another experiment done in the same area, from September 2016 to October 2017 (Pinheiro et al. unpub.), the average of specimens caught per trap in Scolytinae were 3.2, in Platypodinae 2.0, in Bostrichidae 1.2, in Cerambycidae 2.9 and in Cleridae 3.0 times smaller here than in our previous experiment. With smaller numbers of trapped species, it is more difficult for significant differences between treatments to show, and for random factors to interfere in the results. We attribute the low number of catches to an especially dry season - it rained only 481.4 mm during our experiment, which was a little over a year (59 weeks). In our earlier experiment rainfall totaled 1708 mm in the same number of collecting weeks. On average, the normal total yearly rainfall for the region is 1300 mm (Alvares et al. 2013), roughly three times higher than what rained during our experiment, and it is well documented that the abundance of these beetles is positively correlated with rainfall (Safranyik et al. 1989, Flechtmann et al. 1995, Jones et al. 2019, Oliveira et al. 2021). The climate change in translated into less rainfall may have also affected the diversity of these beetles (Chown et al. 2011), by both desiccating these beetles during flight (Kellermann & Heerwaarden 2019) and by affecting negatively their hosts (Wade et al. 2017).

## 5. Conclusion

Under present conditions, inside the fragment the prevailing wind speed was low and turbulence affected its direction, which contrasts with the situation in temperate forests, where most of similar trap architecture and attractive bait experiments are done, and where wind speed is higher and

its direction more constant. It seems the prevalent wind conditions determined most of the general results in this experiment.

We would consider a three-vane trap the best trap option. Even though statistically there is no support for that, we would advise that a hole in the center of the traps might eventually increase beetle catches under weather conditions that would favor higher beetle abundance.

One important factor derived from our results was that a trap with the highest ethanol release rate did not necessarily correspond to respectively the highest beetle catches, and the number of vanes and corresponding architecture for this particular trap influenced in these outcomes.

### **Acknowledgments**

To FEIS/UNESP for granting access to the experimental site, transportation and material, to CNPq for the scholarship (130499/2020-0) to Silvia Y. Tanabe for help with the determination of the beetles and to José A. Agustini for assistance with the field work.

## Reference

- Allison, J.D., Redak, R.A., 2017. The impact of trap type and design features on survey and detection of bark and woodboring beetles and their associates: A review and meta-analysis. *Annual Review of Entomology* 62(1): 127-146.
- Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalves, J.L.M., Sparovek, G., 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift* 22(6): 711-728.
- Baynton, H.W., Biggs, W.G., Hamilton, H.L., Sherr, P.E., Worth, J.J.B., 1965. Wind structure in and above a tropical forest. *Journal of Applied meteorology* 4(6): 670-675.
- Beaver, R.A., 1988. Biological studies on ambrosia beetles of the Seychelles (Col., Scolytidae and Platypodidae). *Journal of Applied Entomology* 105(1-5): 62-73.
- Berti Filho, E., Flechtmann, C.A.H., 1986. A model of ethanol trap to collect Scolytidae and Platypodidae (Insecta, Coleoptera). *Instituto de Pesquisas e Estudos Florestais* 34: 53-56.
- Blatt, S.E., Bishop, C., Sweeney, J., 2017. Incidence of *Monochamus* (Coleoptera: Cerambycidae) species in Nova Scotia, Canada christmas tree plantations and comparison of panel traps and lures from North America and Europe. *Canadian Entomologist* 149(2): 191-203.
- Bouget, C., Brustel, H., Brin, A., Noblecourt, T., 2008. Sampling saproxylic beetles with window flight traps: Methodological insights. *Revue d'Écologie (La Terre et la Vie)* 63(Sup.10): 21-32.
- Bouget, C., Brustel, H., Brin, A., Valladares, L., 2009. Evaluation of window flight traps for effectiveness at monitoring dead wood-associated beetles: The effect of ethanol lure under contrasting environmental conditions. *Agricultural and Forest Entomology* 11(2): 143-152.
- Burbano, E.G., Wright, M.G., Gillette, N.E., Mori, S., Dudley, N., Jones, T., Kaufmann, M., 2012. Efficacy of traps, lures, and repellents for *Xylosandrus compactus* (Coleoptera: Curculionidae) and other ambrosia beetles on *Coffea arabica* plantations and *Acacia koa* nurseries in Hawaii. *Environmental Entomology* 41(1): 133-140.
- Byers, J.A., 1989. Chemical ecology of bark beetles. *Experientia* 45(3): 271-283.
- Cardé, R.T., 2001. Use of semiochemicals for survey and detection of exotic insects: principles and constraints. *The Plant Health Conference (ed.), Detecting and Monitoring Invasive Species, 2000*, Center for Plant Health Science and Technology. The United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Raleigh, pp. 17-25.
- Chown, S.L., Sorensen, J.G., Terblanche, J.S., 2011. Water loss in insects: an environmental change perspective. *Journal of Insect Physiology* 57(8): 1070-1084.
- Clark, J.S., Lewis, M., Horvath, L., 2001. Invasion by extremes: Population spread with variation in dispersal and reproduction. *The American Naturalist* 157(5): 537-554.
- Crall, J.D., Brokaw, J., Gagliardi, S.F., Mendenhall, C.D., Pierce, N.E., Combes, S.A., 2020. Wind drives temporal variation in pollinator visitation in a fragmented tropical forest. *Biology letters* 16(4): 1-6.
- David, C.T., Kennedy, J.S., Ludlow, A.R., Perry, J.N., Wall, C., 1982. A reappraisal of insect flight towards a distant point source of wind-borne odor. *Journal of Chemical Ecology* 8(9): 1207-1215.
- Elkinton, J.S., Schal, C., Onot, T., Cardé, R.T., 1987. Pheromone puff trajectory and upwind flight of male gypsy moths in a forest. *Physiological Entomology* 12(4): 399-406.
- Fares, Y., Charles, P.J.H., Magnuson, C.E., 1980. Pheromone dispersion in forests. *Journal of Theoretical Biology* 84(2): 335-359.
- Flechtmann, C.A.H., Couto, H.T.Z., Gaspareto, C.L., Berti Filho, E., 1995. Manual de pragas em florestas: Scolytidae em reflorestamento com pinheiros tropicais. Instituto de Pesquisas e Estudos Florestais, Piracicaba, 201 p.
- Flechtmann, C.A.H., Gaspareto, C.L., 1997. A new trap for capturing Scolytidae (Coleoptera), based on primary attraction. *Journal of Applied Entomology* 121(1-5): 357-359.
- Flechtmann, C.A.H., Ottati, A.L.T., Berisford, C.W., 2000. Comparison of four trap types for ambrosia beetles (Coleoptera, Scolytidae) in Brazilian *Eucalyptus* stands. *Journal of Economic Entomology* 93(6): 1701-1707.
- Groot, P., Nott, R., 2001. Evaluation of traps of six different designs to capture pine sawyer beetles (Coleoptera:

Cerambycidae). *Agricultural and Forest Entomology* 3(2): 107-111.

Hanula, J.L., Ulyshen, M.D., Horn, S., 2011. Effect of trap type, trap position, time of year, and beetle density on captures of the redbay ambrosia beetle (Coleoptera: Curculionidae: Scolytinae). *Journal of Economic Entomology* 104(2): 501-508.

Harrington, T.C., Aghayeva, D.N., Fraedrich, S.W., 2010. New combinations in *Raffaelea*, *Ambrosiella*, and *Hyalorhinocladia*, and four new species from the redbay ambrosia beetle, *Xyleborus glabratus*. *Mycotaxon* 111: 337-361.

Hulcr, J., Beaver, R.A., Puranasakul, W., Dole, S.A., Sonthichai, S., 2008. A comparison of bark and ambrosia beetle communities in two forest types in northern Thailand (Coleoptera: Curculionidae: Scolytinae and Platypodinae). *Environmental Entomology* 37(6): 1461-1470.

Hulcr, J., Dunn, R.R., 2011. The sudden emergence of pathogenicity in insect–fungus symbioses threatens naive forest ecosystems. *Proceeding of the Royal Society B: Biological Sciences* 278(1720): 2866-2873.

Jones, K.L., Shegelski, V.A., Marculis, N.G., Wijerathna, A.N., Evenden, M.L., 2019. Factors influencing dispersal by flight in bark beetles (Coleoptera: Curculionidae: Scolytinae): from genes to landscapes. *Canadian Journal of Forest Research* 49(9): 1024-1041.

Kellermann, V., Heerwaarden, B.V., 2019. Terrestrial insects and climate change: adaptive responses in key traits. *Physiological Entomology* 44(2): 99-115.

Kelsey, R.G., Joseph, G., 1998. Ethanol in Douglas-fir with black-stain root disease (*Leptographium wageneri*). *Canadian Journal of Forest Research* 28(8): 1207-1212.

Kelsey, R.G., Westlind, D.J., 2017. Physiological stress and ethanol accumulation in tree stems and woody tissues at sublethal temperatures from fire. *Bioscience* 67(5): 443-451.

Kimmerer, T.W., Kozłowski, T.T., 1982. Ethylene, ethane, acetaldehyde, and ethanol production by plants under stress. *Plant Physiology* 69: 840-847.

Kirkendall, L.R., Biedermann, P.H.W., Jordal, B.H., 2015. Evolution and diversity of bark and ambrosia beetles. In Vega, F.E., Hofstetter, R.W. (ed.), *Bark Beetles*. Elsevier, Bergen, pp. 85-156.

Kruijt, B., Malhi, Y., Lloyd, J., Nobre, A.D., Miranda, A.C., Pereira, M.G.P., Culf, A., Grace, J., 2000. Turbulence statistics above and within two amazon rain forest canopies. *Boundary-Layer Meteorology* 94(2): 297–331.

Lewis, T., Macaulay, E.D.M., 1976. Design and elevation of sex-attractant traps for pea moth, *Cydia nigricana* (Steph.) and the effect of plume shape on catches. *Ecological Entomology* 1(3): 175-187.

Martínez, M., Cognato, A.I., Guachambala, M., Boivin, T., 2019. Bark and Ambrosia Beetle (Coleoptera: Curculionidae: Scolytinae) diversity in natural and plantation forests in Ecuador. *Environmental Entomology* 48(3): 603-613.

Meyer, H.J., Norris, D.M., 1973. A mathematical relation to describe the influence of wind on the initial flight dispersal of *Scolytus multistriatus* (Coleoptera: Scolytidae). *Annals of the Entomological Society of America* 66(3): 505-508.

Miller, D.R., Crowe, C.M., Sweeney, J.D., 2020. Trap height affects catches of bark and woodboring beetles (Coleoptera: Curculionidae, Cerambycidae) in baited multiple-funnel traps in southeastern United States. *Journal of Economic Entomology* 113(1): 273-280.

Nascimento, F.N., Zuniga, A.D.G., Carvalho, A.G., 2019. Levantamento, diversidade e sazonalidade de Curculionidae: Scolytinae, Platypodinae e Bostrichidae associados a habitat naturais e cultivados no estado do Tocantins. Doctorage thesis, department of biodiversity and biotechnology of the Bionorte network, Universidade Federal do Tocantins, Palmas, 117 p.

Oliveira, C.P.D., Oliveira, C.M.D., Specht, A., Frizzas, M.R., 2021. Seasonality and distribution of Coleoptera families (Arthropoda, Insecta) in the Cerrado of Central Brazil. *Revista Brasileira de Entomologia* 65(3): 1-9.

Phillips, T.W., 1990. Responses of *Hylastes salebrosus* to turpentine, ethanol, and pheromones of *Dendroctonus* (Coleoptera: Scolytidae). *The Florida Entomologist* 73(2): 286-292.

Ranger, C.M., Reding, M.E., Gandhi, K.J.K., Oliver, J.B., Schultz, P.B., Cañas, L., Herms, D.A., 2011. Species dependent influence of (–)- $\alpha$ -pinene on attraction of ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) to ethanol-baited traps in nursery agroecosystems. *Journal of Economic Entomology* 104(2): 574-579.

Rassati, D., Petrucco Toffolo, E., Roques, A., Battisti, A., Faccoli, M., 2014. Trapping wood boring beetles in Italian ports: A pilot study. *Journal of Pest Science* 87(1): 61-69.

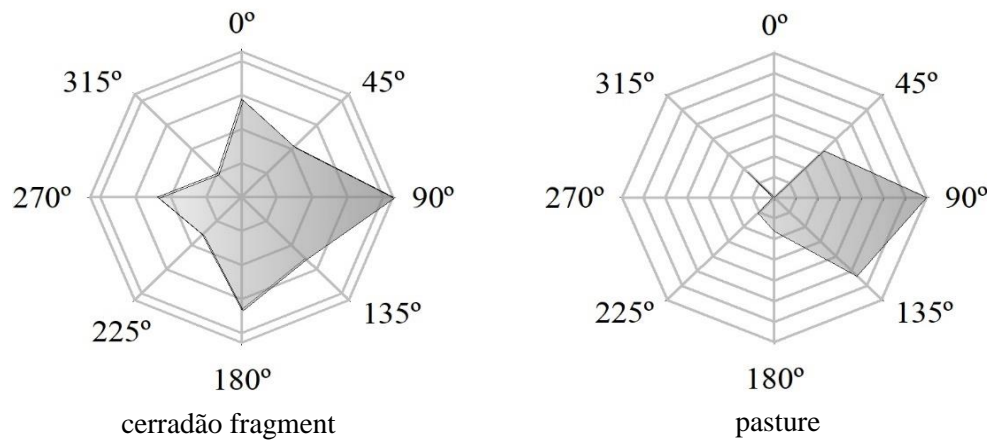
Rassati, D., Toffolo, E.P., Battisti, A., Faccoli, M., 2012. Monitoring of the pine sawyer beetle *Monochamus galloprovincialis* by pheromone traps in Italy. *Phytoparasitica* 40(4): 329-336.

Reding, M., Oliver, J., Schultz, P., Ranger, C., 2010. Monitoring flight activity of ambrosia beetles in ornamental nurseries

- with ethanol-baited traps: Influence of trap height on captures. *Journal of Environmental Horticulture* 28(2): 85-90.
- Reding, M.E., Oliver, J.B., Schultz, P.B., Ranger, C.M., Youssef, N.N., 2013. Ethanol injection of ornamental trees facilitates testing insecticide efficacy against ambrosia beetles (Coleoptera: Curculionidae: Scolytinae). *Journal of Economic Entomology* 106(1): 289-298.
- Reding, M.E., Ranger, C.M., 2019. Attraction of invasive ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) to ethanol-treated tree bolts. *Journal of Economic Entomology* 113(1): 321-329.
- Roeper, R.A., Bunce, M.A., Harlan, J.E., Bowker, R.G., 2015. Observations of *Xyleborus affinis* Eichhoff (Coleoptera:Curculionidae: Scolytinae) in Central Michigan. *The Great Lakes Entomologist* 48(3): 111-113.
- Safranyik, L., Shore, T.L., Linton, D.A., 2004. Measuring trap efficiency for bark beetles (Col., Scolytidae). *Journal of Applied Entomology* 128(5): 337-341.
- Safranyik, L., Silversides, R., McMullen, L.H., Linton, D.A., 1989. An empirical approach to modeling the local dispersal of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) (Col., Scolytidae) in relation to sources of attraction, wind direction and speed. *Journal of Applied Entomology* 108(1-5): 498-511.
- Salom, S.M., McLean, J.A., 1991. Flight behavior of Scolytid beetle in response to semiochemicals at different wind speeds. *Journal of Chemical Ecology* 17(3): 647-661.
- Santana, R.A.S., Dias-Júnior, C.Q., Vale, R.S., Tóta, J., Fitzjarrald, D.R., 2017. Observing and modeling the vertical wind profile at multiple sites in and above the amazon rain forest canopy. *Advances in Meteorology* 2017(Special): 1-8.
- Santana, R.A.S., Dias-Júnior, C.Q., Vale, R.S., Tóta, J., Silva, R., Tapajós, R., Manzi, A.O., Beldini, T.P., 2021. Comparing the air turbulence above smooth and rough surfaces in the amazon region. *Atmosphere* 12(8): 1-14.
- Statistical analysis system- SAS. SAS/STAT user's guide. Cary, 1990.
- Seybert, J.P., Gara, R.I., 1970. Notes on flight and host-selection behavior of the pine engraver, *Ips pini* (Coleoptera: Scolytidae). *Annals of the Entomological Society of America* 63(4): 947-950.
- Sweeney, J., Gutowski, J.M., Price, J., Groot, P., 2006. Effect of semiochemical release rate, killing agent, and trap design on detection of *Tetropium fuscum* (F.) and other longhorn beetles (Coleoptera: Cerambycidae). *Environmental Entomology* 35(3): 645-654.
- Trevisan, H., Souza, T.S., Amancio, J.M.S., 2021. Influence of the color of semi-funnel traps on xylophagous coleoptera capture efficiency in forest fragments. *Bioscience Journal* 37(e37034): 1981-3163.
- Wade, R.N., Karley, A.J., Johnson, S.N. & Hartley, S.E. (2017) Impact of predicted precipitation scenarios on multitrophic interactions. *Functional Ecology* 31(8): 1647-1658.
- Wood, D.L., 1982. The role of pheromones, kairomones, and allomones in the host selection and colonization behavior of bark beetles. *Annual Reviews in Control* 27(1): 411-446.



**Figure 1.** Ethanol-baited flight intercept trap, **A.** with one vane without a central hole and upper hole, **B.** with three vanes without a central hole and upper hole, **C.** with three vanes without central hole and with upper hole, **D.** with four vanes with central hole and without upper hole. Cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil.



**Figure 2.** Wind direction (in degrees) inside the cerradão fragment and in a pasture area. UNESP Farm, Selvíria, state of Mato Grosso do Sul, July 2021 through August 2021.

**Table 1-** Mean ( $\pm$  SE) of the number of Scolytinae, Bostrichidae, Cerambycidae and Cleridae species captured by each different ethanol-baited flight intercept trap design, in a cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, July 2020 through August 2021.

species	trap design <sup>1</sup>								
	1yCU-	1nCU-	1nCU+	3yCU-	3nCU-	3nCU+	4yCU-	4nCU-	4nCU+
<b>Scolytinae</b>									
<i>A. opimus</i>	0.06 $\pm$ 0.02 a	0.03 $\pm$ 0.01 a	0.05 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.06 $\pm$ 0.02 a	0.08 $\pm$ 0.02 a	0.03 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.07 $\pm$ 0.02 a
<i>C. diadematus</i>	0.07 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.06 $\pm$ 0.02 a	0.04 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.05 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a
<i>C. heveae</i>	0.07 $\pm$ 0.02 a	0.05 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.02 $\pm$ 0.01 a	0.05 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.03 $\pm$ 0.01 a	0.07 $\pm$ 0.02 a
<i>C. seriatus</i>	0.05 $\pm$ 0.02 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.05 $\pm$ 0.02 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>H. eruditus</i>	0.30 $\pm$ 0.05 a	0.28 $\pm$ 0.04 a	0.26 $\pm$ 0.05 a	0.19 $\pm$ 0.03 a	0.25 $\pm$ 0.04 a	0.36 $\pm$ 0.06 a	0.35 $\pm$ 0.06 a	0.24 $\pm$ 0.04 a	0.23 $\pm$ 0.04 a
<i>H. javanus</i>	0.06 $\pm$ 0.02 a	0.08 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.03 $\pm$ 0.01 a	0.09 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.13 $\pm$ 0.04 a	0.07 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a
<i>H. obscurus</i>	0.80 $\pm$ 0.16 ab	0.51 $\pm$ 0.09 c	0.51 $\pm$ 0.10 c	0.55 $\pm$ 0.10 bc	0.56 $\pm$ 0.10 bc	0.88 $\pm$ 0.16 a	0.80 $\pm$ 0.12 ab	0.56 $\pm$ 0.09 bc	0.66 $\pm$ 0.13 bc
<i>H. subsulcatus</i>	0.01 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.00 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a
<i>H. suspectus</i>	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>P. cavipennis</i>	0.10 $\pm$ 0.03 a	0.10 $\pm$ 0.02 a	0.13 $\pm$ 0.03 a	0.05 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.05 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a
<i>S. dampfi</i>	0.06 $\pm$ 0.02 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.04 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>X. affinis</i>	0.06 $\pm$ 0.02 ab	0.13 $\pm$ 0.03 a	0.08 $\pm$ 0.02 ab	0.04 $\pm$ 0.01 b	0.09 $\pm$ 0.02 ab	0.10 $\pm$ 0.03 ab	0.06 $\pm$ 0.02 ab	0.06 $\pm$ 0.02 ab	0.03 $\pm$ 0.01 b
<i>X. ferrugineus</i>	0.00 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a
<i>X. spinulosus</i>	0.06 $\pm$ 0.02 a	0.05 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.09 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a
$\Sigma$ Scolytinae	1.80 $\pm$ 0.19 abc	1.45 $\pm$ 0.12 bcd	1.44 $\pm$ 0.14 bcd	1.15 $\pm$ 0.13 d	1.49 $\pm$ 0.14 bcd	1.99 $\pm$ 0.19 a	1.78 $\pm$ 0.16 ab	1.31 $\pm$ 0.12 cd	1.49 $\pm$ 0.17 bcd
<b>Bostrichidae</b>									
<i>M. brasiliensis</i>	0.06 $\pm$ 0.02 a	0.04 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.06 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.05 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.10 $\pm$ 0.02 a
<i>X. picea</i>	0.12 $\pm$ 0.02 ab	0.15 $\pm$ 0.03 ab	0.14 $\pm$ 0.03 ab	0.11 $\pm$ 0.02 ab	0.23 $\pm$ 0.04 a	0.13 $\pm$ 0.02 ab	0.09 $\pm$ 0.02 b	0.13 $\pm$ 0.03 ab	0.10 $\pm$ 0.02 b
<i>X. capucinus</i>	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a
$\Sigma$ Bostrichidae	0.22 $\pm$ 0.03 ab	0.22 $\pm$ 0.04 ab	0.21 $\pm$ 0.03 ab	0.21 $\pm$ 0.03 ab	0.33 $\pm$ 0.05 a	0.25 $\pm$ 0.03 ab	0.18 $\pm$ 0.03 b	0.22 $\pm$ 0.04 ab	0.25 $\pm$ 0.04 ab
<b>Cerambycidae</b>									
<i>A. brunnea</i>	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a
<i>C. elliptica</i>	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a
<i>C. quadriguttata</i>	0.28 $\pm$ 0.05 b	0.57 $\pm$ 0.11 a	0.29 $\pm$ 0.05 b	0.35 $\pm$ 0.08 ab	0.32 $\pm$ 0.07 ab	0.28 $\pm$ 0.07 b	0.20 $\pm$ 0.05 b	0.14 $\pm$ 0.03 b	0.20 $\pm$ 0.04 b
<i>C. vanum</i>	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a
<i>N. pusillus</i>	0.06 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.03 $\pm$ 0.01 a	0.11 $\pm$ 0.02 a
<i>O. aerumnosa</i>	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.02 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a
$\Sigma$ Cerambycidae	0.53 $\pm$ 0.07 ab	0.82 $\pm$ 0.13 a	0.50 $\pm$ 0.06 ab	0.58 $\pm$ 0.08 ab	0.60 $\pm$ 0.07 ab	0.49 $\pm$ 0.08 ab	0.40 $\pm$ 0.06 b	0.35 $\pm$ 0.04 b	0.43 $\pm$ 0.05 b
<b>Cleridae</b>									
<i>M. mucoreus</i>	0.25 $\pm$ 0.05 ab	0.19 $\pm$ 0.04 b	0.14 $\pm$ 0.03 b	0.40 $\pm$ 0.07 a	0.25 $\pm$ 0.05 ab	0.15 $\pm$ 0.03 b	0.22 $\pm$ 0.04 ab	0.11 $\pm$ 0.02 b	0.23 $\pm$ 0.04 ab
$\Sigma$ Cleridae	0.25 $\pm$ 0.05 ab	0.20 $\pm$ 0.04 b	0.15 $\pm$ 0.03 b	0.41 $\pm$ 0.07 a	0.26 $\pm$ 0.05 ab	0.16 $\pm$ 0.03 b	0.23 $\pm$ 0.04 ab	0.13 $\pm$ 0.03 b	0.24 $\pm$ 0.04 ab

Means, transformed from  $\sqrt{x + 0.5}$ , followed by the same letter do not differ statistically from each other in the line ( $P > 0.05$ , Tukey test).

<sup>1</sup>abcde: a=number of vanes (1, 3, 4), bc=presence (yC) or absence (nC) of a central hole, de=presence (U+) or absence (U-) of an upper hole

**Table 2-** Mean ( $\pm$  SE) of the number of Scolytinae, Bostrichidae, Cerambycidae and Cleridae species captured according to the number of vanes, central hole and upper hole by ethanol-baited flight intercept trap, in a cerradão fragment, in Selvíria, state of Mato Grosso do Sul, Brazil, July 2020 through August 2021.

species	number of vanes			central hole		upper hole	
	1	3	4	present	absent	present	absent
<b>Scolytinae</b>							
<i>Ambrosiodmus opimus</i>	0.05 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.04 $\pm$ 0.01 b
<i>Cryptocarenum diadematus</i>	0.07 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Cryptocarenum heveae</i>	0.06 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a
<i>Cryptocarenum seriatus</i>	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.00 a
<i>Hypothenemus eruditus</i>	0.28 $\pm$ 0.03 a	0.26 $\pm$ 0.02 a	0.27 $\pm$ 0.03 a	0.28 $\pm$ 0.03 a	0.27 $\pm$ 0.02 a	0.28 $\pm$ 0.03 a	0.27 $\pm$ 0.02 a
<i>Hypothenemus javanus</i>	0.07 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.09 $\pm$ 0.02 a	0.07 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a
<i>Hypothenemus obscurus</i>	0.61 $\pm$ 0.07 a	0.66 $\pm$ 0.07 a	0.68 $\pm$ 0.07 a	0.72 $\pm$ 0.07 a	0.61 $\pm$ 0.05 a	0.68 $\pm$ 0.07 a	0.63 $\pm$ 0.05 b
<i>Hypothenemus subsulcatus</i>	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.00 b
<i>Hypothenemus suspectus</i>	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.00 b
<i>Premnobius cavipennis</i>	0.11 $\pm$ 0.02 a	0.07 $\pm$ 0.01 ab	0.05 $\pm$ 0.01 b	0.07 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a	0.09 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a
<i>Sampsonius dampfi</i>	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a
<i>Xyleborus affinis</i>	0.09 $\pm$ 0.01 a	0.08 $\pm$ 0.01 ab	0.05 $\pm$ 0.01 b	0.05 $\pm$ 0.01 b	0.08 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a
<i>Xyleborus ferrugineus</i>	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a
<i>Xyleborus spinulosus</i>	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a
$\Sigma$ Scolytinae	1.56 $\pm$ 0.09 a	1.54 $\pm$ 0.09 a	1.53 $\pm$ 0.09 a	1.57 $\pm$ 0.09 a	1.53 $\pm$ 0.06 b	1.64 $\pm$ 0.10 a	1.50 $\pm$ 0.06 b
<b>Bostrichidae</b>							
<i>Micrapate brasiliensis</i>	0.05 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Xyloperthella picea</i>	0.13 $\pm$ 0.01 a	0.16 $\pm$ 0.02 a	0.11 $\pm$ 0.01 a	0.11 $\pm$ 0.01 b	0.14 $\pm$ 0.01 a	0.12 $\pm$ 0.01 a	0.14 $\pm$ 0.01 a
<i>Xylopsocus capucinus</i>	0.02 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a
$\Sigma$ Bostrichidae	0.22 $\pm$ 0.02 a	0.26 $\pm$ 0.02 a	0.21 $\pm$ 0.02 a	0.20 $\pm$ 0.02 b	0.25 $\pm$ 0.02 a	0.24 $\pm$ 0.02 a	0.23 $\pm$ 0.02 a
<b>Cerambycidae</b>							
<i>Aerenea brunnea</i>	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a
<i>Carphina elliptica</i>	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a
<i>Compsa quadriguttata</i>	0.38 $\pm$ 0.04 a	0.31 $\pm$ 0.04 a	0.18 $\pm$ 0.02 b	0.28 $\pm$ 0.04 b	0.30 $\pm$ 0.03 a	0.26 $\pm$ 0.03 a	0.31 $\pm$ 0.03 a
<i>Compsibidion vanum</i>	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.00 a
<i>Neoclytus pusillus</i>	0.07 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a	0.09 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Oreodera aerumosa</i>	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a	0.02 $\pm$ 0.00 a
$\Sigma$ Cerambycidae	0.62 $\pm$ 0.05 a	0.56 $\pm$ 0.05 a	0.39 $\pm$ 0.03 b	0.50 $\pm$ 0.04 b	0.53 $\pm$ 0.03 a	0.47 $\pm$ 0.04 a	0.55 $\pm$ 0.03 a
<b>Cleridae</b>							
<i>Megaphloeus mucoreus</i>	0.19 $\pm$ 0.02 b	0.27 $\pm$ 0.03 a	0.19 $\pm$ 0.02 b	0.29 $\pm$ 0.03 a	0.18 $\pm$ 0.01 a	0.17 $\pm$ 0.02 a	0.24 $\pm$ 0.02 a
$\Sigma$ Cleridae	0.20 $\pm$ 0.02 b	0.28 $\pm$ 0.03 a	0.20 $\pm$ 0.02 b	0.30 $\pm$ 0.03 a	0.19 $\pm$ 0.01 a	0.18 $\pm$ 0.02 a	0.25 $\pm$ 0.02 a

Means, transformed from  $\sqrt{x+0.5}$ , followed by the same letter do not differ statistically from each other in the line ( $P > 0.05$ , Tukey test).

**Table 3.** Mean ( $\pm$  SE) of ethanol baited release rate by each flight intercept trap, in a cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, November 2020 through June 2021

	trap design <sup>1</sup>								
	1 yCU-	1 nCU-	4 yCU-	3 nCU-	1 nCU+	4 nCU+	4 nCU-	3 nCU+	3 yCU-
<b>bait release rate</b>	13.65 $\pm$ 0.85 a	13.00 $\pm$ 0.99 ab	12.40 $\pm$ 1.00 abc	12.04 $\pm$ 0.98 abc	11.68 $\pm$ 0.85 abc	11.08 $\pm$ 0.84 abc	10.79 $\pm$ 0.90 bc	10.62 $\pm$ 0.90 bc	10.15 $\pm$ 0.72 c

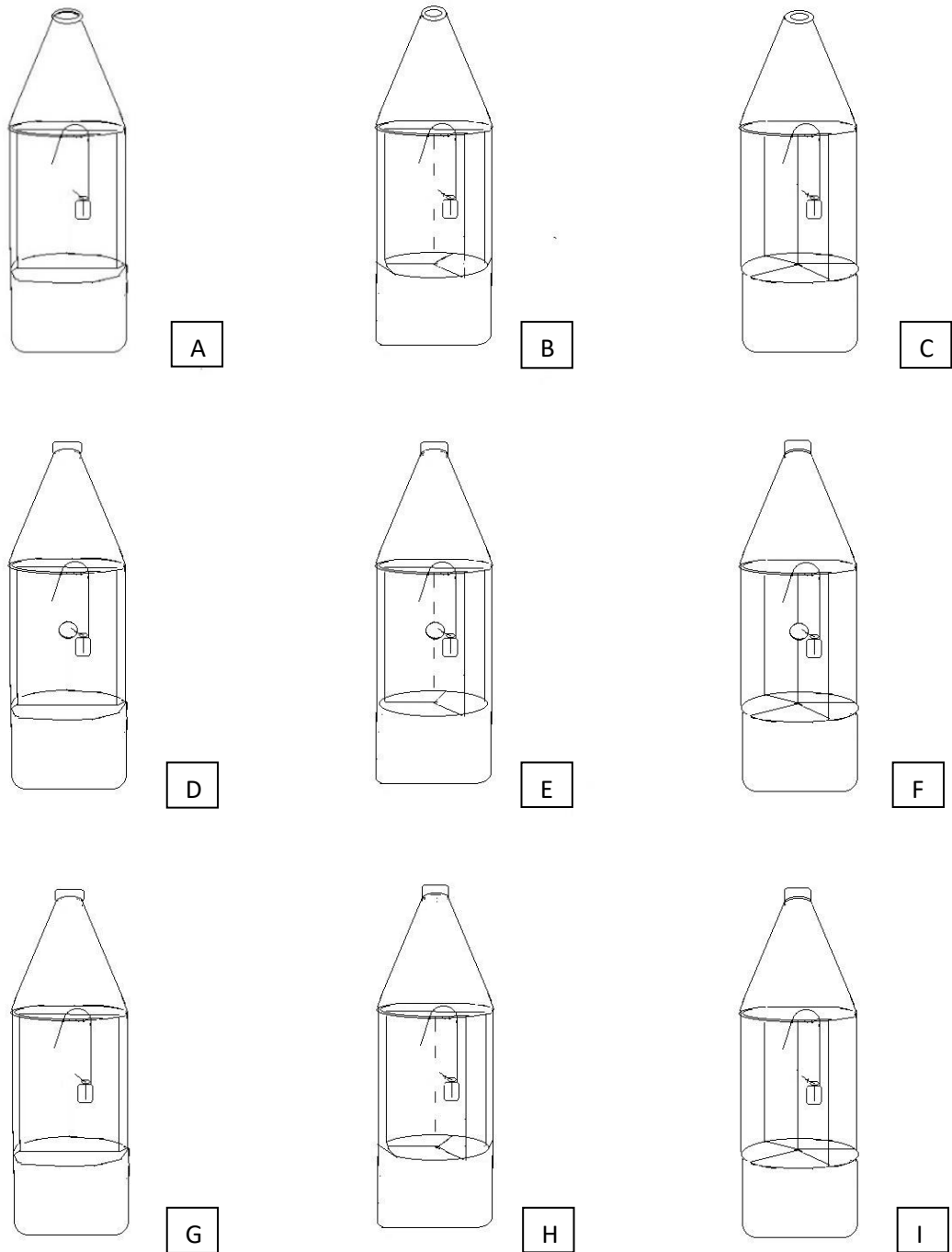
Means, transformed from  $\sqrt{(x + 0.5)}$ , followed by the same letter do not differ statistically from each other in the line ( $P > 0.05$ , Tukey test).

<sup>1</sup>abcde: a=number of vanes (1, 3, 4), bc=presence (yC) or absence (nC) of a central hole, de=presence (U+) or absence (U-) of an upper hole

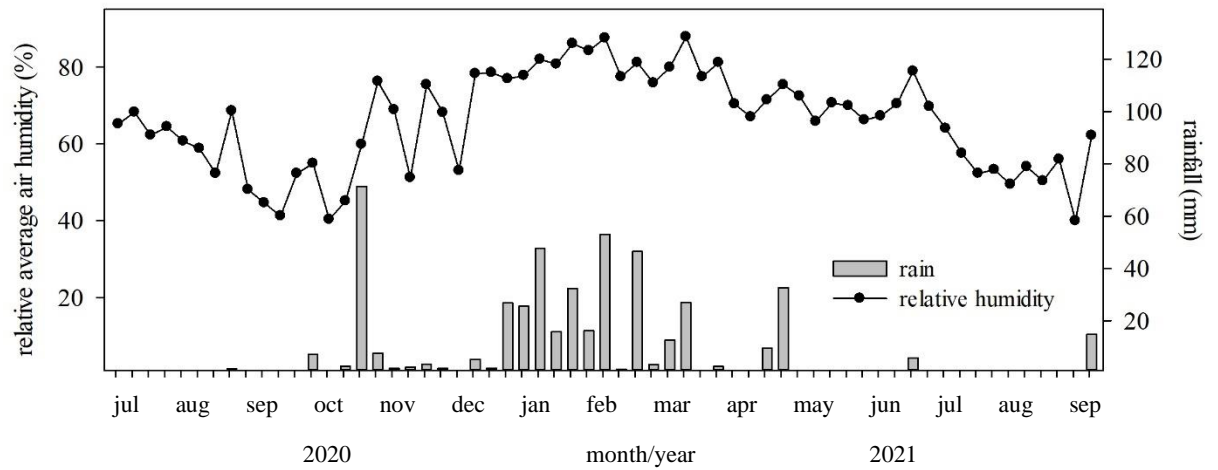
**Table 4.** Mean ( $\pm$  SE) of ethanol baited release rate by number of vanes and presence or absent of central and upper hole in flight intercept traps, in a cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, November 2020 through June 2021.

vanes	present		absent	
	central hole	upper hole	central hole	upper hole
1 vane	13.65 $\pm$ 0.85 a	11.68 $\pm$ 0.85 a	12.34 $\pm$ 0.65 a	13.33 $\pm$ 0.65 a
3 vanes	10.15 $\pm$ 0.72 b	10.62 $\pm$ 0.90 a	11.33 $\pm$ 0.67 a	11.09 $\pm$ 0.62 b
4 vanes	12.40 $\pm$ 1.00 a	11.08 $\pm$ 0.84 a	10.94 $\pm$ 0.61 a	11.59 $\pm$ 0.68 b

Means, transformed from  $\sqrt{(x + 0.5)}$ , followed by the same letter do not differ statistically from each other in the column ( $P > 0.05$ , Tukey test).



**Supplementary Figure 1.** Ethanol-baited flight intercept trap; without central hole and with upper hole, **A.** one vane, **B.** three vanes, **C.** four vanes; with central hole and without upper hole, **D.** one vane, **E.** three vanes, **F.** four vanes; without central hole and without upper hole, **G.** one vane, **H.** three vanes, **I.** four vanes.



**Supplementary Figure 2.** Relative average air humidity (%) and rainfall (mm) in pasture area. UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil. July 2020 through September 2021.



**Supplementary Figure 3.** Anemometer built to measure wind speed and wind direction inside the study area. Cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil.

**Supplementary Table 1-** Total of Scolytinae, Bostrichidae, Cerambycidae and Cleridae species captured in different ethanol-baited flight intercept trap designs, in a cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, July 2020 through August 2021.

species	trap design <sup>1</sup>									total
	1yCU-	1nCU-	1nCU+	3yCU-	3nCU-	3nCU+	4yCU-	4nCU-	4nCU+	
<b>Scolytinae</b>										
<i>Ambrosiodmus obliquus</i>			2		2	2	1	1		8
<i>Ambrosiodmus opimus</i>	15	7	11	10	13	18	7	9	17	107
<i>Araptus</i> sp. 01					1		1			2
<i>Araptus</i> sp. 02	2		1		1	1	1		1	7
<i>Araptus</i> sp. 03					2				1	3
<i>Araptus</i> sp. 04				1				1		2
<i>Araptus</i> sp. 05							1			1
<i>Araptus</i> sp. 06									1	1
<i>Araptus</i> sp. 07	1									1
<i>Cnemonyx</i> sp.01		1			9					10
<i>Cnesinus dividuus</i>			1	1	1	1			2	6
<i>Cnestus laticeps</i>			1			1			1	3
<i>Cnesinus</i> sp. 01						1				1
<i>Coptoborus tolimanus</i>	1	3		1	2					7
<i>Corthylus ustus</i>						1	1	2		4
<i>Cryptocarenum brevicollis</i>			1			3		1		5
<i>Cryptocarenum diadematus</i>	16	16	15	10	13	9	20	11	15	125
<i>Cryptocarenum heveae</i>	17	11	13	5	12	20	13	6	17	114
<i>Cryptocarenum seriatus</i>	11	7	4	3	6	9	11	4	4	59
<i>Dryocoetoides cristatus</i>	1	1		1	1	2				6
<i>Hypothenemus arecae</i>	1				1	1		2	1	6
<i>Hypothenemus bolivianus</i>		3		1	1	2	1	2	2	12
<i>Hypothenemus brunneus</i>	1	2	1		2	2	1	1	2	12
<i>Hypothenemus eruditus</i>	70	66	60	43	57	84	81	55	53	569
<i>Hypothenemus javanus</i>	15	18	13	8	22	16	29	16	20	157
<i>Hypothenemus obscurus</i>	186	118	118	127	130	204	186	131	154	1354
<i>Hypothenemus opacus</i>	1					1				2
<i>Hylocorus retusipenis</i>			1	6	2		3			12
<i>Hypothenemus setosus</i>			1			3	1			5
<i>Hypothenemus</i> sp. 01			1				2			3
<i>Hypothenemus</i> sp. 02				1				1		2
<i>Hypothenemus</i> sp. 03	1									1
<i>Hypothenemus</i> sp. 04									1	1
<i>Hypothenemus subsulcatus</i>	2		7	1	1	6	5	1	2	25
<i>Hypothenemus suspectus</i>	1	2	7	2	4	5	4	3	4	32
<i>Hypothenemus vesculus</i>		1								1
<i>Microcortylus minimus</i>							1			1

Supplementary Table 1 (Continuation)

species	trap design <sup>1</sup>									total
	1yCU-	1nCU-	1nCU+	3yCU-	3nCU-	3nCU+	4yCU-	4nCU-	4nCU+	
<i>Phloeoborus rudis</i>									1	1
<i>Premnobius ambitiosus</i>								1		1
<i>Premnobius cavipennis</i>	23	23	29	11	13	22	12	13	13	159
<i>Sampsonius dampfi</i>	13	4	6		10	3	6	2	4	48
<i>Scolytopsis toba</i>	4				1	1				6
<i>Scolytogenus</i> sp. 01									1	1
<i>Scolytogenus</i> sp. 02								1		1
<i>Taurodemus varulus</i>				1						1
<i>Tricolus subincisuralis</i>			1	1						2
<i>Trischidias</i> sp. 01				1						1
<i>Trischidias</i> sp. 02						1				1
<i>Xyleborus affinis</i>	15	31	19	10	20	24	13	15	8	155
<i>Xyleborus biconicus</i>				1	1					2
<i>Xylosandrus curtulus</i>	1	2	2	5	1	2		2	2	17
<i>Xyleborus ferrugineus</i>	1	6	5	2	3	6	3	1	2	29
<i>Xyleborinus gracilis</i>							1	1		2
<i>Xyleborinus linearicollis</i>	1	1	1		1					4
<i>Xyleborinus saxesenii</i>	1									1
<i>Xyleborus</i> sp. 01								1		1
<i>Xyleborus</i> sp. 02							1			1
<i>Xyleborus spinulosus</i>	14	12	10	12	12	9	7	20	14	110
<i>Xyleborus volvulus</i>	2	1	2	1	1	1			2	10
Σ Scolytinae	417	336	333	266	346	461	413	304	345	3221
<b>Platypodinae</b>										
<i>Euplatypus parallelus</i>	1		1		1		2			5
<i>Euplatypus segnis</i>						1				1
<i>Teloplatypus ratzeburg</i>	1	2								3
Σ Platypodinae	2	2	1		1	1	2			9
<b>Bostrichidae</b>										
<i>Bostrychopsis uncinata</i>	1	1	1				1		1	5
<i>Melalgus</i> sp. 01		1								1
<i>Micrapate atra</i>						2		1	2	5
<i>Micrapate brasiliensis</i>	15	10	10	14	13	17	11	16	23	129
<i>Micrapate germani</i>				1			1		2	4
<i>Micrapate</i> sp. 01	1	3	2	3	3	4	5		2	23
<i>Xylopsocus capucinus</i>	6	2	4	4	8	6	3	4	3	40
<i>Xyloperthella picea</i>	28	34	32	26	53	30	21	29	24	277
Σ Bostrichidae	51	51	49	48	77	59	42	50	57	484

Supplementary Table 1 (Continuation)

species	trap design <sup>1</sup>									total
	1yCU-	1nCU-	1nCU+	3yCU-	3nCU-	3nCU+	4yCU-	4nCU-	4nCU+	
<b>Cleridae</b>										
<i>Amboakis nova</i>							1	1		2
Cleridae sp. 01							1			1
Cleridae sp. 02			1			1				2
Cleridae sp. 03				1	1			1		3
Cleridae sp. 04				2				1	1	4
Cleridae sp. 05						2				2
Cleridae sp. 06									1	1
Cleridae sp. 07		1	1		1					3
Cleridae sp. 08		1								1
Cleridae sp. 09						1				1
Cleridae sp. 10			1							1
Cleridae sp. 11				1						1
<i>Megaphloeus mucoreus</i>	57	44	32	92	59	34	51	26	53	448
Σ Cleridae	57	46	35	96	61	38	53	29	55	470
<b>Cerambycidae</b>										
<i>Adetus odestus</i>							1			1
<i>Aerenea brunnea</i>	8	4	4	7	4	4	6	6	3	46
<i>Aegoschema moniliferum</i>	1	2			1	3	1			8
<i>Ambonus distinctus</i>		1	1					1		3
<i>Andraegoidus fabricii</i>				1						1
<i>Ataxia luteifrons</i>								1		1
<i>Carphina elliptica</i>	7	2	1	3	2	2	6	4	2	29
<i>Callisema rufipes</i>		2			1			1		4
Cerambycidae sp. 01	1									1
Cerambycidae sp. 02		2	1		1			1	3	8
Cerambycidae sp. 03				1				1		2
Cerambycidae sp. 04			1							1
Cerambycidae sp. 05		1								1
<i>Chlorida festiva</i>	3	2	2	4	3	1	3	1	1	20
<i>Cipriscola fasciata</i>	2	2	1	2	1	2		1	1	12
<i>Compsibidion fairmairei</i>		1				1				2
<i>Compsa quadriguttata</i>	65	133	68	81	74	65	46	33	47	612
<i>Colobothea rubroornata</i>					1	1				2
<i>Compsibidion vanum</i>	6	6	5	4	10	7	4	5	6	53
<i>Desmiphora crocata</i>			1							1
<i>Eburodacrys assimilis</i>					1					1

Supplementary Table 1 (Continuation)

species	trap design <sup>1</sup>									total
	1yCU-	1nCU-	1nCU+	3yCU-	3nCU-	3nCU+	4yCU-	4nCU-	4nCU+	
<i>Eburodacrys punctipennis</i>				1	1					2
<i>Eburodacrys vittata</i>			1	1		1		1		4
<i>Estola flavescens</i>	1			3			1	1		6
<i>Eutrachyderes thoracicus</i>	1	2		1	2			1	2	9
<i>Exalphus foveatus</i>						1				1
<i>Exalphus gounellei</i>				1						1
<i>Gorybia ruficauda</i>				1				1		2
<i>Hylettus seniculus</i>	2	1	3		2	1	2	2	2	15
<i>Itaclytus olivaceus</i>							1			1
<i>Lepturgantes prolatus</i>								1		1
<i>Lysimena fuscata</i>	1			1	1	1		1	1	6
<i>Megacyllene falsa</i>	1					1		1		3
<i>Mecometopus polygenus</i>	2	1	1		3	1	2	2		12
<i>Mionochroma electrinum</i>				1	2		2			5
<i>Nesozineus lineolatus</i>	1									1
<i>Neoclytus pusillus</i>	15	17	20	14	22	17	14	8	25	152
<i>Odontocera fasciata</i>	1	1								2
<i>Oreodera aerumnosa</i>	2	7	5	5	8	3	3	7	3	43
<i>Oreodera glauca</i>			1							1
<i>Oxymerus aculeatus</i>	1									1
<i>Piezocera costula</i>	1								2	3
<i>Placaederus glaberrimus</i>		1				1				2
<i>Polyrhaphis spinipennis</i>			1							1
<i>Psapharochrus jaspideus</i>		2		2		1		1	1	7
<i>Sydax flechtmani</i>	1									1
Σ Cerambycidae	123	190	117	134	140	114	92	82	99	1091
<b>Total</b>	650	625	535	544	625	673	602	465	557	5276

<sup>1</sup>abcde: a=number of vanes (1, 3, 4), bc=presence (yC) or absence (nC) of a central hole, de=presence (U+) or absence (U-) of an upper hole

**Supplementary Table 2-** Mean ( $\pm$  SE) of the number of Scolytinae, Bostrichidae, Cerambycidae and Cleridae species captured according to the number of vanes and presence/absence of a central hole by ethanol-baited flight intercept trap, in a cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, July 2020 through August 2021.

species	central hole present			central hole absent		
	1 vane	3 vanes	4 vanes	1 vane	3 vanes	4 vanes
<b>Scolytinae</b>						
<i>Ambrosiodmus opimus</i>	0.06 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Cryptocarenum diadematus</i>	0.07 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.09 $\pm$ 0.02 a	0.07 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Cryptocarenum heveae</i>	0.07 $\pm$ 0.02 a	0.02 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a
<i>Cryptocarenum seriatus</i>	0.05 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>Hypothenemus eruditus</i>	0.30 $\pm$ 0.05 a	0.18 $\pm$ 0.03 a	0.35 $\pm$ 0.06 a	0.27 $\pm$ 0.03 a	0.30 $\pm$ 0.03 a	0.23 $\pm$ 0.03 a
<i>Hypothenemus javanus</i>	0.06 $\pm$ 0.02 a	0.03 $\pm$ 0.01 a	0.12 $\pm$ 0.04 a	0.07 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a	0.08 $\pm$ 0.02 a
<i>Hypothenemus obscurus</i>	0.80 $\pm$ 0.16 a	0.55 $\pm$ 0.10 a	0.80 $\pm$ 0.12 a	0.51 $\pm$ 0.07 b	0.72 $\pm$ 0.09 a	0.61 $\pm$ 0.08 ab
<i>Hypothenemus subsulcatus</i>	0.01 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a
<i>Hypothenemus suspectus</i>	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a
<i>Premnobius cavipennis</i>	0.10 $\pm$ 0.03 a	0.04 $\pm$ 0.02 a	0.05 $\pm$ 0.02 a	0.11 $\pm$ 0.02 a	0.07 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Sampsonius dampfi</i>	0.06 $\pm$ 0.02 a	0.00 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a
<i>Xyleborus affinis</i>	0.06 $\pm$ 0.02 a	0.04 $\pm$ 0.01 a	0.06 $\pm$ 0.02 a	0.11 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.05 $\pm$ 0.01 a
<i>Xyleborus ferrugineus</i>	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a
<i>Xyleborus spinulosus</i>	0.06 $\pm$ 0.02 a	0.05 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a
$\Sigma$ Scolytinae	1.80 $\pm$ 0.19 a	1.15 $\pm$ 0.13 a	1.78 $\pm$ 0.16 a	1.44 $\pm$ 0.09 ab	1.74 $\pm$ 0.12 a	1.40 $\pm$ 0.10 b
<b>Bostrichidae</b>						
<i>Micrapate brasiliensis</i>	0.06 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.05 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a
<i>Xyloperthella picea</i>	0.12 $\pm$ 0.02 a	0.11 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.14 $\pm$ 0.02 a	0.18 $\pm$ 0.02 a	0.11 $\pm$ 0.02 a
<i>Xylopsocus capucinus</i>	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a
$\Sigma$ Bostrichidae	0.22 $\pm$ 0.03 a	0.21 $\pm$ 0.03 a	0.18 $\pm$ 0.03 a	0.21 $\pm$ 0.02 a	0.29 $\pm$ 0.03 a	0.23 $\pm$ 0.03 a
<b>Cerambycidae</b>						
<i>Aerenea brunnea</i>	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>Carphina elliptica</i>	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a
<i>Compsa quadriguttata</i>	0.28 $\pm$ 0.05 ab	0.35 $\pm$ 0.08 a	0.20 $\pm$ 0.05 b	0.43 $\pm$ 0.06 a	0.30 $\pm$ 0.05 a	0.17 $\pm$ 0.02 a
<i>Compsibidion vanum</i>	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>Neoclytus pusillus</i>	0.06 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.08 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a
<i>Oreodera aerumnosa</i>	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
$\Sigma$ Cerambycidae	0.53 $\pm$ 0.07 ab	0.58 $\pm$ 0.08 a	0.40 $\pm$ 0.06 b	0.66 $\pm$ 0.07 a	0.55 $\pm$ 0.05 a	0.39 $\pm$ 0.03 a
<b>Cleridae</b>						
<i>Megaphloeus mucoreus</i>	0.25 $\pm$ 0.04 ab	0.40 $\pm$ 0.07 a	0.22 $\pm$ 0.04 b	0.16 $\pm$ 0.02 a	0.20 $\pm$ 0.03 a	0.17 $\pm$ 0.02 a
$\Sigma$ Cleridae	0.25 $\pm$ 0.04 b	0.41 $\pm$ 0.07 a	0.23 $\pm$ 0.04 b	0.17 $\pm$ 0.02 a	0.21 $\pm$ 0.03 a	0.18 $\pm$ 0.02 a

Means, transformed from  $\sqrt{x + 0.5}$ , followed by the same letter do not differ statistically from each other in the line ( $p > 0.05$ , Tukey test).

**Supplementary Table 3-** Mean ( $\pm$  SE) of the number of Scolytinae, Bostrichidae, Cerambycidae and Cleridae species captured according to the number of vanes and upper hole by ethanol-baited flight intercept trap, in a cerradão fragment, UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, July 2020 through August 2021.

species	upper hole present			upper hole absent		
	1 vane	3 vanes	4 vanes	1 vane	3 vanes	4 vanes
<b>Scolytinae</b>						
<i>Ambrosiodmus opimus</i>	0.05 $\pm$ 0.01 a	0.08 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a
<i>Cryptocarenum diadematus</i>	0.06 $\pm$ 0.02 a	0.04 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.07 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a
<i>Cryptocarenum heveae</i>	0.06 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.06 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a
<i>Cryptocarenum seriatus</i>	0.02 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a
<i>Hypothenemus eruditus</i>	0.26 $\pm$ 0.05 b	0.36 $\pm$ 0.05 a	0.23 $\pm$ 0.04 b	0.29 $\pm$ 0.03 a	0.21 $\pm$ 0.03 a	0.29 $\pm$ 0.04 a
<i>Hypothenemus javanus</i>	0.06 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.09 $\pm$ 0.02 a	0.07 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.10 $\pm$ 0.02 a
<i>Hypothenemus obscurus</i>	0.51 $\pm$ 0.10 b	0.88 $\pm$ 0.16 a	0.66 $\pm$ 0.13 ab	0.65 $\pm$ 0.09 a	0.55 $\pm$ 0.07 a	0.68 $\pm$ 0.07 a
<i>Hypothenemus subsulcatus</i>	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.00 $\pm$ 0.00 a	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a
<i>Hypothenemus suspectus</i>	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a
<i>Premnobius cavipennis</i>	0.12 $\pm$ 0.03 a	0.09 $\pm$ 0.02 a	0.06 $\pm$ 0.02 a	0.10 $\pm$ 0.02 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a
<i>Sampsonius dampfi</i>	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>Xyleborus affinis</i>	0.08 $\pm$ 0.02 ab	0.10 $\pm$ 0.03 a	0.03 $\pm$ 0.01 b	0.10 $\pm$ 0.02 a	0.06 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Xyleborus ferrugineus</i>	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a
<i>Xyleborus spinulosus</i>	0.04 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	0.06 $\pm$ 0.02 a	0.06 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
$\Sigma$ Scolytinae	1.43 $\pm$ 0.13 b	1.99 $\pm$ 0.19 a	1.49 $\pm$ 0.17 b	1.62 $\pm$ 0.11 a	1.32 $\pm$ 0.09 a	1.54 $\pm$ 0.10 a
<b>Bostrichidae</b>						
<i>Micrapate brasiliensis</i>	0.04 $\pm$ 0.01 a	0.07 $\pm$ 0.02 a	0.10 $\pm$ 0.02 a	0.05 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a
<i>Xyloperthella picea</i>	0.14 $\pm$ 0.03 a	0.13 $\pm$ 0.02 a	0.10 $\pm$ 0.02 a	0.13 $\pm$ 0.02 a	0.17 $\pm$ 0.02 a	0.11 $\pm$ 0.02 a
<i>Xylopsocus capucinus</i>	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a
$\Sigma$ Bostrichidae	0.21 $\pm$ 0.03 a	0.25 $\pm$ 0.03 a	0.25 $\pm$ 0.04 a	0.22 $\pm$ 0.02 a	0.27 $\pm$ 0.03 a	0.20 $\pm$ 0.02 a
<b>Cerambycidae</b>						
<i>Aerenea brunnea</i>	0.02 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a
<i>Carphina elliptica</i>	0.00 $\pm$ 0.00 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>Compsa quadriguttata</i>	0.29 $\pm$ 0.05 a	0.28 $\pm$ 0.07 a	0.20 $\pm$ 0.04 a	0.43 $\pm$ 0.06 a	0.33 $\pm$ 0.05 a	0.17 $\pm$ 0.03 b
<i>Compsibidion vanum</i>	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
<i>Neoclytus pusillus</i>	0.09 $\pm$ 0.02 a	0.07 $\pm$ 0.02 a	0.11 $\pm$ 0.02 a	0.07 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a
<i>Oreodera aerumnosa</i>	0.02 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a
$\Sigma$ Cerambycidae	0.50 $\pm$ 0.06 a	0.49 $\pm$ 0.08 a	0.43 $\pm$ 0.05 a	0.67 $\pm$ 0.07 a	0.59 $\pm$ 0.06 a	0.37 $\pm$ 0.03 b
<b>Cleridae</b>						
<i>Megaphloeus mucoreus</i>	0.14 $\pm$ 0.03 a	0.15 $\pm$ 0.03 a	0.23 $\pm$ 0.04 a	0.22 $\pm$ 0.03 ab	0.32 $\pm$ 0.04 a	0.17 $\pm$ 0.02 b
$\Sigma$ Cleridae	0.15 $\pm$ 0.03 a	0.16 $\pm$ 0.03 a	0.24 $\pm$ 0.04 a	0.22 $\pm$ 0.03 b	0.34 $\pm$ 0.04 a	0.18 $\pm$ 0.02 b

Means, transformed from  $\sqrt{x + 0.5}$ , followed by the same letter do not differ statistically from each other in the line ( $p > 0.05$ , Tukey test).

**Supplementary Table 4.** Mean ( $\pm$ SE) wind speed (in m/s) and wind direction (in degrees) inside the cerradão fragment and in a pasture area. UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, during different periods of the day, July 2021 through August 2021.

place	wind speed			wind direction		
	morning	afternoon	full day	morning	afternoon	full day
cerradão fragment	0.11 $\pm$ 0.00 b	0.09 $\pm$ 0.00 b	0.10 $\pm$ 0.00 b	137.46 $\pm$ 4.22 a	126.75 $\pm$ 4.73 a	132.24 $\pm$ 3.16 a
pasture area	0.68 $\pm$ 0.04 a	0.23 $\pm$ 0.03 a	0.46 $\pm$ 0.03 a	137.80 $\pm$ 4.50 a	117.80 $\pm$ 2.68 a	128.05 $\pm$ 2.68 a

Means, transformed from  $\sqrt{(x + 0.5)}$ , followed by the same letter do not differ statistically from each other in the column ( $p > 0.05$ , Tukey test).

**Supplementary Table 5.** Mean ( $\pm$ SE) wind speed (in m/s) and wind direction (in degrees) during different periods of the day inside the cerradão fragment and in a pasture area. UNESP Farm, Selvíria, state of Mato Grosso do Sul, Brazil, July 2021 through August 2021.

period	wind speed		wind direction	
	cerradão fragment	pasture area	cerradão fragment	pasture area
morning	0.11 $\pm$ 0.00 a	0.68 $\pm$ 0.04 a	137.46 $\pm$ 4.22 a	137.80 $\pm$ 4.50 a
afternoon	0.09 $\pm$ 0.00 b	0.23 $\pm$ 0.03 b	126.75 $\pm$ 4.73 a	117.80 $\pm$ 2.68 b

Means, transformed from  $\sqrt{(x + 0.5)}$ , followed by the same letter do not differ statistically from each other in the column ( $p > 0.05$ , Tukey test).