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DE RECURSOS NATURAIS



**A IMPORTÂNCIA DA FLORAÇÃO SEQÜENCIAL DE
MALPIGHACEAE PARA A MANUTENÇÃO DA DIVERSIDADE
DE TRIPES (THYSANOPTERA) NO CERRADO**

ESTEVÃO ALVES DA SILVA

UBERLÂNDIA – MG
FEVEREIRO, 2010

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“Dissertação apresentada à Universidade Federal de
Uberlândia, como parte das exigências para obtenção
do título de Mestre em Ecologia e Conservação de
Recursos Naturais”.

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RESUMO

Alves-Silva, E. **A importância da floração seqüencial de *Malpighiaceae* para a manutenção da diversidade de tripes (Thysananoptera) no cerrado.** 2010. 77f. Dissertação (Mestrado em Ecologia e Conservação de Recursos Naturais) – Universidade Federal de Uberlândia, Uberlândia, 2010.

Para se entender o papel de cada planta na ecologia de tripes, dois principais critérios precisam ser quantificados: a regularidade temporal em que os indivíduos são encontrados em uma planta e sua abundância em uma determinada planta relativamente a outras. A escolha de plantas representativas pode fornecer informações que permitam definir padrões temporais de ocorrência e avaliar a importância de fatores ambientais na comunidade destes insetos. Neste contexto, plantas que apresentem floração seqüencial podem prover elementos a respeito da importância de cada hospedeiro em abrigar populações de tripes ao longo do ano. Este estudo teve o objetivo de testar a hipótese de que malpighiáceas com floração seqüencial são responsáveis pela manutenção de tripes no decorrer do ano, assumindo a premissa que tripes migram de planta em planta de acordo com a fenologia de floração. O estudo foi realizado em uma área de Cerrado sentido restrito em Uberlândia, Minas Gerais, Brasil. As plantas estudadas foram *Banisteriopsis malifolia*, *B. campestris*, *B. laevifolia*, *Byrsonima intermedia* e *Peixotoa tomentosa*. As coletas foram realizadas de março de 2008 a fevereiro de 2009. Foram encontradas 19 espécies de tripes distribuídas em oito gêneros e três famílias Phlaeothripidae, Thripidae e Heterothripidae, perfazendo 3788 (5.61 ± 6.49 , $\bar{X} \pm 1SD$) indivíduos nas 675 flores analisadas. Testes de fenologia mostraram que todas as cinco malpighiáceas apresentaram floração seqüencial, o que permitiu aos tripes migrarem entre as plantas e encontrarem alimento e abrigo o ano todo. A planta com maior abundância de tripes foi *P. tomentosa*, seguida por *B. laevifolia*, no entanto, a diversidade foi maior em *B. malifolia*. As únicas espécies de tripes presentes em todas as plantas e passíveis de migrar dependendo da fenologia de floração foram *Frankliniella condei*, *Scutothrips nudus*, *Frankliniella* sp. 1. e *Heterothrips peixotoa*. A riqueza e diversidade encontradas nas malpighiáceas são umas das maiores já registradas para a ocorrência de tripes em plantas relacionadas taxonomicamente e isso se deve ao aspecto conservativo das flores que fornecem tanto alimento quanto proteção contra predadores. Este estudo mostra que malpighiáceas com floração seqüencial têm um importante papel na manutenção da diversidade de tripes, atuando como um recurso natural que auxilia na sobrevivência e diversificação destes insetos no cerrado brasileiro.

Palavras-chave: *Heterothrips peixotoa*, *Frankliniella*, plantas hospedeiras, fenologia

ABSTRACT

Alves-Silva, E. **The importance of sequential flowering Malpighiaceae to the maintenance of thrips (Thysanoptera) in Brazilian Savanna.** 2010. 77f. Dissertação (Mestrado em Ecologia e Conservação de Recursos Naturais) – Universidade Federal de Uberlândia, Uberlândia, 2010.

To understand the role of each plant species in the ecology of thrips, two principal criteria need to be quantified: the regularity with which individuals are found on a plant species over time, and their abundance on that particular plant species relative to other ones. The choice of representative plants may supply subsidies to define temporary patterns and to evaluate the importance of environmental factors on the community of these insects. In this context sequential flowering plants can provide insightful information about the importance of each host in supporting thrips populations along the year. This study aimed to test the hypothesis that Malpighiaceae sequential flowering is responsible for the maintenance of thrips throughout the year, assuming the premise that thrips migrate from different plants according to the flowering phenology. Fieldwork was carried out from March 2007 to February 2009 at a *strictu sensu* Cerrado area in Uberlândia, Minas Gerais State, Brazil. The plants studied comprised *Banisteriopsis malifolia*, *B. campestris*, *B. laevifolia*, *Byrsonima intermedia*, and *Peixotoa tomentosa*. We found a total of 19 species of thrips in eight genera distributed in the three families Phlaeothripidae, Thripidae and Heterothripidae. Phenological analysis showed that the five Malpighiaceae species studied presented sequential flowering, enabling thrips to migrate from plants and to find food and shelter along the year. The plant which presented more thrips was *P. tomentosa*, followed by *B. laevifolia* whereas the diversity was higher in *B. malifolia*. The only thrips species present in all plants and likely to migrate from hosts according flowering phenology were *Frankliniella condei*, *Scutothrips nudus*, *Frankliniella* sp. 1 and *Heterothrips peixotoa*. The richness and diversity recorded are the highest ever sampled for thrips occurrence in a group of related taxonomic plants, because the conservative aspect of Malpighiaceae flowers provide food resources and protection against predators. This study showed that sequential flowering Malpighiaceae plays an important role in the maintenance of thrips diversity, being an important natural resource to help in the survivorship and diversification of these insects in Brazilian Savanna.

Key words: *Heterothrips peixotoa*, *Frankliniella*, host plants, phenology

CAPÍTULOS DE REVISÃO

1. TRIPES (THYSANOPTERA: INSECTA)

1.1 CARACTERÍSTICAS GERAIS

Tripes são insetos fitófagos, micófagos ou predadores que ocupam uma vasta gama de habitats, ocorrendo nas regiões tropicais, subtropicais e temperadas (Ananthakrishnan 1993). Sua diversidade adaptativa lhes permitiu a exploração de diversos nichos como flores, serapilheira e cascas de árvores (Richards & Davies 1988).

A ordem Thysanoptera evoluiu presumivelmente de ancestrais que se alimentavam de fungos e detritos, um hábito que foi retido nos membros da família Merothripidae e também pela ordem Psocoptera, que provavelmente dividiu um ancestral comum com tripes (Mound & Marullo 1996). Tripes podem ter agido como polinizadores durante a radiação das fanerógamas e este comportamento foi mantido para algumas espécies (Momose *et al.* 1998, Sakai 2001). Subseqüentemente, três formas majoritárias de alimentação foram adotadas – hifas e esporos de fungos, folhas e flores, além de néctar, tecidos florais, o conteúdo das células de folhas jovens; e o fluido corporal de pequenos artrópodes (Mound 2002a, Morse & Hoddle 2006).

Atualmente são reconhecidas duas subordens de tripes, Tubulifera e Terebrantia (Grimaldi & Engel 2005). As diferenças mais conspícuas destas duas subordens estão no ovipositor e no formato das asas. As fêmeas dos Terebrantia têm um ovipositor em forma de serra, visível ventralmente nos últimos segmentos abdominais, enquanto que nos Tubulifera, o abdome de ambos os sexos é tubular no ápice, não havendo ovipositor visível (Mound & Marullo 1996) (FIGURA 1). Quanto às asas, nos Terebrantia, o primeiro par possui venações que podem ser acompanhadas de cerdas. Já nos Tubulifera, as asas não dispõem de venações. Mais de 95% das espécies de Terebrantia estão associadas a plantas enquanto que 60% dos Tubulifera são fungívoros (Mound 2005). O sistema de acasalamento em Thysanoptera é complexo e pode envolver ferormônios, atrativos visuais, sons ou uma combinação destes. A corte é feita pelo macho que usa suas antenas para fazer contato com a fêmea e deixá-la imóvel para que a cópula ocorra (Milne *et al.* 2007).

O ciclo de vida dos tripes é intermediário entre holometábolo e hemimetábolo. Os estágios imaturos são chamados de larvas e todas as espécies de tripes possuem mais de um estágio de pupa (Mound & Marullo 1996). (FIGURA 2). A maioria das espécies completa seu ciclo de ovo a adulto em duas ou três semanas. A duração varia de acordo com o hospedeiro e com fatores abióticos como temperatura, umidade e fotoperíodo (Ananthakrishnan 1993, Whittaker & Kirk 2004).

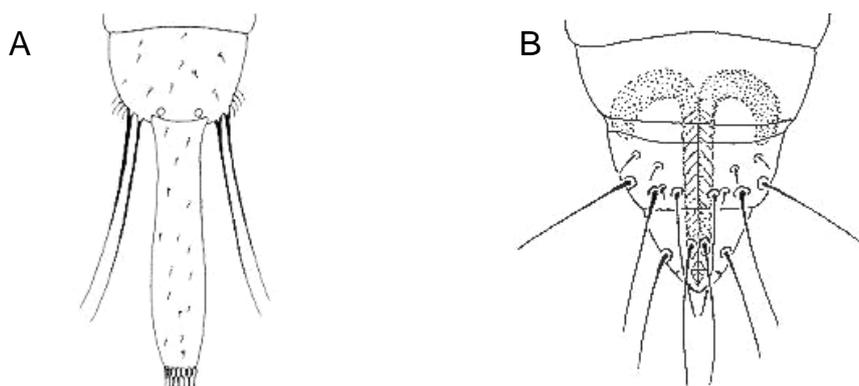


FIGURA 1. Diferenças morfológicas das duas subordens de tripses, evidenciadas pelo ovipositor que na (A) subordem Tubulifera o ovipositor tem a forma cônica e está presente nos últimos segmentos abdominais e na (B) subordem Terebrantia é serrado e localizado ventralmente (FIGURA: Frantz *et al.* (2010)).

As larvas das espécies que habitam flores empupam no solo enquanto que nas espécies que se alimentam de fungos, as pupas são encontradas em associação com adultos e larvas, o que pode ter sido importante para o desenvolvimento da socialidade em algumas espécies (Crespi *et al.* 1997). Crespi (1988) descreve o comportamento de *Hoplothrips karnyi* (Hood), uma espécie que se alimenta de fungos, onde o macho defende um território com massa de ovos e acasala com fêmeas que eventualmente aparecem para ovipor. As lutas com outros machos por território levam frequentemente a morte de um deles, sendo que os indivíduos menores são os mais injuriados após as lutas. Este comportamento de guarda envolve danos físicos devido às lutas e um custo energético substancial, que deve ser compensado por um aumento no valor adaptativo do indivíduo ao acasalar com mais fêmeas.

Adultos e larvas de ambas as subordens compartilham um único atributo estrutural: somente a mandíbula esquerda é desenvolvida, a direita é reabsorvida no estágio embrionário (Mound 2005). Apesar dos diversos hábitos alimentares, os estiletes dos tripses são marcadamente uniformes em estrutura. A mandíbula única é usada para criar um buraco no alimento, como em grãos de pólen ou células de folhas e flores. Os estiletes maxilares são pares e estão ligados para formar um canal alimentar único, que se insere na fonte alimentar. Assim, os conteúdos de cada célula da folha, flor ou grão de pólen são sugados (Mound & Marullo 1996) (FIGURA 3). Cerca de 700 espécies de tripses são conhecidas no Brasil, compreendendo 10% da fauna mundial (Monteiro 2002, Mound 2002b). Um terço destas espécies são agrupadas na subordem Terebrantia e dois terços na Tubulifera (Monteiro 2002).

No país, Thripidae (Terebrantia) e Phlaeothripidae (Tubulifera) são as famílias mais representativas, com 27% e 66,5%, respectivamente. As outras quatro famílias, Uzelothripidae (0,2%), Merothripidae (1,8%), Aelothripidae (1,5%) e Heterothripidae (3%)

são pouco conhecidas. Devido à ênfase que é dada à agricultura, os registros de tripses são mais extensos para espécies que são pragas associadas à plantações, como *Frankliniella* e *Thrips* (Nagata *et al.* 1999, Monteiro *et al.* 2001).

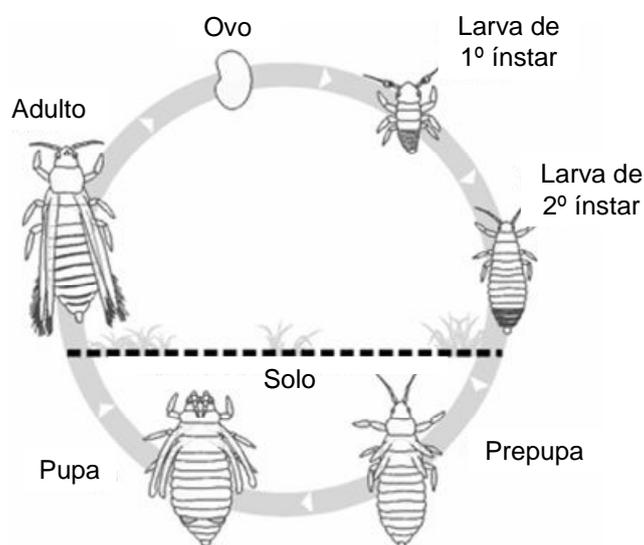


FIGURA 2. Esquema do ciclo de vida de tripses. As fases larvais são acompanhadas das fases de pupa que se enterram no solo para completar seu desenvolvimento ao estágio adulto. (FIGURA: Hoodle (2010)).

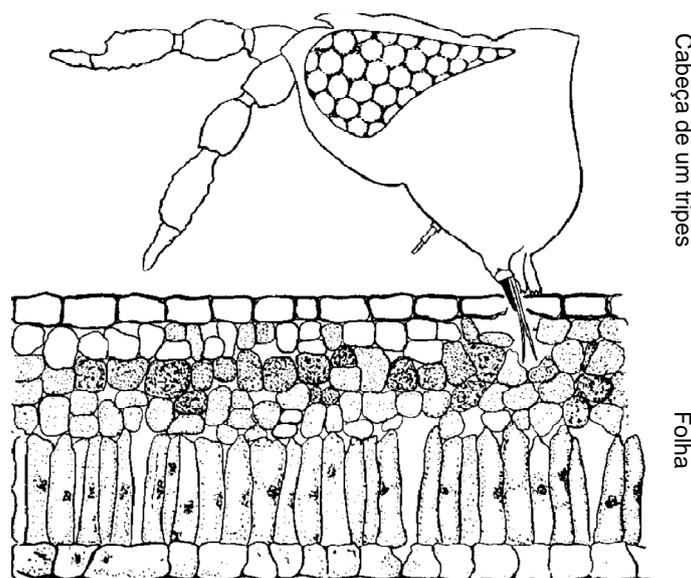


FIGURA 3. Diagrama da alimentação de tripses, onde a mandíbula perfura o tecido foliar para sugar seu conteúdo. (Figura: Costa Lima 1936).

1.2 MORFOLOGIA DE TRIPES

1.2.1 Morfologia externa – a cabeça é levemente quadrangular, de forma que um par de pequenos, porém proeminentes olhos compostos com largas facetas são vistos superiormente. Três ocelos estão presentes nas formas aladas e ausentes nas formas ápteras. As antenas possuem de seis a 10 segmentos e sua inserção ocupa uma posição frontal na cabeça. O corpo

possui cerdas que são taxonomicamente importantes. As partes bucais são adaptadas para perfurar e sugar o alimento. As asas são membranosas, estreitas, possuem franjas nas bordas e podem ou não ter venações. O abdômen é longo e composto por 11 segmentos (FIGURA 4). Os machos possuem um edeago eversível (Ross 1965, Richards & Davies 1988, Mound & Marullo 1996, Grimaldi & Engel 2005).

1.2.2 Anatomia interna – o sistema digestório é caracterizado por um mecanismo de bomba de sucção provida de músculos radiais, um longo esôfago, um extenso intestino e quatro túbulos de Malpighi. Dois ou três pares de glândulas salivares estão localizadas no tórax e abdome e seus ductos se unem para formar um canal comum que se abre em frente ao esôfago. O intestino médio forma a maior porção do tubo alimentar e é dividido em uma câmara anterior seguida de uma região posterior circular. O final do intestino forma uma passagem direta para o ânus e possui quatro papilas retais.

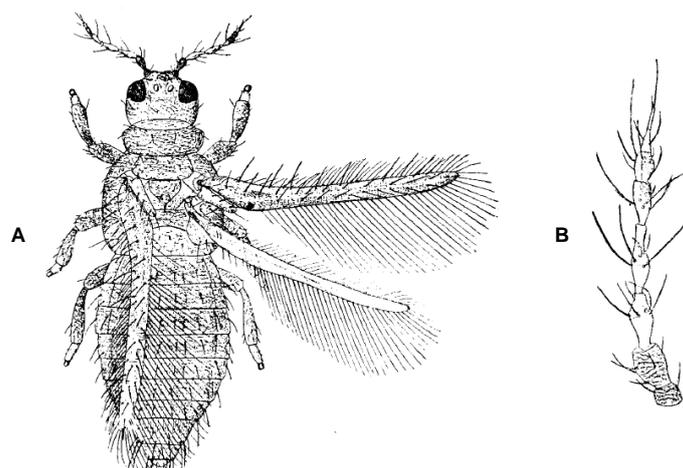


FIGURA 6. (A) Tripes adulto, as asas franjadas e a disposição das cerdas ao longo do corpo e das (B) antenas são usadas para a identificação das espécies. (Figura: Costa Lima 1936).

Quanto ao sistema nervoso, o cérebro é bem desenvolvido, o gânglio subesofageano e o protorácico são fundidos enquanto que os gânglios meso e metatorácicos são separados. O sistema circulatório consiste de uma pequena bomba contrátil no oitavo segmento abdominal. Nas fêmeas, os ovários contêm quatro pequenos ovariolos panoísticos, uma pequena espermateca pigmentada e uma glândula em forma de saco. Nos machos, um par de testículos fusiformes se comunicam ao vaso deferente e ao ducto ejaculatório. O sistema traqueal é bem desenvolvido e se abre ao exterior por meio de quatro pares de espiráculos, localizados no meso e metatórax e no primeiro e oitavo segmentos abdominais (Richards & Davies 1988).

1.3 INTERAÇÕES ECOLÓGICAS

A gama de plantas em que tripses podem ser encontrados é considerável. Inclui algumas briófitas, pteridófitas e gimnospermas, bem como as folhas e flores de muitas angiospermas, particularmente aquelas que ofereçam locais para abrigo, reprodução e permitam a manutenção do inseto (Mound & Terry 2001). Muitas espécies de tripses que vivem em flores se alimentam de pólen. Seria fácil pensar em tal associação como mera predação de tripses nas plantas, porém adultos podem ser observados freqüentemente carregando pólen em seus corpos e voando ativamente entre flores (Terry 2002). Não há dúvida de que tripses conduzem pólen entre plantas, mas a demonstração da significância destes pequenos insetos na polinização raramente tem sido estudada.

Apesar das queixas de Charles Darwin de que tripses interferiam em seus experimentos de polinização, sabe-se hoje que estes insetos podem atuar como polinizadores principais ou secundários de várias espécies de plantas (Mound 2005). Sakai (2001) estudando a evolução de sistemas de polinização demonstrou que tripses têm relações mutualísticas com *Castilla elastica* Sessé ex. Cerv., na qual a planta provê alimentação para o inseto e este promove polinização cruzada. Momose *et al.* (1998) também observaram que em, *Popowia pisocarpa* (Blume) somente pequenos insetos como tripses conseguiam entrar na câmara floral reduzida e promover polinização, assim como Mound & Terry (2001) demonstraram para *Macrozamia macdonnellii* (F. Muell. ex Miq.) F. Muell. ex A. DC. Similarmente, Hagerup & Hagerup (1953), Eisikowitch & Woodell (1975), Thien (1980), Bawa *et al.* (1985), Moog *et al.* (2002) entre outros, descrevem sistemas em que tripses são polinizadores. As adaptações de tripses como polinizadores envolvem aspectos tais como a disponibilidade de pólen ou néctar como fonte alimentar e um microclima dentro do tubo da corola no qual tripses podem se reproduzir (Ananthakrishnan 1993). Estas interações envolvem múltiplas recompensas: alimento, local protegido para atividades reprodutivas, substrato para oviposição; todos fornecidos por estruturas florais (Pellmyr & Thien 1986, Armstrong & Marsh 1997, Momose *et al.* 1998, Sakai 2001).

Esta característica mais nobre de tripses, entretanto, não os remove de seu status mais conhecido. Algumas espécies são reconhecidamente pragas em vários agroecossistemas economicamente importantes (Morse & Hoddle 2006, Dreistadt *et al.* 2007). No Brasil, *Frankliniella* juntamente com *Thrips*, são os gêneros de Thysanoptera que reúnem o maior número de espécies-praga, seja pelos danos diretos causados aos tecidos vegetais durante a alimentação e/ou pela transmissão de agentes fitopatogênicos, especialmente *Tospovirus*, que acarretam grandes perdas econômicas na agricultura (Nagata & Avila 1999). Os hábitos

alimentares das larvas são similares aos dos adultos, porém, somente as larvas adquirem o vírus se alimentando de plantas previamente infectadas (Mound & Marullo 1996). O vírus se desenvolve no inseto e este quando adulto, inocula o vírus nas plantas em que se alimenta, via saliva. A infecção de vírus nas plantas é ruim para os tripes, pois isso diminui a sobrevivência das larvas das gerações subsequentes e conseqüentemente afeta o *fitness* da população (Belliere *et al.* 2005).

Além de polinização e herbivoria, tripes exibem outras interações ecológicas como predação (Agrawal *et al.* 1999), características como mimetismo (Mound & Reynaud 2005) e formação de galhas (McLeish *et al.* 2007) (FIGURA 5). Os tripes que formam galhas são espécie-específicos (Mound & Marullo 1996) e preferem plantas com tecidos jovens, os quais são alterados celular e metabolicamente após a colonização, em tecidos com elementos nutritivos que servem de base alimentar, permitindo a uma população de tripes alcançar até 12 gerações por ano (Ananthkrishnan 1993).

Não há um consenso a respeito de quais mecanismos ou elementos são responsáveis pela atração de tripes para um hospedeiro específico. Mound (2005) afirma que tripes não são encontrados associados a flores de morfologia aberta que atraem abelhas e moscas, nem com aquelas com grandes quantidades de néctar, no entanto, Kirk (1997) relata que algumas espécies de tripes são encontradas somente em flores pequenas, brancas e com um forte odor, mesmo quando estão abertas. No Cerrado, tripes podem ser encontrados sob tipos variados de flores (dados não publicados.) que se encaixariam perfeitamente em ambas as proposições defendidas pelos autores acima. Considerando-se a literatura presente sobre tripes, convém considerar que estes insetos são atraídos pelo odor liberado de flores (Momose *et al.* 1998), mas também podem ocorrer fatores conjuntos de atração (Milne & Walter 2000, Sakai 2001), como acontece com alguns besouros (Gottsberger & Silberbauer-gottsberger 1991). Poucos autores fornecem listas com informações de tripes e suas plantas hospedeiras e possíveis interações com outros insetos que também possam utilizar a mesma planta. Del-Claro *et al.* (1997), estudando *Peixotoa tomentosa* A. Juss verificaram que a espécie de tripes presente, *Heterothrips peixotoa* Del-Claro, Marullo & Mound, 1997, provocava danos nas flores pela herbivoria. Porém estes tripes conseguiam escapar de predadores se escondendo nas câmaras formadas entre a pétala e a sépala destas flores. Apesar desta interação não ser benéfica para a planta, os tripes obtém alimento, local protegido para atividades reprodutivas e substrato para oviposição, todos fornecidos pelas estruturas florais (Pellmyr & Thien 1986, Armstrong & Marsh 1997).



FIGURA 5. Diversidade de interações e comportamento de tripses. (A) Indivíduo de *Frankliniothrips vespiformis* (DL Crawford, 1909) adulto que mimetiza formigas; (B) larva de *F. vespiformis* se alimentando de outro tripses; (C) Cicadófito polinizada por tripses na Austrália; (D) larva de *Aulacothrips dictyotus* Hood fixada na porção ventral do membracídeo *Enchenopa brasiliensis* Strümpel, realizando ectoparasitismo; (E) Dano foliar provocado em *Morinda citrifolia* L. (Rubiaceae) pela espécie de tripses *Heliothrips haemorrhoidalis* (Bouché, 1833); (F) Folha de amendoim (*Arachis hypogaea* L. (Fabaceae)) apresentando anéis concêntricos causados por vírus (*Tomato spotted wilt virus* (TSWV)) transmitidos por tripses. (FIGURAS A e B: www.entocare.nl/nl/eigen%20producten/predatrip.htm; C: www.bugwise.net.au/invertebrates/pollination; D: Estevão Alves da Silva; E: www.ctahr.hawaii.edu/noni/thrips.asp. F: www.lookfordiagnosis.com/mesh_info.php?term=Tospovirus&lang=3).

Além de ser o primeiro estudo que abordava ecologia de interações de tripses no Cerrado, este estudo também teve o mérito de descrever uma nova espécie de tripses. Pouco tempo depois, um novo gênero de tripses, *Nexothrips*, espécie *N. delclaroi*, foi encontrado em flores de *Hortia* sp., também no Cerrado (Marullo & Mound 2000). Mais recentemente, uma interessante e notável interação ecológica foi registrada no cerrado. Indivíduos imaturos da espécie de tripses *Aulacothrips dictyotus* Hood foram registrados como sendo ectoparasitas de *Enchenopa brasiliensis* Strümpel (Membracidae) enquanto que os tripses adultos utilizavam os membracídeos para forese (Alves-Silva & Del-Claro dados não publicados). Das mais de 6000 espécies de tripses conhecidas, somente *A. dictyotus* apresenta hábito ectoparasítico enquanto que as outras espécies são em sua maioria fitófagas ou fungívoras (Mound & Morris 2007). Exceto por estes trabalhos, para o Cerrado existem poucas informações sobre tripses,

suas plantas hospedeiras, interações ecológicas com outros insetos e caracterização das populações destes insetos ao longo do ano.

Talvez o estudo mais extenso e conclusivo já realizado com populações de tripes seja o de Davidson & Andrewartha (1948). Estes autores analisaram a variação na população de *Thrips imaginis* Bagnall durante seis anos em rosas na Austrália e concluíram que apesar de a espécie de tripes ser ativa durante todo o ano, as maiores densidades ocorrem durante a primavera e o verão, no período de floração das rosas, suas plantas hospedeiras. Entretanto, atualmente também são considerados que fatores dependentes da densidade influenciam as populações de tripes (Mound 2005). Os estudos atuais, longe de abrangerem um período tão extenso, buscam principalmente descrever espécies associadas à agricultura ou ligadas ao controle biológico (Deligeorgidis *et al.* 2005).

No Brasil, o estudo mais amplo abordando tripes, suas plantas hospedeiras e a ocupação de diferentes microhabitats foi realizado por Pinent *et al.* (2006). Em um inventário conduzido no sul do Brasil, estes pesquisadores amostraram 73 espécies de tripes, pertencentes a quatro famílias (Merothripidae, Heterothripidae, Thripidae e Phlaeothripidae), na qual *Frankliniella* foi o gênero mais representativo. Este trabalho abrangeu não somente as flores, mas também ramos e serapilheira, denotando uma grande ocupação de tripes nestes locais. A diversidade encontrada, no entanto, é pouco representativa para a thysanopteroфаuna do Brasil como um todo, devido a falta de amostragens em áreas extensas do país, dada a diversidade de nossa flora e ecossistemas (Monteiro 2002). Deste modo, nosso conhecimento sobre tripes e suas plantas hospedeiras é largamente subestimado.

São boas as perspectivas para o estudo de tripes no Brasil e no mundo. Hoje existem diversas técnicas disponíveis para a identificação (Moritz *et al.* 2000, Mound & Morris 2007) e criação de tripes em laboratório (Murai & Loomans 2001), apesar de haver poucos taxonomistas e ecólogos. No Brasil, particularmente no Cerrado, estudos têm sido conduzidos desde 1996 pelo Dr. Kleber Del Claro a fim de se identificar tripes e suas plantas hospedeiras, com um enfoque mais ecológico. Contando desde então com o apoio do Dr. Laurence Mound (Csiro, Austrália), duas novas espécies de tripes já foram encontradas (Del-Claro *et al.* 1997, Marullo & Mound 2000) e devido a alta diversidade florística do Cerrado (Furley 1999), é bem provável que novas espécies venham a ser descobertas.

As expectativas para os próximos anos prevêm a caracterização das populações de tripes presentes nas espécies vegetais mais abundantes no Cerrado buscando identificar padrões sazonais de sua ocorrência. Isto permitirá o estabelecimento de uma linha de pesquisa firme e duradoura em thysanopterologia em uma fração de um dos mais importantes biomas do país

(Furley & Ratter 1988). A dimensão destes nossos estudos pretende abordar aspectos da biodiversidade, ecologia e comportamento de tripses.

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2 MALPIGHIACEAE (MALPIGHIALES)

2.1 Características gerais

A família Malpighiaceae apresenta aproximadamente 60 gêneros e 1.200 espécies de árvores, arbustos e lianas, distribuídas pelas regiões tropicais e subtropicais, especialmente no continente americano, onde ocorrem 44 gêneros e 800 espécies (Vicentini & Anderson 1999, Joly 2002). O Brasil é representado por 32 gêneros, com cerca de 300 espécies, distribuídas nas diversas regiões do país (Barroso *et al.* 1991). É uma das famílias mais importantes no Cerrado em termo de diversidade (Furley 1999) contabilizando aproximadamente 62 espécies, em sua maioria pertencentes aos gêneros *Banisteriopsis* e *Byrsonima* (Castro *et al.* 1999).

A morfologia das flores de Malpighiaceae é bastante homogênea. A corola possui cinco pétalas livres, alternadas com as sépalas, e um androceu com 10 estames envolvendo um ovário súpero tricarpelar (Anderson 1979, Joly 2002, Souto & Oliveira 2008). As flores possuem também uma pétala modificada que atua na atração e orientação de polinizadores, chamada de pétala estandarte ou guia (FIGURA 1A), que se distingue das demais pelo tamanho menor e pela maior espessura da unha (Costa *et al.* 2006). As inflorescências são paniculadas e surgem nas axilas superiores ou terminais. Seus frutos possuem extrema diversidade, apresentando-se indeiscentes, secos e carnosos, e frutos secos deiscentes, que podem ser alados ou não, glabros ou pilosos (Taylor & Crepet 1987, Vicentini & Anderson 1999). Algumas Malpighiaceae possuem sâmaras (FIGURA 1B) que podem ser utilizadas para taxonomia quando não se conhece a espécie de origem (Mirle & Burnham 1999). As flores possuem cinco sépalas com um par de glândulas de óleo (elaióforos) (FIGURA 1C). Às vezes, os elaióforos aparecem sobre quatro sépalas, ficando a quinta sépala desprovida da glândula (Barroso *et al.* 1991). Os elaióforos são importantes no mecanismo de polinização e algumas espécies de Orchidaceae são consideradas miméticas das Malpighiaceae, pois possuem estruturas similares, envolvidas também na polinização (Stpiczynska *et al.* 2007). Os indivíduos são perenes com folhas inteiras de disposição alterna. Nas folhas o indumento é constituído de pêlos simples, unicelulares, implantados em elevações da epiderme e providos de pé e de uma porção horizontal, agudos nas extremidades, denominados de pêlos malpighiáceos. O comprimento do pé pode ser reduzido ou muito longo e apresentar ramificações (Barroso *et al.* 1991).

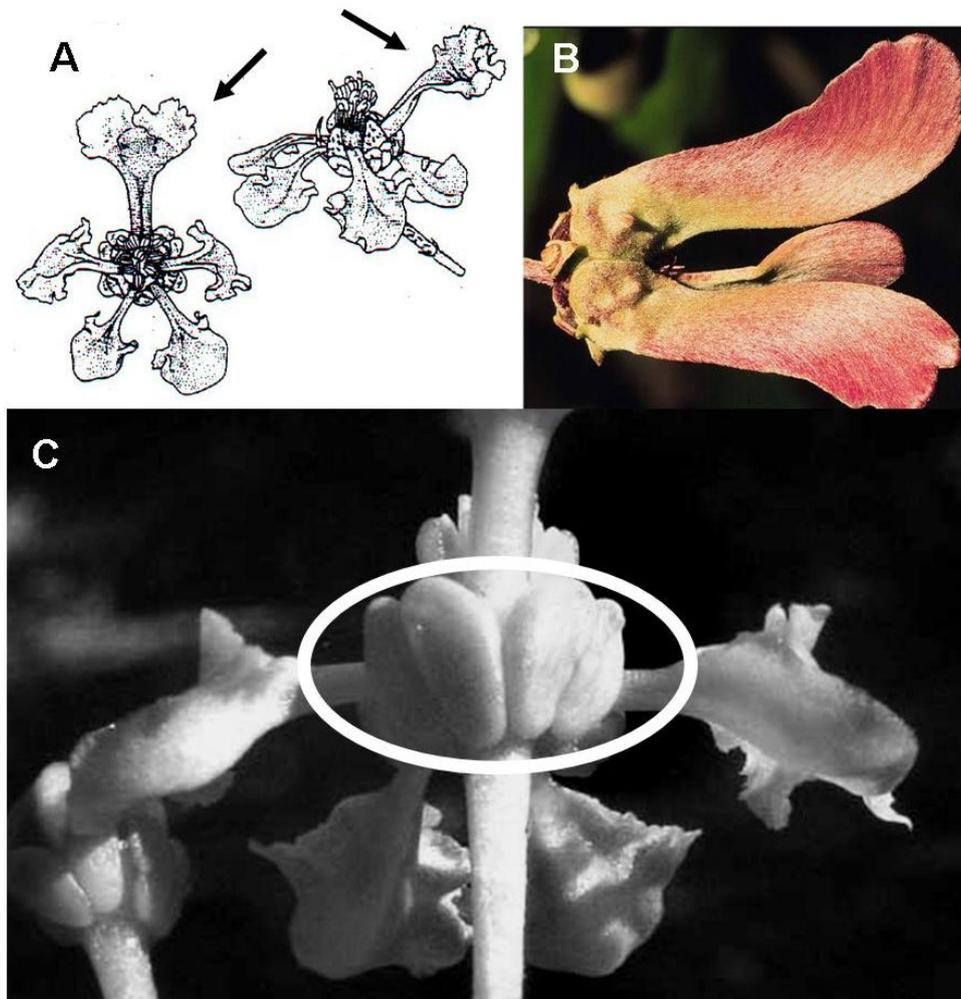


FIGURA 1 (A) flor típica de Malpighiaceae evidenciando suas cinco pétalas, uma delas sendo mais longa, a pétala estandarte; (B) fruto do tipo sâmara; (C) glândulas de óleo (Figura A: Farmer (2010); B: Spjut (2010); C: Conrad (2010).

2.2 Espécies abordadas no estudo

Foram investigadas as espécies de Malpighiaceae mais abundantes na área de estudo: *Banisteriopsis malifolia* (Nees & Mart.) B. Gates, *B. campestris* (A. Juss.) Little, *B. laevifolia* (A. Juss.) B. Gates, *Peixotoa tomentosa* A. Juss e *Byrsonima intermedia* A. Juss.

Os três gêneros, *Byrsonima*, *Banisteriopsis* e *Peixotoa*, e suas respectivas espécies, são reconhecidas pelos seguintes caracteres:

Byrsonima é um arbusto ereto, com inflorescências simples e constituída de racemos. Possui brácteas e bractéolas não foliáceas e pêlos malpighiáceos com a parte superior horizontal e furcada. Seus frutos têm a forma de drupas. A consistência das folhas é levemente coriácea e pilosa e possuem células com cristais de oxalato de cálcio, sob a forma de cristais isolados, geminados ou em drusas (Barroso *et al.* 1991).

Byrsonima intermedia A. Juss. é um arbusto que possui muitos ramos com subdivisões. A folha é coriácea, com coloração verde escuro, de margem lisa e glabra, peciolada e sem nectários extraflorais. Seus ramos apresentam pequenas flores amarelas com simetria bilateral reunidas em racemos terminais. A flor é hermafrodita (completa) com corola dialipétala, composta por cinco pétalas unguiculadas e franjadas, sendo a pétala estandarte mais elevada que as outras. As cinco sépalas apresentam um par de elaióforos (cada uma) na face abaxial, totalizando 10 glândulas de óleo. Os frutos são do tipo drupa. O androceu apresenta 10 estames concêntricos, com deiscência longitudinal nas anteras. O gineceu é tricarpelar, com os estiletos separados e as superfícies estigmáticas puntiformes localizadas internamente no anel de anteras.

Banisteriopsis e *Peixotoa* são arbustos com inflorescências compostas. Em *Banisteriopsis* as flores contêm 10 estames férteis, desiguais entre si. Os estiletos possuem papilas estigmáticas localizadas na porção terminal. O samarídeo tem uma porção convexa, mais espessada e nerviforme, voltada para o centro do fruto (lado interno), com inserção do samarídeo basal (Barroso *et al.* 1991).

Banisteriopsis malifolia (Ness & Martius) B. Gates é um arbusto que possui muitos ramos com subdivisões. As folhas são coriáceas, com coloração verde escuro nas folhas adultas e verde muito claro nas folhas jovens, a margem é lisa e há pilosidade nas duas faces, com um par de nectários extraflorais margeando a base da nervura principal. A flor é hermafrodita (completa) de simetria bilateral, possui cinco sépalas, com oito ou 10 elaióforos. A corola é dialipétala, composta por cinco pétalas rosadas, unguiculadas e franjadas, sendo a pétala estandarte mais elevada que as outras. O androceu apresenta cinco estames concêntricos, com estiletos separados e as superfícies estigmáticas localizadas internamente no anel de anteras. Os frutos são tipo sâmara, com um, dois, três ou raramente quatro unidades de dispersão por fruto (Torezan-Silingardi 2006).

Banisteriopsis laevifolia (A. Juss.) B. Gates é um arbusto com ramos pouco divididos. Suas folhas são coriáceas, com coloração verde escuro, com margem lisa e pilosidade na face inferior. A flor é hermafrodita (completa) de simetria bilateral, possui cinco sépalas com oito elaióforos. A corola é dialipétala, composta por cinco pétalas amarelas, unguiculadas e franjadas, sendo a pétala estandarte mais elevada que as outras. O androceu apresenta 10 estames e as anteras amarelas circundam o gineceu, que é tricarpelar, com os estiletos separados e as superfícies estigmáticas puntiformes localizadas internamente no anel de anteras. Os frutos são do tipo sâmara, com um, dois, três ou raramente quatro unidades de dispersão por fruto (Torezan-Silingardi 2006).

Banisteriopsis campestris (A. Juss.) Little é um arbusto cujos ramos apresentam poucas subdivisões. As folhas são verde claro, membranosas, com a nervura bem marcada e a margem lisa, há pilosidade nas faces abaxial e adaxial, possuem um par de nectários extraflorais na base da nervura principal. A flor é hermafrodita (completa), de simetria bilateral, rosada, possui cinco sépalas com oito elaióforos. A corola é dialipétala, composta por cinco pétalas unguiculadas e franjadas, sendo a pétala estandarte mais elevada que as outras. O androceu apresenta oito estames concêntricos, amarelos. O gineceu é tricarpelar, com os estiletos separados e as superfícies estigmáticas discóides localizadas internamente no anel de anteras. Os frutos são tipo sâmara, com um, dois, três ou raramente quatro unidades de dispersão por fruto (Torezan-Silingardi 2006, Souto & Oliveira 2008).

No gênero *Peixotoa* o androceu é constituído de cinco estames e cinco estaminódios com ápice claviforme ou piriforme. As estípulas interpeciolares são cordiformes, bem desenvolvidas, de dois ou mais centímetros de largura e concrecidas entre si. Suas umbelas possuem quatro flores, providas na base de duas bractéolas foliáceas ovais ou cordiformes. O ovário contém três estiletos. A forma de cristalização do oxalato de cálcio nas folhas tem importância sistemática e os cristais geminados caracterizam as espécies de *Peixotoa* (Barroso *et al.* 1991, Torezan-Silingardi 2006).

Peixotoa tomentosa A. Juss. é uma planta do estrato arbustivo da vegetação de cerrado. Apresenta, geralmente, um ou dois ramos que podem chegar a três metros de altura, tem poucas folhas e possui nectários extraflorais pares na face inferior da base das folhas (Del-Claro *et al.* 1997), que também possuem pêlos malpighiáceos nas faces adaxial e abaxial. Suas flores são amarelas e possuem oito glândulas de óleo funcionais distribuídas aos pares, na base de quatro sépalas. As pétalas são unguiculadas e fimbriadas. A pétala estandarte é mais elevada que as outras. Há cinco estames funcionais com formato típico e coloração amarela opaca, além de cinco estaminódios globosos de coloração amarela brilhante. Estames e estaminódios ficam na mesma altura em relação à flor. Há geralmente três estiletos, cada qual com seu estigma puntiforme. Cada flor pode produzir até três sementes aladas (raramente quatro) do tipo sâmara (Torezan-Silingardi 2006).

2.3 Estudos em ecologia com Malpighiaceae

Estudos em ecologia de Malpighiaceae no Brasil, particularmente no cerrado, são bastante raros. No entanto, por ser uma das famílias mais importantes do cerrado em termo de número de espécies (Furley 1999), as Malpighiaceae são encontradas com frequência em levantamentos fitosociológicos.

Castro *et al.* (1999) em uma revisão sobre a riqueza florística do cerrado, fornecem uma lista com as principais espécies botânicas encontradas neste bioma. Quanto às Malpighiaceae, das 61 espécies desta família abordadas, os gêneros mais representativos são *Byrsonima*, com 31 espécies e *Banisteriopsis*, com 13 espécies encontradas. *Banisteriopsis campestris*, *B. laevifolia*, *B. malifolia* e *Byrsonima intermedia* foram amostradas enquanto que *Peixotoa tomentosa* não foi listada neste inventário. No entanto, os próprios autores admitem um erro na estimativa de riqueza de espécies, visto que os estudos revisados não abrangem toda a área geográfica do cerrado. Este padrão de maior riqueza de *Byrsonima* também foi evidenciado no levantamento feito por Saporetti Jr *et al.* (2003) em uma área de cerrado no centro-oeste de Minas Gerais. Das quatro espécies amostradas, três pertenciam ao gênero *Byrsonima*, sendo que *B. intermedia* foi uma das plantas mais abundantes na área, quando comparada a todas as outras espécies botânicas amostradas. *Byrsonima* também foi representado no levantamento realizado por Campos *et al.* (2006) em um gradiente de cerradão e cerrado, perfazendo duas das três espécies de Malpighiaceae encontradas.

Na revisão de Castro *et al.* (1999) o gênero *Heteropterys* aparece com oito espécies ocorrendo no cerrado. Schmidt *et al.* (2005) estudando efeitos do fogo sobre uma população de *Heteropterys pteropetala* (Adr. Juss.), verificaram que queimadas prolongadas podem afetar a viabilidade e a germinação da espécie, porém os diásporos podem resistir às queimadas caso estejam enterrados no solo. Ainda, queimadas precoces (junho) prejudicam o recrutamento e crescimento dos indivíduos, além de influenciar a distribuição espacial da população. *Byrsonima* também é o gênero mais estudado com relação a interações inseto-planta, muito provavelmente devido a sua grande ocorrência e abundância no cerrado (Saporetti Jr. *et al.* 2003, Campos *et al.* 2006).

Estudando os efeitos de formigas do gênero *Camponotus* na comunidade de insetos em inflorescências de *Byrsonima crassifolia* (L.) Kunth, Fernandes *et al.* (2005), constataram que inflorescências em ramos onde formigas estavam presentes foram significativamente menos atacadas por insetos mastigadores e sugadores do que inflorescências em ramos com formigas excluídas. Estes resultados sugerem então que a presença de formigas influencia a estrutura da comunidade de insetos herbívoros associados com *B. crassifolia*.

Em outro estudo com formigas, Leal & Oliveira (1998), observaram que indivíduos da tribo Attini utilizavam os frutos de *Byrsonima intermedia* para criar fungos e deste modo serviam de agentes dispersores secundários, já que as sementes de *B. intermedia* são dispersas primariamente por aves que se alimentam das drupas. Estes autores sugerem que as formigas

se alimentam da polpa dos frutos reduzindo a infestação por fungos e aumentando a taxa de germinação das sementes.

Galhas também fazem uso de *Byrsonima intermedia* e também ocorrem em outras três espécies de Malpighiaceae (*Banisteropsis pubipetala*, *B. pubipetala* e *Heteropterys byrsonimifolia*) em uma reserva de cerrado no estado de São Paulo (Urso-Guimarães & Scareli-Santos 2006). Para *Byrsonima sericea* DC., presentes em restingas, Flinte *et al.* (2006), constataram que os meses de outubro e dezembro eram os que apresentavam as maiores frequências de plantas atacadas pelos galhadores, tanto Diptera quanto Lepidoptera.

Outros estudos com Malpighiaceae dizem respeito à biologia reprodutiva (Sigrist & Sazima 2004, Costa *et al.* 2006) e polinização por abelhas da tribo Centridini (Ramalho & Silva 2002). Rego *et al.* (2006) fornecem uma lista com nove malpighiaceas em diferentes ecossistemas que são visitadas por abelhas da espécie *Centris flavifrons* (Friese), (*Byrsonima crassifolia* (L.) Kunth, *Byrsonima sericea* A.DC., *Byrsonima amoena* Cuatrec., *Byrsonima intermedia* A. Juss., *Byrsonima coccolobifolia* Kunth, *Mcvaughia bahiana* W.R. Anderson, *Banisteriopsis* sp. *Malpighia glabra* L. e *Malpighia puniceifolia* L.) e adiciona a espécie *Tetrapterys* sp. à lista prévia.

Além de polinizadores, as malpighiáceas suportam uma grande gama de insetos fitófagos. Flinte *et al.* (2006) encontraram um total de 45 espécies de insetos associados à *Byrsonima sericea* DC., sendo 20 de lepidópteros exofíticos, 17 de coleópteros exofíticos, quatro de minadores e quatro de galhadores. Já Del-Claro *et al.* (1997) constataram que tripses eram o principais herbívoros das estruturas reprodutivas de *Peixotoa tomentosa*. O pequeno tamanho dos tripses permitia que estes insetos se escondessem abaixo das sépalas, nas câmaras florais, onde formigas predadoras de tamanho grande não conseguiam entrar.

Percebe-se com estes estudos citados acima que Malpighiaceae possui uma grande diversidade quanto à entomofauna associada e dada sua grande abrangência, representatividade e significância no cerrado (Furley 1999), esta família botânica tem recebido pouca atenção quanto às interações ecológicas.

Segundo Flinte *et al.* (2006) a escolha de plantas representativas, com ampla distribuição geográfica, como Malpighiaceae, é promissora para o estudo comparativo da entomofauna associada, uma vez que fornece subsídios para definir padrões temporais e avaliar a importância de fatores ambientais sobre a comunidade de insetos fitófagos.

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A IMPORTÂNCIA DA FLORAÇÃO SEQUENCIAL DE MALPIGHIACEAE PARA A MANUTENÇÃO DE TRIPES (THYSANOPTERA) NO CERRADO

1 INTRODUÇÃO

Tripes são insetos onipresentes, em sua maioria fitófagos, micófagos ou predadores, (Mound 2002a, Mound & Morris 2007). Muitas espécies são abundantes em estruturas de vários táxons, principalmente flores de angiospermas (Mound & Terry 2001, Mound 2005) e os padrões de abundância e ocorrência em muitas plantas são fatores importantes que determinam a dinâmica de populações de tripes (Ananthkrishnan 1993, Morse & Hoddle 2006). No entanto estas relações são raramente consideradas. A maioria dos registros relativos a populações de tripes compreende estudos de curta duração em culturas economicamente importantes (Childers & Bullock 1999, Dreistadt *et al.* 2007) e com poucas exceções (Cho *et al.* 2000, Pearsal & Myers 2001, Seal *et al.* 2006) os pesquisadores não levam em consideração o número de espécies envolvidas, a partição de recursos, ou mesmo a diversidade entre os habitats.

Geralmente a abundância e diversidade de tripes estão ligadas a características estruturais do meio ambiente que ocorrem em uma escala específica (Pinent *et al.* 2006) refletindo importantes requisitos no habitat como disponibilidade de espaço, fuga de predadores, eficiência no forrageamento e facilidades reprodutivas (Strauss & Karban 1994, Del-Claro, 1998, Mound & Terry 2001, Carvalho *et al.* 2006). As plantas que oferecem estes benefícios são definidas por Mound & Marullo (1996) como plantas hospedeiras eficazes ou verdadeiras de tripes (Mound & Marullo 1996). Como a fenologia das plantas muda no decorrer do ano dependendo das variações sazonais (Gill *et al.* 1998), os tripes, assim como outros insetos, devem procurar por microhabitats favoráveis, migrando entre hospedeiros ao longo do ano (Barbosa 1988, Mound & Marullo 1996).

Milne & Walter (2000) deram uma abordagem diferente à classificação de plantas hospedeiras de tripes, estabelecendo os termos “hospedeiros primários” e “secundários”, levando em consideração como um habitat seria bom em sustentar populações de tripes. A necessidade para esta caracterização recai no fato de que em alguns casos tripes alternam entre hospedeiros somente para conseguir alimento e outros recursos que permitam a eles sobreviverem, mas não se reproduzir; ou tripes adultos podem se acumular em massa em hospedeiros secundários ou temporários, mas em quantidades menores se comparados aos hospedeiros principais. Assim sendo, as espécies de tripes podem se reproduzir e atingir picos de abundância somente em seus hospedeiros primários, e quando estes não estão disponíveis,

tripes sobrevivem com poucos indivíduos em hospedeiros secundários. Deste modo, a alternância entre hospedeiros parece ter uma forte influência no valor adaptativo de tripes (Barbosa 1988, Ananthakrishnan 1993). Ainda, a presença ou qualidade de estruturas específicas presentes nos hospedeiros primários podem determinar a abundância de espécies e a diversidade de tripes (Pinent *et al.* 2005, Cavalleri *et al.* 2006).

Cerca de 6000 espécies de tripes são conhecidas mundialmente e o Brasil é representado por 700 espécies (Mound 2002b, Mound & Morris 2007). Apesar de existirem algumas pesquisas realizadas com tripes no Brasil, a maioria restringe estes insetos a pragas e vetores de viroses na agricultura (Monteiro *et al.* 1998, Nagata *et al.* 1999). Considerando o Cerrado brasileiro como um importante bioma do Brasil (Furley & Ratter, 1988, Oliveira & Marquis 2002), é surpreendente o fato de que pouco é conhecido a respeito dos tripes associados a plantas de comum ocorrência neste bioma. Até agora grandes densidades de tripes foram encontradas provocando danos nas flores de *Peixotoa tomentosa* A. Juss., (Malpighiaceae) (Del-Claro *et al.* 1997). Esta família botânica exhibe uma morfologia floral bastante conservativa e partilha a mesma guilda de polinizadores (Anderson 1979). Observações posteriores sugeriram que uma comunidade de Malpighiaceae no cerrado apresentava floração seqüencial e abrigava uma grande comunidade de tripes (Torezan-Silingardi, 2006).

A avaliação da densidade de tripes ao longo do ano em plantas de floração seqüencial pode fornecer informações sobre a importância de cada hospedeiro em sustentar populações de tripes. Nos neotrópicos, casos de floração seqüencial foram extensivamente estudados para Bromeliaceae (Araujo *et al.* 1994, Varassin & Sazima 2000, Siqueira Filho & Machado 2001, Machado & Semir 2006, Marques & Lemos Filho 2008). Todos estes autores concordam que a floração seqüencial das bromeliáceas pode ser de extrema importância para a manutenção de polinizadores em uma determinada área. Machado & Semir (2006) relataram floração seqüencial em 14 bromeliáceas na Mata Atlântica no Brasil. No nível de comunidade, certas espécies de plantas podem facilitar a polinização de outras espécies. A facilitação ocorre quando espécies que florescem primeiro sustentam polinizadores que posteriormente visitam as espécies que florescem tardiamente (“mutualismo seqüencial” Waser & Real 1979, Brody 1997), assim é esperado que a comunidade dependente de recursos florais acompanhe os ciclos de floração (Appanah 1985). Considerando-se que muitas espécies de tripes neotropicais não sofrem diapausa devido às altas temperaturas nesta região e são ativos durante o ano todo (Van Houten *et al.* 1995, Murai 2000) podemos assumir que as malpighiáceas com floração seqüencial têm um papel significativo em fornecer microhabitats para tripes em diferentes estações.

Para se entender a função ecológica de cada planta na ecologia de um inseto herbívoro, dois principais critérios precisam ser quantificados: a regularidade temporal em que os indivíduos em diferentes estágios de desenvolvimento são encontrados na planta; e sua abundância em uma planta particularmente a outras (Walter & Benfield 1994, Milne & Walter 2000). Sugere-se que a escolha de plantas representativas, com grande abrangência geográfica, como as malpighiáceas, é promissora para o estudo comparativo da thysanopterofauna associada, uma vez que pode fornecer informações que auxiliem na definição de padrões temporais de ocorrência e permitam examinar a importância de fatores ambientais na comunidade destes insetos (Flinte *et al.* 2006).

Neste estudo nós testamos a hipótese de que a floração sequencial das malpighiáceas é responsável pela manutenção de tripes ao longo do ano, assumindo a premissa de que tripes migram entre diferentes plantas de acordo com a fenologia de floração. Além disso, também procuramos 1) identificar as espécies de tripes presentes em Malpighiaceae; 2) classificar as diferentes plantas como hospedeiros principais ou secundários; 3) buscar relações entre a densidade de tripes e o tamanho das flores e ainda 4) buscamos verificar se as variações sazonais tiveram influência na abundância e diversidade de tripes.

2 CONCLUSÃO

Neste estudo nós amostramos 19 espécies de tripes das quais as mais importantes foram *Frankliniella condei*, *Heterothrips peixotoa* e *Scutothrips nudus* e mostramos que a floração sequencial das malpighiáceas tem um importante papel na manutenção da comunidade de tripes ao longo do ano, principalmente para *Heterothrips peixotoa*, a espécie de tripes mais abundante em todas as amostragens que tem por hospedeiros principais *Peixotoa tomentosa* e *Banisteriopsis laevifolia*. A riqueza e diversidade de Thysanoptera em Malpighiaceae são as maiores já registradas para tripes em um grupo de plantas relacionadas taxonomicamente, possivelmente devido ao aspecto conservativo das malpighiáceas que podem fornecer alimento e proteção contra predadores. Flores maiores abrigavam uma quantidade maior de tripes e a fenologia das plantas foi tão importante quanto o clima na manutenção destes insetos nas malpighiáceas. Estudos futuros prevêem o exame dos danos ou benefícios provenientes da ocupação dos hospedeiros por tripes como também a análise da ocorrência destes insetos em outras plantas comuns no cerrado.

3 INTRODUCTION

Thrips are ubiquitous insects, mainly phytophagous, mycophagous or predatory in habit (Mound 2002a, Mound & Morris 2007). Many species are abundant in structures of a wide range of plant taxa, mostly in flowers of Angiosperms (Mound & Terry 2001, Mound 2005) and the patterns of abundance and occurrence in several plants are important factors that determine the population dynamics of thrips (Ananthkrishnan 1993, Morse & Hoddle 2006). However these relationships are rarely considered. Massive records comprise short period studies of thrips populations in economical important crops (Childers & Bullock 1999, Dreistadt *et al.* 2007) and with a few exceptions (Cho *et al.* 2000, Pearsall & Myers 2001, Seal *et al.* 2006) researchers often do not take into account the number of species involved, the portioning of resources and thrips intra and inter habitat diversity.

Generally, species abundance and diversity of thrips are linked to structural characteristics of environment that occur on a specific scale (Pinent *et al.* 2006) reflecting important habitat requirements such as space availability, escape from predation, foraging efficiency and reproductive needs (for examples see Strauss & Karban 1994, Del-Claro 1998, Terry 2001, Carvalho *et al.* 2006). The plants which offer these benefits are defined by Mound & Marullo (1996) as effective thrips host plants. As plant phenology changes along the year depending on habitat seasonal variations (Gill *et al.* 1998), thrips, just like other insects, will search for more favorable microhabitats, moving between hosts throughout the year (Barbosa 1988).

Milne & Walter (2000) gave a different approach to the classification of thrips host plants, establishing the terms “major” and “minor” hosts, taking into account how good the habitat might be in supporting thrips populations. The need for this characterization relies in the fact that in some cases thrips alternate the hosts only in order to get food and other resources that allow them to survive, but not to reproduce; or adult thrips can accumulate in mass in secondary or temporary hosts (minor hosts), but in smaller densities when compared to the major ones. So thrips species can reproduce and reach a peak of abundance only in its major hosts, while surviving with a few individuals in minor hosts, when the major ones are not available in time and space. Therefore, the alternation of hosts seems to have a strong influence in thrips fitness (Barbosa 1988, Ananthkrishnan 1993). In addition, the presence or quality of major host specific structures may determine species abundance and in some cases the richness and diversity of thrips species (Pinent *et al.* 2005, Cavalleri *et al.* 2006).

About 6000 species of thrips are known worldwide and Brazil is represented by 700 species (Mound 2002b, Mound & Morris 2007). Although some research has been carried out with thrips in Brazil, the majority restrict these insects as agricultural pests and crop virus

vectors (Monteiro *et al.* 1998, Nagata *et al.* 1999). Considering the Brazilian Savanna (Cerrado) an important biome from Brazil (Furley & Ratter 1988, Oliveira & Marquis 2002), it is surprising that little is known about the thrips associated with the plants of common occurrence in this biome. So far, great densities of thrips were found damaging flowers of *Peixotoa tomentosa* A. Juss., an oil-rewarding Malpighiaceae (Del-Claro *et al.* 1997). This botanical family exhibits highly conservative floral morphology and shares the same guild of pollinators (Anderson 1979). Previous observations and evidence suggested that Malpighiaceae community in an area of Cerrado presented sequential flowering and supported a whole thrips assemblage (Torezan-Silingardi 2006).

The evaluation of the abundance in thrips community along the year in sequential flowering plant species can provide information about the importance of each host in supporting thrips populations. In neotropics cases of sequential flowering were extensively studied for Bromeliaceae (Araujo *et al.* 1994, Varassin & Sazima 2000, Siqueira Filho & Machado 2001, Machado & Semir 2006, Marques & Lemos Filho 2008). All these authors agree that Bromeliaceae sequential flowering may be of extreme importance for the maintenance of pollinators in a given area. Machado & Semir (2006) reported sequential flowering in 14 Bromeliaceae at Atlantic Rain Forest in Brazil. At the community level, plant species may facilitate one another's pollination. Facilitation occurs when early-flowering species support pollinators that then visit later-flowering species ("sequential mutualism" *sensu* Waser & Real 1979, Brody 1997) so the animal community dependent on flower resources can be expected to follow the cycles of flowering (Appanah 1985). Given that many Neotropical thrips are not supposed to overwinter due the high temperatures (see Van Houten *et al.* 1995, Murai 2000) and are active throughout the year we may assume that sequential flowering Malpighiaceae play a significant role to provide thrips microhabitats in different seasons.

To understand the role of each plant species in the ecology of an herbivore insect, two principal criteria need to be quantified: the regularity with which individuals of the different life stages are found on a plant species over time, and their abundance on that particular plant species relative to other plant species (Walter & Benfield 1994, Milne & Walter 2000). It is suggested that the choice of representative plants, with wide geographical distribution, like some Malpighiaceae, is promising for the comparative study of the associated thysanopterofauna, once it can supply subsidies to define temporary patterns and to evaluate the importance of environmental factors on the community of these insects (Flinte *et al.* 2006).

In this study we tested the hypothesis that Malpighiaceae sequential flowering is responsible for the maintenance of thrips throughout the year, assuming the premise that thrips migrate among different plants according to the flowering phenology. Moreover we 1) aimed to identify the species of thrips present in Malpighiaceae; 2) to classify the different plants as major or minor hosts and 3) seek for relations between thrips abundance and the size of flowers and 4) to verify if seasonal variations in the habitat and host plant phenology had influence on thrips abundance and diversity.

4 MATERIAL AND METHODS

4.1 Study area

Fieldwork was carried out from March 2007 to February 2009 in an area of Cerrado vegetation (*sensu* Goodland 1971) at the Ecological Reserve of Clube de Caça e Pesca Itororó de Uberlândia (CCPIU, 640 ha, 18°97'S, 48°29'W; 863m) in Uberlândia municipality, Minas Gerais State, Brazil (FIGURE 1). Cerrado *sensu strictu* (savanna woodland) is the main vegetation type in the reserve. This vegetation is dominated by trees and shrubs often 2–4m tall and a fair amount of herbaceous vegetation (Oliveira-Filho & Ratter 2002). The climate in the region present two well characterized seasons, a dry winter (May to September) and rainy summer (October to March) (see Reu & Del-Claro 2005 for details about the study site).



FIGURE 1. Aerial photograph of the Clube Caça e Pesca Itororó de Uberlândia where the fieldwork was carried out. The opaque polygon indicates the place where the fieldwork was carried out. On the North, at the top of the photo, the downtown of Uberlândia municipality. Surrounding the field area there is a predominance of crop fields. (Point of view altitude 4.88km, photo by Google Earth (2009).

4.2 Preliminary observations

Initially, throughout 2007, we sampled the most abundant Malpighiaceae present in the study area in order to verify the plant species in which thrips were most common associated. Samplings were made at the peak flowering, based on Torezan-Silingardi (2006).

A single plant of the appropriate species was selected and 5 flowers in anthesis were collected and conserved in 60% ethanol (Milne & Walter 2000). The 2007 results indicated that thrips were more abundant in flowers of *Banisteriopsis malifolia* (Nees & Mart.) B. Gates, *B. campestris* (A. Juss) Little, *B. laevifolia* (A. Juss.) B. Gates, *Byrsonima intermedia* A. Juss., and *Peixotoa tomentosa* A. Juss. (FIGURE 2). This Malpighiaceae community was supposed to present sequential flowering and shrubs of all are very common in the study area (Torezan-Silingardi 2006). Hereafter the species *Byrsonima intermedia* will be presented without abbreviation in order to avoid confusion with the *Banisteriopsis* species.

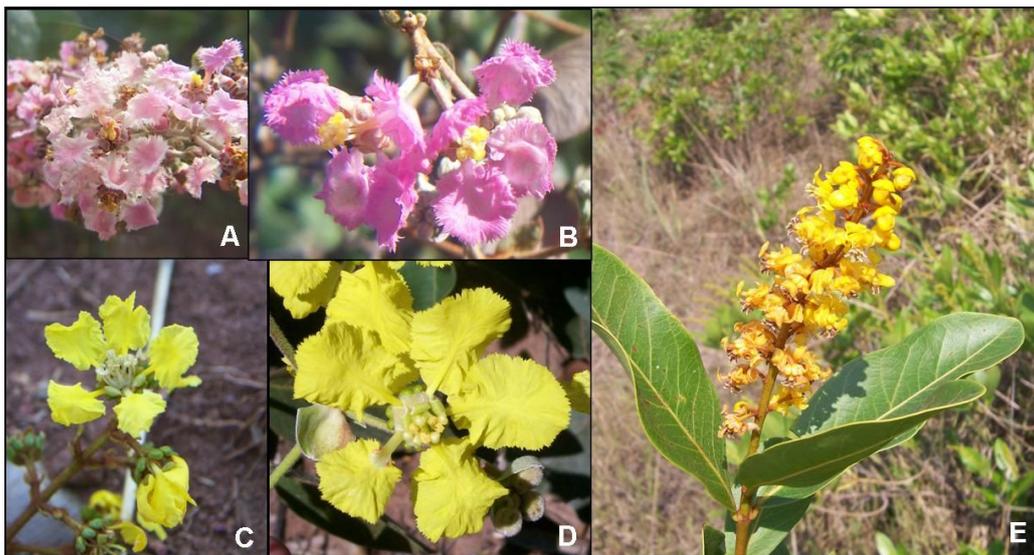


FIGURE 2. A) *Banisteriopsis malifolia*; B) *Banisteriopsis campestris*; C) *Banisteriopsis laevifolia*; D) *Peixotoa tomentosa*; E) *Byrsonima intermedia*. (Photos A-D: by Estevão Alves-Silva; E – by Helena Maura Torezan Silingardi)

4.3 Data collecting

Once the Malpighiaceae species were chosen, thrips samplings started in March 2008, when *B. malifolia* was flowering. Data collecting covered an entire year, from March 2008 to February 2009, with samples being taken every two weeks. In each sampling five individuals of each species were randomly chosen and five flowers in anthesis were collected. This procedure was made until flowers were present in the plant. No plant individuals were sampled more than once, to avoid pseudo-replication of data (Hulbert 1984). The same procedure adopted for *B. malifolia* was made in the other four plants: *P. tomentosa*, *B.*

laevifolia, *Byrsonima intermedia* and *B. campestris*. In the case of overlapping flowering between two species, flowers of both were collected.

The sampling methodology adopted for determining thrips abundance in the flowers was the destructive sampling in which the flowers were extracted from the plants and thrips evaluation (species and number of individuals) was made in laboratory conditions. According to Pearsall & Myers (2000) this is the best technique for thrips detection because samples are likely to be less biased and more appropriate for population monitoring. The flowers were involved with a plastic sack to avoid the escape of the thrips before the cutting and then kept individually in 60% ethanol. During the samplings some sporadic behavioral observations of thrips and other arthropod were made on the plants.

Thrips were mounted in microscope slides according to Mound & Marullo (1996) and the species were primarily identified with keys from different authors (Mound & Marullo 1996, Monteiro unpubl. data, Milne *et al.* 1997, Monteiro *et al.* 2001, Arevalo *et al.* 2006). Species level identification was possible only with the collaboration of Dr. Laurence A. Mound (*Commonwealth Scientific and Industrial Research Organisation*, Australia). However, in many cases it was not possible to reach species level, either because the specimens are undescribed (new species and in some cases new genera) or because the difficulty in recognize certain intraspecific polymorphic taxonomic patterns inherent to many species. Additionally, Neotropical thysanopterofauna is poorly known and species not related to crops are seldom studied. In those cases in which it was not possible to determine the species, the individuals were presented by genera and morphospecified.

4.4 Thysanopterofauna descriptions

Thysanopterofauna descriptions included the following indexes according to Ludwig & Reynolds (1988), Manly (1997), Lansac-Tôha *et al.* (2000), Ott & Carvalho (2001), Magurran (2004) and Uramoto *et al.* (2005).

Richness: total number of thrips species observed in each plant species.

Constancy index: it was calculated for each one of the five Malpighiaceae species and their associated thrips. The formula was given by " $C=p(100)/N$ " where p was the number of samples in that a given thrips taxa was recorded and N was the total number of samples for each plant. According to this index, constant taxa were considered to be those that occurred in

more than 50% of the samples, accessory taxa those occurring in 25% to 49.9% of the samples and accidental taxa those occurring in less than 24.9% of the samples.

Number of dominant species: it was calculated for each one of the five Malpighiaceae species and their associated thrips. Species dominance was defined as $D\%=(i/t).100$, where i was the total number of individuals of a given species and T was the total number of individuals collected. The categories were established as: eudominant>10%; dominant=5-10%; subdominant=2-5%; eventual=1-2% and rare<1%.

Jackknife index: used to estimate the species richness in the samplings. We used the formula: $J = S + \{(n-1)/n\} f$, where S was the total number of species observed in all samples, n was the number of samples and f was the number of a single species recorded in just one of the n samples.

Simpson index: represented the probability that two randomly selected individuals in any two consecutively sampling belonged to the same species. It ranged from 0 to 1, with 0 representing infinite diversity and 1 representing no diversity. The formula was $D = \sum n(n-1)/N(N-1)$, where n was the total number of organisms of a particular species and N was the total number of organisms of all species.

Species evenness is a diversity index, a measure of biodiversity which quantifies how equal the communities are numerically. When all species in a sample are equally abundant, the species evenness assumes its maximum value. It was calculated by the formula: $E=H'/H'max$ where H' was the Shannon index and $H'max$ was the natural logarithm of the number of species in a given plant. E was constrained between 0 and 1. The less variation in communities among the species, the higher E will be.

Shannon index: is a measure of diversity and was used to compare the thrips diversity in each plant species. The calculation was made by the following formula $H_s = - \sum_{i=1}^S ni \ln ni$.

The proportion of species i relative to the total number of species (p_i) was calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product was summed across species, and multiplied by -1: A low Shannon index indicates low diversity.

4.5 Flower size and the abundance of thrips

To analyze the influence of flower size in the abundance of thrips, a portion of the flowers used for thrips sampling (N=60 flowers of each Malpighiaceae species) were measured. A caliper (1/10 mm accuracy) was used to evaluate the distance between the two petals adjacent to the flag petal, named here as flower diameter. Data of thrips abundance and the diameter of flowers were then submitted to a procedure known as Curve Adjustment test, provided by Bioestat 5.0 software. This technique is used to demonstrate if the data has linear, power, logarithmic or geometric distribution and regression is made simultaneously. The highest value of R^2 provided in the different regressions shows which regression type is more appropriate for the data.

The same measurements obtained for flowers of different Malpighiaceae species were also tested in order to verify differences among the flower sizes, evidenced by a Kruskal-Wallis test.

4.6 Environmental data

Data of rainfall (mm), mean temperature and relative humidity from March 2008 to February 2009 were obtained from the Laboratório de Climatologia, Instituto de Geografia of the Universidade Federal de Uberlândia, MG, Brazil. The month values of each environment parameter were tested for linear regression with thrips monthly abundance in the plants.

4.7 Plant phenology

Each plant species had 20 adult individuals randomly chosen for the phenological observations, in order to detect changes in the reproductive phenology throughout the year. These plants were not used for thrips sampling. Observations were made every 15 days. The intensity of each plant phenological event was scored from 0 to 4; meaning respectively, 0, 1–25, 26–50, 51–75, or 76–100 percent of flowers present (*sensu* Morellato *et al.* 2000) and the mean of each month was used for statistical functions.

The patterns of flowering were made according to Newstrom *et al.* (1994) who consider a continuum from continuous to very infrequent flowering. Classes are based on frequency, defined as the number of cycles per year (one cycle consists of a flowering episode followed by a non-flowering interval). The four basic classes are continual (flowering with sporadic briefs), subannual (flowering in more than once cycle per year), annual (only one major cycle per year) and supra-annual (one cycle over more than one year). Brief flowering was

understood as a period lesser than 1 month , intermediate flowering as a period from 1 to 5 months and extended flowering as a period over than 5 months.

4.8 Testing the occurrence of seasonality

We performed circular statistical analysis of directional (circular) data, using the phenology values measured for plant species. Months were converted into single numerical variables. Each month was given a number from 1 to 12, starting with January and combined with its respective value of plant phenology. Circular statistics provided (1) the mean angle α , meaning the time of the year in which the dates of a given phenophase, in our case the flowering, occurred at most; (2) the Rayleigh test (z) which determines the significance of the mean angle and (3) the vector r , which is a measure of concentration around the mean angle. In directional analysis the interest relies in the direction and not in the magnitude of the vector r and therefore it is unitless, ranging from zero (when phenological activity is distributed uniformly throughout the year) to one (when phenological activity is concentrated around one time of year) and indicates the degree of asymmetry or the degree of seasonality (Fisher 1996, Aradottir *et al.* 1997, Morellato *et al.* 2000, Jammalamadaka & Sengupta 2001). As we predicted that the flower phenology of plants would have seasonality, that is, each species would not flower uniformly over the year, we expected that there would be a significant angle or mean direction observed in the circular statistics, denoted by r tending to one.

5. RESULTS

Thrips sampling in all 675 flowers from all plants studied accomplished 3788 (5.61 ± 6.49 , $\bar{X} \pm 1SD$) individuals distributed in 2626 (3.89 ± 4.95 , $\bar{X} \pm 1SD$) adults and 1162 (1.72 ± 3.10 , $\bar{X} \pm 1SD$) immatures. We identified 19 species of thrips in eight genera and three families: Phlaeothripidae, Thripidae and Heterothripidae. This latter was the most abundant family in all plants (FIGURE 3).

The plant which presented more thrips was *P. tomentosa* (10.4 ± 8.0 , $\bar{X} \pm 1SD$, $n=1561$ thrips in 150 flowers) followed by *B. laevifolia* (11.41 ± 7.37 , $\bar{X} \pm 1SD$, $n=856$ thrips in 75 flowers), *B. malifolia* (3.26 ± 3.19 , $\bar{X} \pm 1SD$, $n=489$ thrips in 150 flowers), *B. campestris* (3.11 ± 3.03 , $\bar{X} \pm 1SD$, $n=467$ thrips in 150 flowers) and *Byrsonima intermedia* (2.74 ± 4.45 , $n=411$ thrips in 150 flowers). Kruskal-Wallis test ($H=195.7355$, $df=4$, $p<0.0001$) and Dunn's method of multiple comparisons revealed statistical significant differences between all plants concerning the number of thrips sampled per plant (FIGURE 4A).

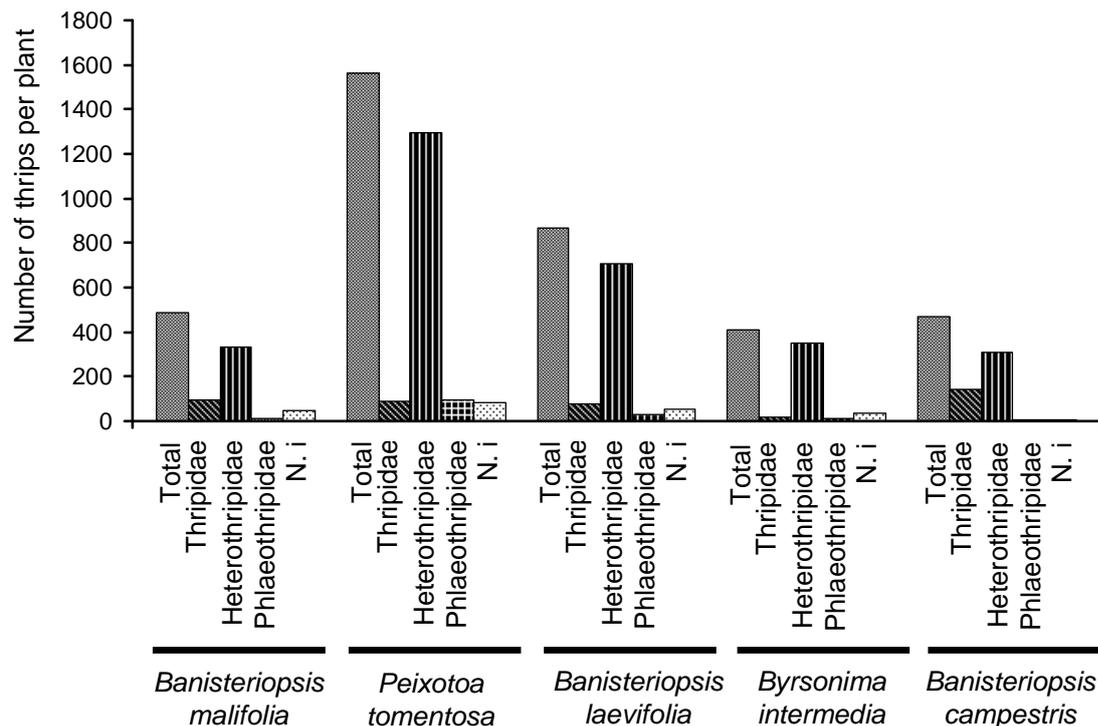


FIGURE 3. Thrips (total number of individuals and individuals per thrips family) observed in flowers of Malpighiaceae species in the Brazilian savanna. N.i – means “not identified species”.

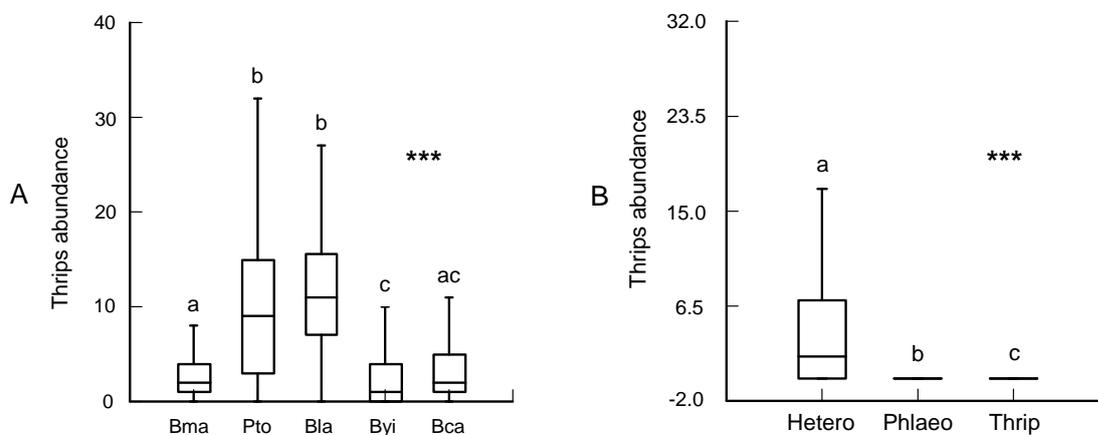


FIGURE 4. (A) Thrips ($\bar{X} \pm 1SD$) observed in flowers of Malpighiaceae species of Brazilian Savanna vegetation: Bma - *Banisteriopsis malifolia*, Pto - *Peixotoa tomentosa*, Bla - *Banisteriopsis laevifolia*, Byi - *Byrsonima intermedia*, Bca - *Banisteriopsis campestris*; (B) The number of all thrips ($\bar{X} \pm 1SD$) observed in all samplings, divided per thrips families: Hetero – Heterothripidae, Phlaeo – Phlaeothripidae, Thrip – Thripidae. *** means statistical differences ($p < 0.0001$, Kruskal-Wallis test). Lowercase letters upon the bars indicate significant statistical differences ($p < 0.0001$, Dunn’s test for multiple comparisons).

The most abundant family, Heterothripidae (4.13 ± 5.61 , $\bar{X} \pm 1SD$, $n=2790$ individuals in 675 flowers) ($H=495.24$, $df=2$, $p < 0.0001$) (FIGURE 2B) accounted for eight species in which only to *Scutothrips nudus* (Moulton, 1932) and *Heterothrips peixotoa* Del-Claro, Marullo and Mound 1997 the species level identification was possible. The other species were identified to genera and were named as “*Heterothrips* sp. 1” to “*Heterothrips* sp. 5” and *Lenkothrips* sp.

Thripidae (0.94 ± 1.99 ; $\bar{X} \pm 1SD$, $n=633$ individuals in 675 flowers) was represented by six species: *Frankliniella condei* John, 1928, *Frankliniella minuta* (Moulton), *Frankliniella schultzei* (Trybom), *Frankliniella occidentalis* (Pergande), *Frankliniella* sp. 1 and *Halmathrips* (*Demetriothers*) sp. The family Phlaeothripidae (0.22 ± 0.96 ; $\bar{X} \pm 1SD$, $n=148$ individuals in 675 flowers) was represented by *Haplothrips gowdeyi* (Franklin 1908) and other four morphospecies: three *Pseudophilothrips* and one *Liothrips* (TABLE 1). All the morphospecies listed by genus are currently being studied and most of them are likely new species (Laurence Mound, pers. comm). As soon the information about these species is available, the results will be brought out.

Heterothrips peixotoa was the most frequent species in all plants and considered constant in *P. tomentosa* and *B. laevifolia*. In the other plants this species was classified as accessory. *Heterothrips peixotoa* was also the only eudominant species in all plants. The only thrips present in all plants were *F. condei*, *H. peixotoa*, *S. nudus* and *Frankliniella* sp. 1. but immatures identification was not possible for *Frankliniella* sp. 1.

Heterothrips peixotoa was seen early in the morning wandering on the petals and anthers, where it feed (FIGURE 5). Usually no more than three individuals were seen and at the lighter disturbance (shaking of flowers) these thrips took flight, in this occasion the thrips stayed still, opened the wings and rapidly disappeared. In the other hand *Frankliniella* instead of flighting it firstly leaped on the petals and in case the disturbance continued, the thrips flew away. *Heterothrips peixotoa* was active during all the day. Foraging behavior took place in the mornings, until 1100h approximately and during the hottest part of day, from 1100h to 1500h thrips often stayed inside the flower chambers, foraging again in the evening. Nocturnal observations were not made. The dissections of flowers showed no immature stage beyond larvae for any species and for *Pseudophilothrips* their red larvae were sometimes seen on the trunks of the plants walking towards the soil, where they get buried to pupate. In the other species thrips larvae just jumps from flowers to the soil in order to complete the metamorphosis. Differently from the gregarious habit of Thripidae and Heterothripidae, *Pseudophilothrips* was seen very often wandering alone on the buds, flowers, leaves and branches and was very reticent to take flight, even when disturbed. Although no measures were made, *Pseudophilothrips* individuals were two times larger than the other thrips species, avoiding its entry in the flower chambers used by the other species as shelter.

TABLE 1. The values of frequency, constancy and dominance of thrips species in the five Malpigiaceae studied. ($\bar{X} \pm 1SD$ (N)); nS – number of flowers infested by thrips; % - frequency; C (Constancy index) – Ct=constant, Ac=accessory, Acd=accidental; %D – percentage of the thrips species in relation to the total thrips found in the plant; D-dominant; E-eudominant; D-dominant; Sd-subdominant; Ev-eventual; Rr-rare.

		$\bar{X} \pm 1SD$ (N)	nS	%	C	%D	D
<i>Banisteriopsis malifolia</i>	<i>Frankliniella condei</i>	0.57±1.19 (86)	42	0.28	Ac	0.18	E
	<i>Frankliniella minuta</i>	0.01±0.08 (1)	1	0.01	Acd	0.01	Ev
	<i>Frankliniella</i> sp. 1	0.07±0.38 (10)	5	0.03	Acd	0.02	Sd
	<i>Scutothrips nudus</i>	0.48±1.02 (72)	32	0.21	Acd	0.15	E
	<i>Heterothrips peixotoa</i>	1.09±1.68 (163)	61	0.41	Ac	0.33	E
	<i>Heterothrips</i> sp. 1	0.58±1.39 (87)	33	0.22	Acd	0.18	E
	<i>Heterothrips</i> sp. 2	0.04±0.26 (6)	4	0.03	Acd	0.01	Ev
	<i>Heterothrips</i> sp. 3	0.02±0.14 (3)	3	0.02	Acd	0.01	Ev
	<i>Heterothrips</i> sp. 4	0.01±0.08 (1)	1	0.01	Acd	0.00	Rr
	<i>Pseudophilothrips</i> sp. 1	0.07±0.35 (11)	8	0.05	Acd	0.02	Sd
N. i	0.33±0.94 (109)	31	0.21	-	0.22	-	
<i>Peixotoa tomentosa</i>	<i>Frankliniella condei</i>	0.47±1.47 (70)	17	0.11	Acd	0.06	D
	<i>Frankliniella</i> sp. 1	0.12±0.65 (18)	7	0.05	Acd	0.02	Sd
	<i>Halmathrips</i> sp.	0.01±0.08 (1)	1	0.01	Acd	0.00	Rr
	<i>Scutothrips nudus</i>	0.05±0.28 (8)	6	0.04	Acd	0.01	Ev
	<i>Heterothrips peixotoa</i>	8.51±6.96 (1276)	132	0.88	Ct	0.82	E
	<i>Heterothrips</i> sp. 2	0.02±0.18 (3)	2	0.01	Acd	0.00	Rr
	<i>Heterothrips</i> sp. 3	0.02±0.14 (3)	3	0.02	Acd	0.00	Rr
	<i>Heterothrips</i> sp. 5	0.04±0.26 (6)	4	0.03	Acd	0.01	Ev
	<i>Pseudophilothrips</i> sp. 2	0.58±1.71 (87)	25	0.17	Acd	0.08	D
	<i>Liothrips</i> sp.	0.04±0.30 (6)	3	0.02	Acd	0.01	Ev
N. i	0.55±1.41 (83)	28	0.19	-	0.08	-	
<i>Banisteriopsis laevifolia</i>	<i>Frankliniella condei</i>	0.83±2.09 (62)	13	0.17	Acd	0.07	D
	<i>Frankliniella schultzei</i>	0.04±0.20 (3)	3	0.04	Acd	0.00	Rr
	<i>Frankliniella</i> sp. 1	0.16±0.74 (12)	4	0.05	Acd	0.01	Ev
	<i>Lenkothrips</i> sp.	0.01±0.12 (1)	1	0.01	Acd	0.00	Rr
	<i>Scutothrips nudus</i>	1.20±2.16 (90)	22	0.29	Ac	0.10	D
	<i>Heterothrips peixotoa</i>	8.21±6.57 (616)	50	67	Ct	0.71	E
	<i>Heterothrips</i> sp. 3	0.04±0.26 (3)	2	0.03	Acd	0.00	Rr
	<i>Liothrips</i> sp.	0.01±0.12 (1)	1	0.01	Acd	0.00	Rr
	<i>Pseudophilothrips</i> sp. 3	0.35±0.85 (26)	14	0.19	Acd	0.03	Sd
N. i	0.83±2.09 (54)	18	0.24	-	0.06	-	
<i>Byrsonima intermedia</i>	<i>Frankliniella condei</i>	0.03±0.16 (4)	4	0.03	Acd	0.01	Ev
	<i>Frankliniella occidentalis</i>	0.01±0.08 (1)	1	0.01	Acd	0.00	Rr
	<i>Frankliniella</i> sp. 1	0.06±0.35 (9)	5	0.03	Acd	0.02	Sd
	<i>Lenkothrips</i> sp.	0.02±0.14 (3)	3	0.02	Acd	0.01	Ev
	<i>Scutothrips nudus</i>	0.07±0.46 (10)	5	0.03	Acd	0.02	Sd
	<i>Heterothrips peixotoa</i>	2.27±4.42 (340)	59	0.39	Ac	0.83	E
	Phlaeothripidae larvae	0.07±0.53 (11)	3	0.02	Acd	0.03	Sd
	N. i	0.22±0.84 (33)	12	0.08	-	0.08	-
<i>Banisteriopsis campestris</i>	<i>Frankliniella condei</i>	0.65±1.29 (98)	43	0.29	Ac	0.21	E
	<i>Frankliniella</i> sp. 1	0.31±0.81 (47)	25	0.17	Acd	0.10	D
	<i>Scutothrips nudus</i>	0.19±0.76 (28)	10	0.07	Acd	0.06	Sd
	<i>Heterothrips peixotoa</i>	1.74±2.23 (261)	84	0.56	Ct	0.56	E
	<i>Heterothrips</i> sp. 1	0.14±0.59 (21)	10	0.07	Acd	0.04	Sd
	<i>Haplothrips gowdeyi</i>	0.01±0.08 (1)	1	0.01	Acd	0.00	Rr
	Phlaeothripidae larvae	0.03±0.41 (5)	1	0.01	Acd	0.01	Ev
	N. i	0.01±0.04 (6)	3	0.02	-	0.01	-

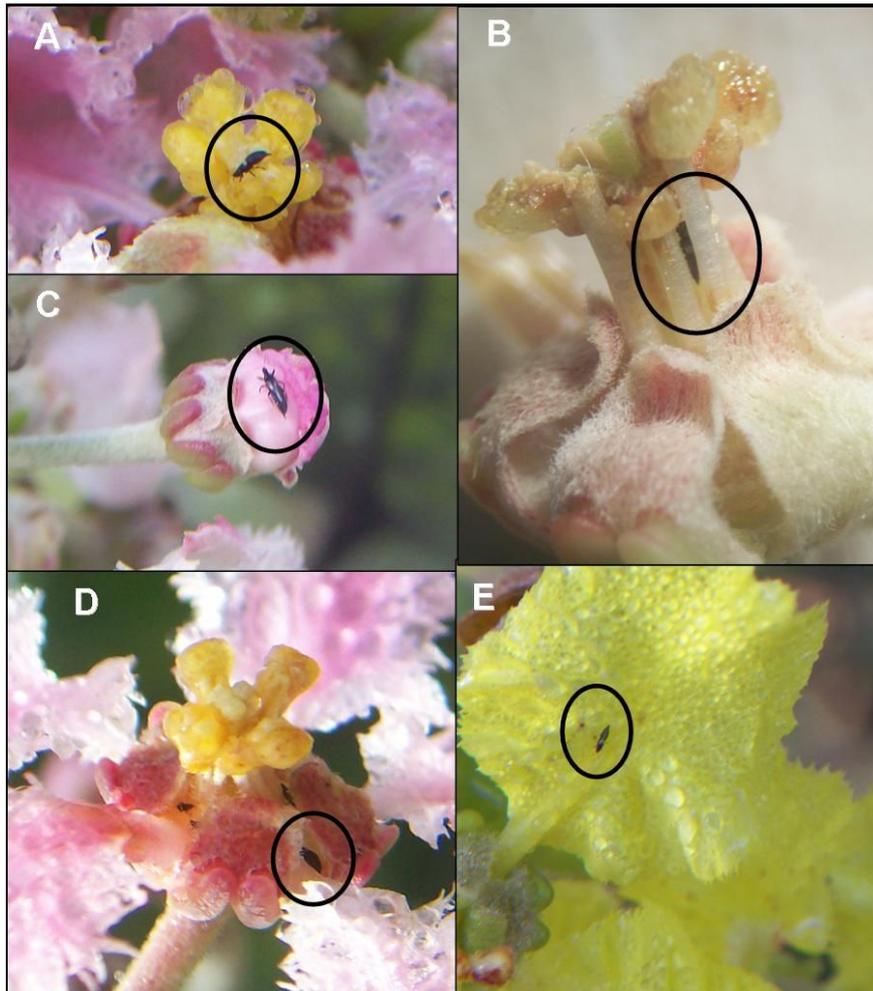


FIGURE 5. A) *Heterothrips peixotoa* feeding on pollen of *Banisteriopsis malifolia*; B) *H. peixotoa* between the stamens of *B. malifolia*; C) *Pseudophilothrips* sp. 1 on a pre anthesis flower of *B. malifolia*; D) thrips under the chambers of *B. malifolia*; E) *H. peixotoa* foraging on a petal of *Peixotoa tometosa*. Circles in the figures indicate the position of thrips. (Photos by Estevão Alves-Silva).

In general thrips were most common during the dry season ($H=231.84245$; $df=11$; $p<0.0001$), from June to October (FIGURE 6A). This pattern was in great part caused by the abundance of the most profuse species in our study, *H. peixotoa* ($H=235.38337$; $df=11$; $p<0.0001$). The FIGURE 6A shows that the pattern of occurrence of the total number of thrips along the year was similar to that of *H. peixotoa*, (FIGURE 6B) but different from the other abundant species like *F. condei* ($H=70.64970$; $df=11$; $p<0.0001$) (FIGURE 6C) and *S. nudus* ($H=56.34501$; $df=11$; $p<0.0001$) (FIGURE 6D). The highest densities of these three species are coincident with the flowering of *P. tomentosa* and *B. laevifolia*, as shown in the next sections.

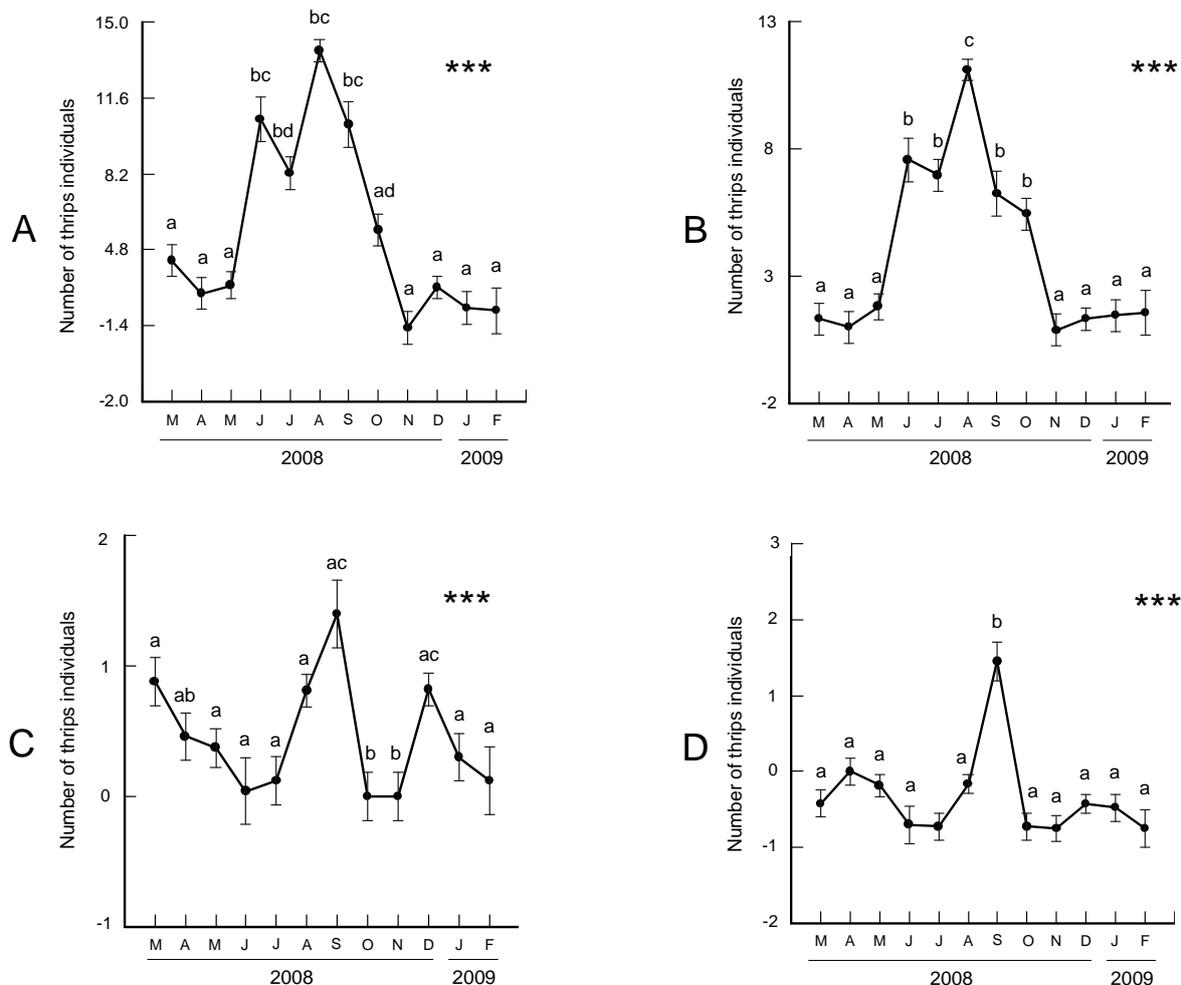


FIGURE 6. Fluctuation of thrips along the year. A) Total number of thrips; B) *Heterothrips peixotoa*; C) *Frankliniella condei*; D) *Scutothrips nudus*. *** means statistical differences ($p < 0.0001$; Kruskal-Wallis test). Lowercase letters upon the bars indicate significant statistical differences ($p < 0.0001$, Dunn's test for multiple comparisons).

Other than thrips, ants and spiders were also found on the plants (FIGURE 7). Although no counting was performed, the most frequent ants were *Camponotus crassus* (Mayr 1862) (Formicinae: Formicidae) and *Ectatomma tuberculatum* (Olivier 1804) (Ectatomminae: Formicidae) but some *Pachycondyla villosa* (Fabricius) (Ponerienae: Formicidae) were also observed foraging on the plants sometimes. Both ants and spiders did not preyed on thrips and at the time these predators were foraging thrips stayed concealed under the flower chambers. The tiny entry of chambers allowed thrips to come and go but predators were too big to have access to these structures.

Species richness estimated through Jackknife had a close value to that observed for the plants indicating a good effort in thrips sampling (TABLE 2). Simpson index of diversity, which is influenced by the importance of most dominant species, evidenced differences between the plants. The elevated value of Simpson index together with the low evenness in

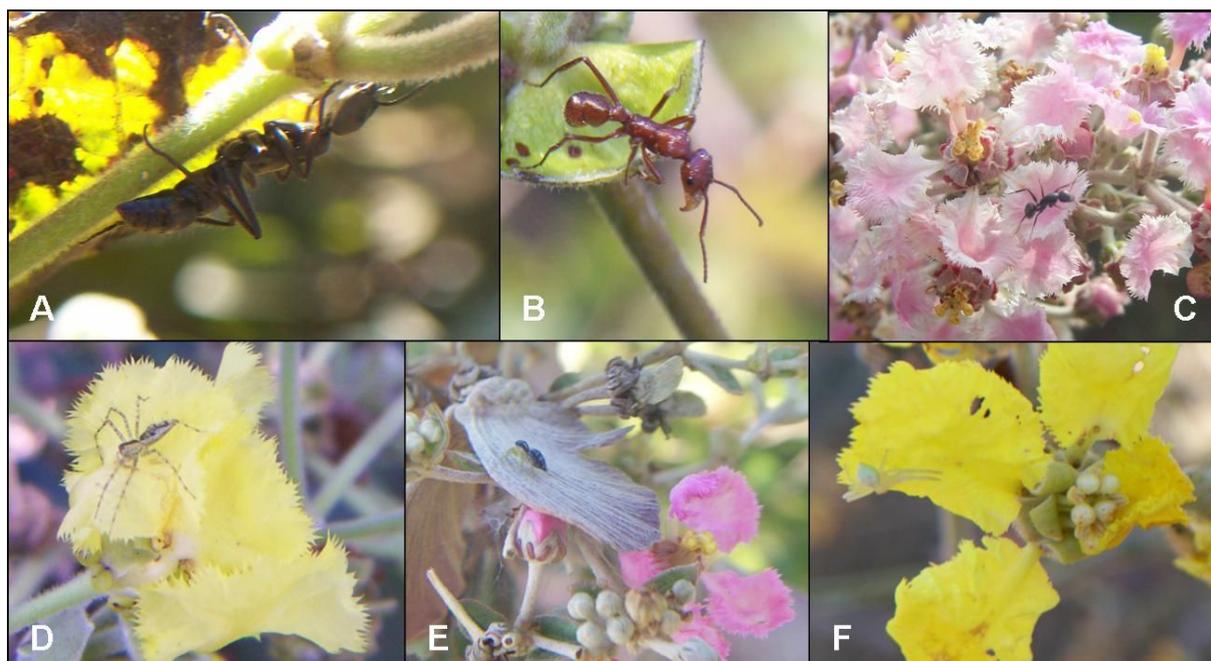


FIGURE 7. Potential predators of thrips in Malpighiaceae. A) *Pachycondyla villosa* on a branch of *Peixotoa tomentosa*; B) *Ectatoma tuberculatum* on a leaf of *P. tomentosa*; C) *Camponotus crassus* on a flower of *Banisteriopsis malifolia*; D) Oxyopidae spider on a flower of *P. tomentosa*; E) Salticidae spider on a fruit of *B. campestris*; F) Thomisidae spider on a flower of *P. tomentosa*. (Photos by Estevão Alves-Silva).

P. tomentosa and *Byrsonima intermedia* resulted from the high abundance and frequency of *H. peixotoa* revealing the existence of a dominant species.

TABLE 2. Thysanopteroфаuna analysis in the five Malpighiaceae species studied

	<i>Banisteriopsis malifolia</i>	<i>Peixotoa tomentosa</i>	<i>Banisteriopsis laevifolia</i>	<i>Byrsonima intermedia</i>	<i>Banisteriopsis campestris</i>
Flowers collected	150	150	75*	150	150
Species richness	10	10	9	7	7
Jackknife	11.8	10.9	10.8	7.9	7.9
Shannon index	1.59	0.60	0.88	0.49	1.26
Simpson index	0.24	0.75	0.59	0.81	0.38
Species evenness	0.7	0.26	0.40	0.25	0.65

*This species presented smaller quantities of flowers to be sampled than other ones

According to the Shannon index, *B. malifolia* was the species with higher thrips diversity, followed by *B. campestris*, *B. laevifolia*, *P. tomentosa* and *Byrsonima intermedia*, respectively. The lowest value for Shannon index was observed in *Byrsonima intermedia* since *H. peixotoa* accounted for 83% of the thrips individuals present. The same situation occurred in *P. tomentosa* where the high abundance of *H. peixotoa* (82%) resulted in low diversity. The balance between species richness/species diversity was registered *B. malifolia* where the Simpson index was lower and species evenness higher.

The variation of environmental data can be seen in FIGURE 8. Linear multiple regression showed that thrips were negatively related with relative humidity ($R^2=0.74$, $F_{1,8}=7.402$ $p<0.05$) but not with temperature and rainfall (FIGURE 9).

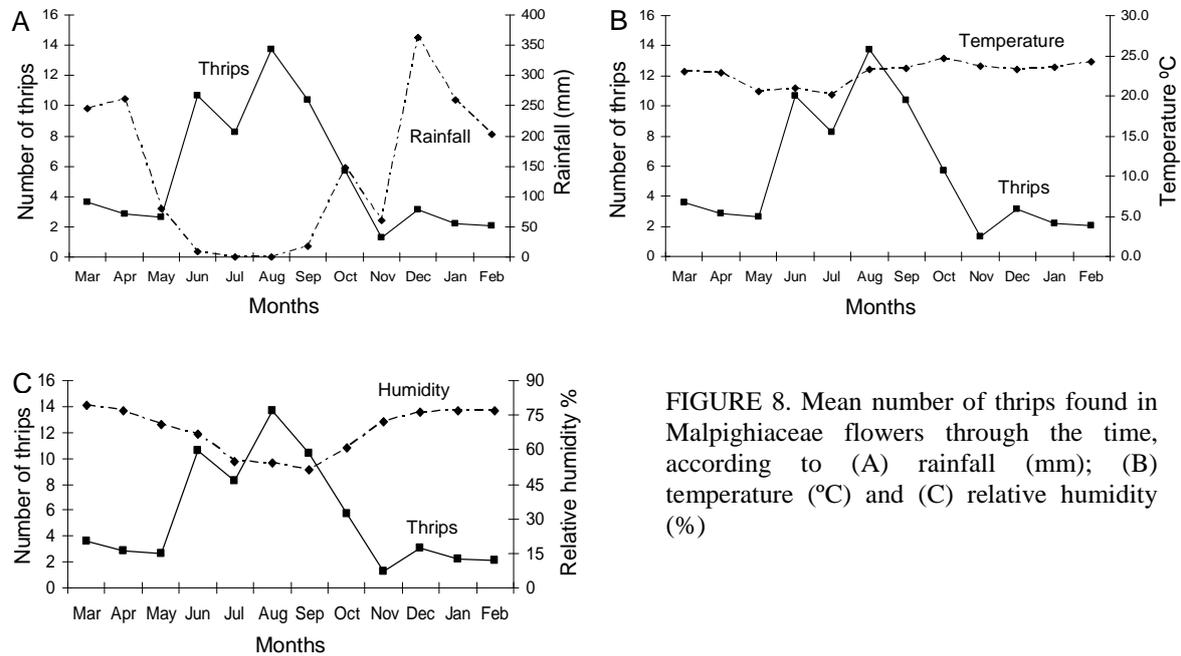


FIGURE 8. Mean number of thrips found in Malpighiaceae flowers through the time, according to (A) rainfall (mm); (B) temperature (°C) and (C) relative humidity (%)

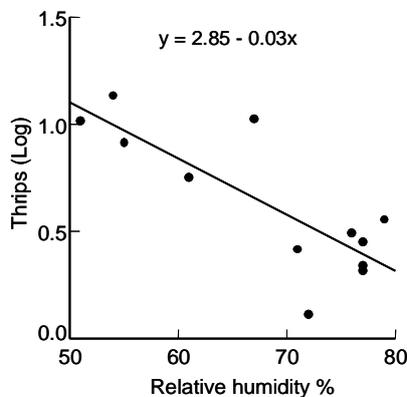


FIGURE 9. Linear multiple regression showed relation between thrips and relative humidity. The number of thrips was log transformed to fit in normal distribution

Phenological analysis (FIGURE 10), showed that the five Malpighiaceae species studied presented sequential flowering, enabling thrips to find food and shelter in any of these species along the year. *P. tomentosa* presented the largest flowering period while *B. laevifolia* had the shortest. Low intensity of flowers was noted in *B. campestris*, as shown by the numbers inside the circles in FIGURE 10. All plants presented high levels of seasonality (TABLE 3), denoted by the elevated values of r , and the Rayleigh significance values of the mean angles (α). The highest value of r was obtained in *B. laevifolia*, which flowers first appeared in August and after a short boom in September, the plant ceased the flower production. The patterns of

flowering based on frequency showed that these Malpighiaceae species presented annual and intermediate flowering episodes, in a period varying from two (*B. laevifolia*) to four months (*P. tomentosa*). The other three species bloomed for three months each.

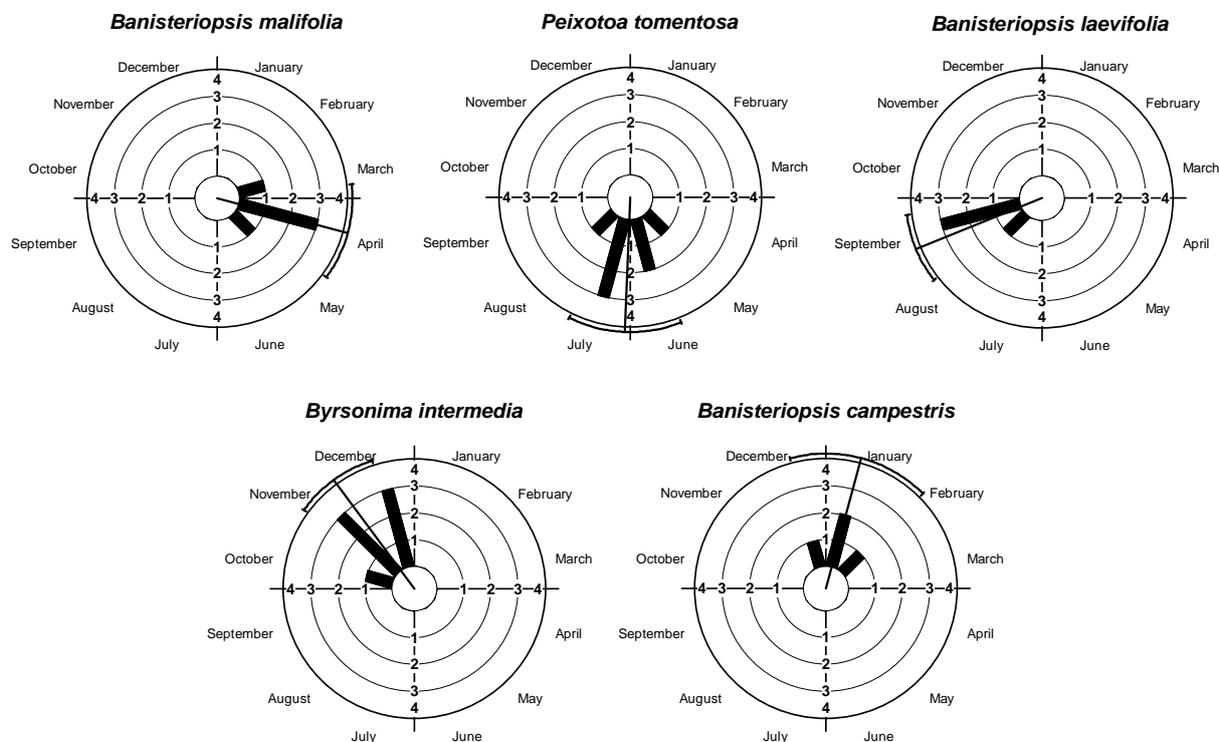


FIGURE 10. Phenological data (Circular statistics analysis) of five Malpighiaceae species in the tropical savanna of Uberlândia, MG, Brazil. The outside and bold curves (circular standard deviation) indicate the flowering season of each species. Black bars and inside dotted lines indicate the percent of flowers from 0 to 4; meaning 1=1–25%; 2=26–50%; 3=51–75% and 4=76–100% percent of flowers present.

TABLE 3. Results of circular statistic analyses tested for five Malpighiaceae species in the Tropical Savanna of Uberlândia, MG, Brazil.

	Phenological Variables				
	<i>Banisteriopsis malifolia</i>	<i>Peixotoa tomentosa</i>	<i>Banisteriopsis laevifolia</i>	<i>Byrsonima intermedia</i>	<i>Banisteriopsis campestris</i>
Mean angle (a)	105°	182.374°	247.631°	323.794°	15°
Month of peak in flowering	April	July	September	November	January
Circular standard deviation	16.93°	25.88°	9.70°	19.24°	19.50°
Length of mean vector (r)	0.96	0.90	0.99	0.95	0.94
Rayleigh test of uniformity (P)	<0.01	<0.001	<0.01	<0.001	<0.05

All flowers present bilateral symmetry with five petals and sepals. *Banisteriopsis laevifolia*, *B. campestris* and *P. tomentosa* flowers have eight oil glands under the sepals while *B. malifolia* may have eight or 10 and *Byrsonima intermedia* contains 10 elaiophores.

Corolla is composed of five nail-shaped free petals. The limb is flat in all species except in *Byrsonima intermedia*, which it is concave and the flowers born in great number in dense inflorescences. In all plants the claw of the posterior "flag" petal is often conspicuously thicker than the lateral petals. The most conspicuous differences among the flowers rely on the color and the size (TABLE 4).

TABLE 4. Differences in flower color and size of the five Malpigiaceae species studied. Subscribed lowercase letters indicate statistical significant differences in flower size.

	Flower color	Flower diameter $\bar{X} \pm 1SD (N)$	Kruskal-Wallis
<i>Banisteriopsis malifolia</i>	Pink	$2.6 \pm 0.14 (60)^a$	H=258.8708 GI=4 p< 0.0001
<i>Peixotoa tomentosa</i>	Yellow	$4.11 \pm 0.15 (60)^b$	
<i>Banisteriopsis laevifolia</i>	Yellow	$1.64 \pm 0.13 (60)^c$	
<i>Byrsonima intermedia</i>	Yellow	$1.6 \pm 0.06 (60)^{cd}$	
<i>Banisteriopsis campestris</i>	Pink	$2.6 \pm 0.07 (60)^a$	

Regarding the flower size and the abundance of thrips the curve adjustment technique showed that linear regression was appropriate for all plants. Floral dimensions were positively related with thrips abundance, thus the bigger was the flower diameter, more thrips could be hosted inside it (FIGURE 11).

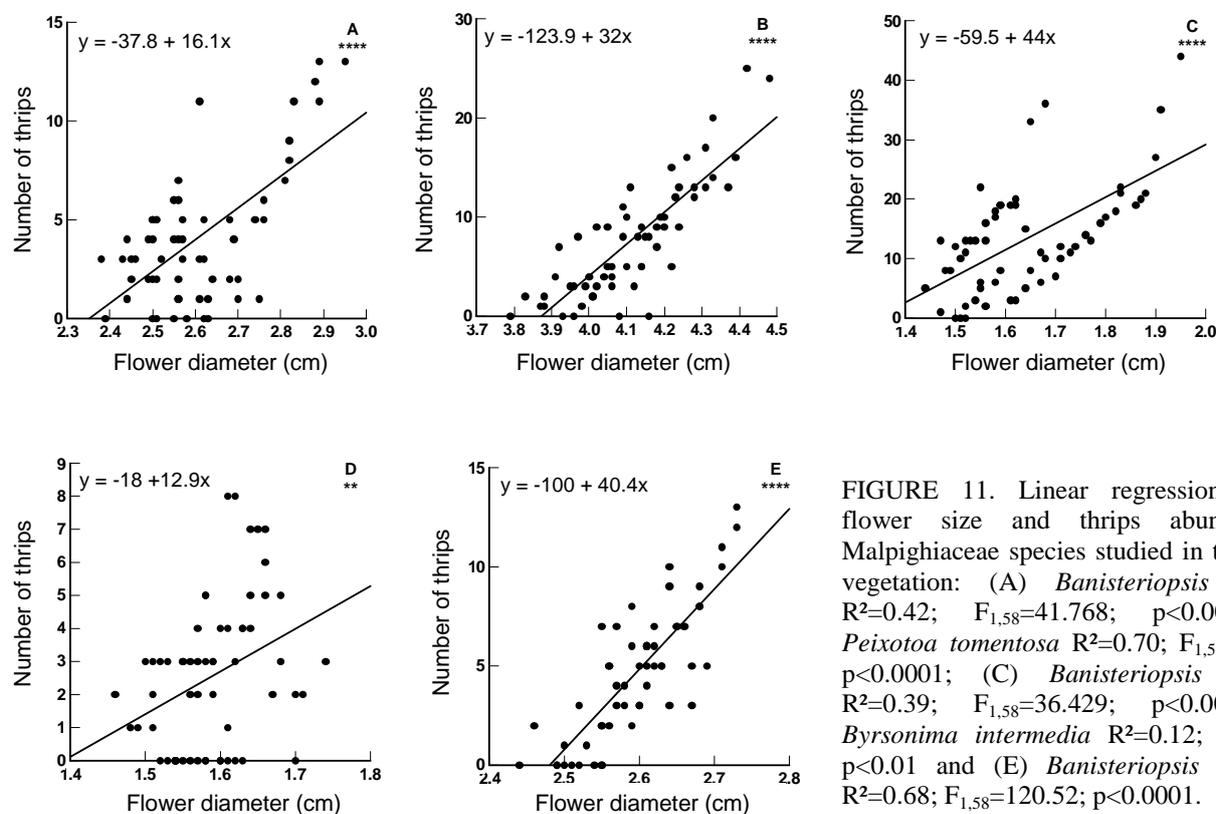


FIGURE 11. Linear regression between flower size and thrips abundance in Malpigiaceae species studied in the cerrado vegetation: (A) *Banisteriopsis malifolia* $R^2=0.42$; $F_{1,58}=41.768$; $p<0.0001$; (B) *Peixotoa tomentosa* $R^2=0.70$; $F_{1,58}=134.570$; $p<0.0001$; (C) *Banisteriopsis laevifolia* $R^2=0.39$; $F_{1,58}=36.429$; $p<0.0001$; (D) *Byrsonima intermedia* $R^2=0.12$; $F_{1,58}=8.16$; $p<0.01$ and (E) *Banisteriopsis campestris* $R^2=0.68$; $F_{1,58}=120.52$; $p<0.0001$.

6. DISCUSSION

This study showed that Brazilian Savannah Malpighiaceae supports a great diversity of thrips (at least 19 species) and we present evidence that sequential flowering plays an important role in the maintenance of this diversity. As a matter of fact, flowering plants and insects are two of the major groups of living beings. The origin of flowering plants opened new niches for insect diversification, which in turn may have driven plant speciation. Alternatively, one group may have tracked the previous diversification of the other group (Ehrlich & Raven 1964, Pellmyr 1992). In this context, sequential flowering is an important natural resource to help in the survivorship and diversification of generalist species of herbivores and/or pollinators (Bascombe & Jordano 2007). Relative to other host plants the diversity and richness of thrips registered in this study is so far one of the most remarkable features (see Pinent *et al.* 2005 for comparisons).

To a better comprehension on the importance of these plants in thrips ecology, and the impact of these insects as floral herbivores in Brazilian Savanna vegetation, this discussion will be divided in two parts. The first one will present a brief review of thrips species recorded and its importance in a Brazilian context. The second part will discuss the ecological implications of host plant preferences and seasonality in this thrips-Malpighiaceae relationship.

6.1 Thrips occurrence and its importance: a brief review

6.1.1 Suborder Terebrantia

This suborder was the most representative and important to the study comprising over 95% of all the individuals analyzed occurring in all Malpighiaceae. Suborder Terebrantia encompasses about 2400 species in eight families: Uzelothripidae, Merothripidae, Melanthripidae, Aeolothripidae, Fauriellidae, Adiheterothripidae, Heterothripidae and Thripidae (Mound & Morris 2007) and Brazil is represented by five of them: Uzelothripidae, Merothripidae, Aeolothripidae, Heterothripidae and Thripidae. About one-third of the 700 species of thrips registered in Brazil are grouped in the suborder Terebrantia and about 22 species are considered to damage cultivated plants and five to transmit tospovirus (Monteiro 2002, Mound 2002a). Inventories in natural areas of Brazil revealed that Thripidae and Heterothripidae are the most common families to be sampled (Pinent *et al.* 2006) and in our study this pattern was maintained. Thripidae and Heterothripidae accounted for 14 species and were responsible for the high levels of diversity. The Thripidae pests we found in our

study like *Frankliniella schultzei* and *F. occidentalis* were of low occurrence and not thought to be causing notable damages to Malpighiaceae species.

Terebrantia members have the ovipositor well developed and saw-like, their wings are usually covered with microtrichia and the fore wing presents at least one longitudinal vein reaching to apex (Richards & Davies 1988). The eggs are inserted below the plant cuticle, into the tissue of the plant on which the female is feeding. Terebrantia has two pupal stages (Mound & Marullo 1996). Individuals in this suborder have very wide habits, from fungus, leaf and flower-feeding to predatory and ectoparasitic behavior habits (Grimaldi & Engel 2005, Alves-Silva & Del-Claro unpubl. data). In Malpighiaceae we presumed that all fed on flower tissues and pollen, either because thrips lived on the flowers and also because fungus were not registered.

Family Heterothripidae

Heterothripidae accounted for the most diversity in Terebrantia with eight species against six from Thripidae. The high richness and diversity of Heterothripidae in all Malpighiaceae studied shows that these plants are very important as major and/or minor hosts for thrips maintenance along the year in Cerrado natural areas, particularly for *H. peixotoa*.

Heterothripidae is a family comprising over 70 species in four genera and it is usually found in dicotyledons and only in the New World (Mound & Marullo 1996, Mound & Morris 2007). With one exception, all the species are flower-living. The exception, *Aulacothrips dictyotus* Hood has been shown to be ectoparasitic on a species of Homoptera (Izzo *et al.* 2002) and also uses the membracids for phoresy (Alves-Silva & Del-Claro unpubl. data). Out of the 71 species described in Heterothripidae, 64 belong in *Heterothrips*, however almost nothing is known of the biology of the species (Mound & Marullo 1996). Available studies reported the occurrence of Heterothripidae in only a few plants. Feller *et al.* (2002), observed *Heterothrips arisaemae* Hood feeding on *Arisaema triphyllum* (L.) Schott. (Araceae) in United States and this thrips was also implicated on pollination. In Brazil Heterothripidae was found on flowers of Poaceae, Myrtaceae, Rubiaceae, Asteraceae (Pinent *et al.* 2005) and Malpighiaceae (Del-Claro *et al.* 1997). In our study *Heterothrips* sp. 1 was very frequent in *B. malifolia*, its major host but the other *Heterothrips* morphospecies were not representative. The possibility that these *Heterothrips* morphs are new species is big, particularly for *Heterothrips* sp 4. which possesses a pair of curved horns on the abdomen dorsally, an anatomic feature never seen before.

***Heterothrips peixotoa* Del-Claro, Marullo and Mound 1997** – This was the most abundant species in this study and its dominance in the plants was constant and regular all over the year. All Malpighiaceae analyzed can be considered good hosts for *H. peixotoa* but population rates reach its maximum on *P. tomentosa* and *B. laevifolia*, though the other plants serve as quite good hosts as well, since adults and immatures were found simultaneously. *Heterothrips peixotoa* was an undescribed species until 1997, when it was first discovered and studied in the flowers of *P. tomentosa* coexisting with ants (Del-Claro *et al.* 1997). So far *H. peixotoa* was registered only in Brazil and other than Malpighiaceae this species was recorded in *Eryngium* sp. (Apiaceae) and *Homolepis glutinosa* (Sw.) F. Zuloaga & Soderstr. (Poaceae) (Pinent *et al.* 2005).

***Scutothrips nudus* (Moulton, 1932)** – This species was abundant in *B. malifolia* and *B. laevifolia* which may be considered major hosts. In the other plants *S. nudus* occurrence was low, blurred either by *H. peixotoa* as well as *F. condei* (Thripidae). Though its commonness in *B. malifolia* and *B. laevifolia*, this thrips species was not seen foraging on the anthers and petals like *H. peixotoa* and its habits remain unknown. In structure this genus is intermediate between *Aulacothrips* and *Heterothrips*. Four South American species are currently placed in this genus (Mound & Marullo 1996). No information is available of *S. nudus* biology or ecology. In our study this species was present in all plants but the major hosts were *B. malifolia* and *B. laevifolia*.

***Lenkothrips* sp.** – There is not what to say about this species since only three individuals were sampled in the flowers of *Byrsonima intermedia*. This taxon is recognized at generic level because of anatomical remarkable features of the only included species (Mound & Marullo 1996). No information about its host associations is available.

Family Thripidae

This family is, with 2060 known species, by far the largest of the Sub Order Terebrantia (Mound & Morris 2007) but in this study the abundance of Thripidae individuals was exceeded by Heterothripidae members. The Thripidae is found worldwide, and includes almost all of the pest species of thrips (Morse & Hoddle 2006) which were represented by *F. condei*, *F. schultzei* and *F. occidentalis* in our study, but only *F. condei* was abundant whereas the other two were represented by one individual each. The species of many genera are associated only with grasses, whereas others are associated only with dicotyledonous plants, some in flowers

but others only on leaves (Mound 2002a). Pest species are commonly more adaptable in their habits, and many of them feed and breed both on leaves and in flowers (Strauss & Karban 1994, Leite *et al.* 2006). There are no registers of the number of Thripidae species in Brazil, however in the genera *Frankliniella* about 40 species have been recorded, 18 of them described originally from this country (Monteiro 2002). This diversity is quite similar to Costa Rica with 44 species (Mound & Marullo 1996). *Frankliniella* is a large genus of about 180 species, 90% of which are from the Neotropics; species recognition is peculiarly difficult particularly amongst the small pale bodied forms (Mound & Marullo 1996).

***Frankliniella condei* John, 1928** – Among the Thripidae this species was the most abundant occurring in all Malpighiaceae studied, its population was low only in *Byrsonima intermedia* therefore not considered a host for *F. condei*. These individuals are very vagile and easily come and go from flowers all day long. They often stayed under the flower chambers with other co-specifics and went out to forage on the petals alone. The small size together with pale-yellow color of individuals makes them hard to see on the flowers. *Frankliniella condei* seems to be common and endemic to Brazil and it was already found in several plants both mono and dicotyledons in Santa Catarina, Minas Gerais and São Paulo States (Monteiro *et al.* 2001). This species has economic importance by attacking nectarine (*Prunus persica* var. *nuscipersica* (L.) Batsch) causing damage to flower's ovarium and fruits (Hickel & Ducroquet 1998, Pinent *et al.* 2008). Other registers include *Rosa* sp., *Citrus aurantium* L., *Citrus limon* (L.) Burm. f., *Persea Americana* Mill., *Mangifera indica* L., *Zea mays* L. and *Medicago sativa* L. (Silveira *et al.* 2005). In Cerrado *F. condei* was found in the flowers of *Hancornia speciosa* Gomez in high densities and coexisting with staphilinidae beetles. Apparently there was no competition between these two taxa and while beetles fed on pollen thrips fed on floral tissues (pers. obs). Natural enemies of *F. condei* are unknown (Silveira *et al.* 2005).

***Frankliniella minuta* (Moulton)** – The only one individual sampled in our study does not permit us to state about its ecology and host associations and therefore we may not consider *B. malifolia* as a host plant for *F. minuta*. By the way is the first register of this species on Cerrado natural plants. *Frankliniella minuta* is a group of related species which were initially thought to be pollinators of daisy flowers in United States (Annand 1926). Indeed Asteraceae seems to be the main hosts for this group where they breed and feed (Mound & Marullo 1996). *Frankliniella minuta* distribution seems to be restricted to Americas where it was registered

from United States to Peru (Mound & Marullo 1996, Kirk 2002). In Brazil, *F. minuta* had been described based in a few specimens and the records were very doubtful (Monteiro 2002) with no information about its host plants. Later samples brought out three species of *minuta* group: *F. bertelsi* (De Santis, 1967), *F. distinguenda* Bagnall, 1919 and *F. oxyura* Bagnall, 1919, all of them common to Asteraceae (Pinent *et al.* 2005, Cavalleri *et al.* 2006).

***Frankliniella schultzei* (Trybom)** – This was also a low occurrence thrips species with only three individuals found on *P. tomentosa*. This polymorphic pollen feeding species is common to South America and has been seen in large numbers in southern Brazil on cultivated flower crops such as *Chrysanthemum* (Asteraceae) and *Gladiolus* (Iridaceae) (Mound & Marullo 1996). In Australia this species was recorded in eight natural plants in which *Malvaviscus arboreus* Cav. (Malvaceae) was considered as *F. schultzei* main host (Milne & Walter 2000, Milne *et al.* 2007). Although *F. schultzei* is sometimes considered a pest and a vector of Tospovirus (Sakurai 2004), it is also known as a predator of mites in Australia (Mound & Marullo 1996). *Frankliniella schultzei*, like *F. occidentalis*, does not seem to be specifically adapted for preying on mite eggs, even though such predation enhances performance and reproductive output of *F. schultzei* when constrained on leaves (Milne & Walter 2000). In Brazil most studies on *F. schultzei* regards its association with crops and the transmission of virus (Nagata & de Avila 2000, Monteiro *et al.* 2001) and its ecology and biology on Brazil natural plants are unknown. The three individuals found in *B. laevifolia* are not representative and this is not a major host *F. schultzei*.

***Frankliniella occidentalis* (Pergande)** – Like *F. minuta*, *F. occidentalis* was represented by only one individual and we may assume that no Malpighiaceae is a host for this species. Known as western flower thrips, this polymorphic, polyphagous and omnivorous thrips is the species which accounts for almost all of the published studies about these thrips. Such importance is not surprising given that this species is a major worldwide pest of agricultural and horticultural crops (Trichilo & Leigh 1986, Agrawal & Klein 2000, Morse & Hoddle 2006). The species causes considerable damage to a wide range of plants through feeding, oviposition and transmission of tospoviruses, and the financial cost of this spread has been enormous (Kirk & Terry 2003). *Frankliniella occidentalis* populations in crops are suppressed by predators like *Orius insidiosus* (Say 1832) (Hemiptera: Anthocoridae) (Funderburk *et al.* 2000) or by the use of chemicals (Helyer & Brobyn 1992), however the vagility, high reproduction rates and the intrinsic resistance of *F. occidentalis* to pesticides (Immaraju *et al.*

1992), makes this species difficult to control on integrated pest management programmes (Gaum *et al.* 1994, Jensen 2000, Bielza 2008). In Brazil it has been registered in many plants (Monteiro 2002). In *Byrsonima intermedia* its occurrence is rare and clearly this is not a host for this thrips species.

Halmathrips (Demetriothrips) – One more species to join the group of one individual sampled which does not permit assumptions about the ecology and host associations. So far, five species have been described in this genus; but few individuals exist to compare. Because so few specimens are available and because all of them are inadequately mounted for critical study it is not possible to assess their taxonomic or systematic positions with any confidence (Mound & Marullo 1996). In Brazil *Halmathrips* was found on the leaves of *Casearia decandra* Jacq. (Flacourtiaceae) (Pinent *et al.* 2005). The subgenus *Demetriothrips* was described by a single female from Mexico and no information about its ecology is available. In Brazil this is the first register for this subgenus. They probably all feed on the leaves of forest trees (Mound & Marullo 1996).

6.1.2 Sub Order Tubulifera, family Phlaeothripidae

The large individuals of suborder Tubulifera were well represented and if we take into account that most species in this suborder are fungivorous, its occurrence in flowers of Malpighiaceae is quite interesting. The suborder Tubulifera comprises the single and largest family within Thysanoptera, the Phlaeothripidae with about 3500 described species (Mound & Morris 2007). About two-thirds of the 700 species of thrips registered in Brazil are grouped in the suborder Tubulifera and only two species are considered to damage cultivated plants and none are known to be associated with any tospoviruses (Monteiro 2002, Mound 2002a). This family exhibits a wide range of life styles, particularly fungus feeding and gall forming (Mound & Marullo 1996). Members of this suborder have the ovipositor developed into a chute, the wings have no microtrichia and the veins are absent or vestigial (Richards & Davies 1988). Eggs are usually deposited horizontally, but more rarely vertically on the leaf or other surface on which the female is feeding. Tubuliferans have three pupal stages (Mound & Marullo 1996).

Pseudophilothrips – Surprisingly each one of the three Malpighiaceae in which this genera was found (*B. malifolia*, *P. tomentosa* and *B. laevifolia*) supports one different species of *Pseudophilothrips* (Laurence Mound pers. comm.) which account for four species worldwide

(Mound & Marullo 1996). Malpighiaceae are host for *Pseudophilothrips* because both adult and immature were found concomitant on the plant. This genus is known as leaf feeding and responsible for high levels of herbivory on their hosts (Hight *et al.* 2002, Cuda *et al.* 2009). The most remarkable case occurs in *Schinus terebinthifolius* Raddi, a native Anarcadiaceae from Brazil (Manrique *et al.* 2008). *Pseudophilothrips ichini* (Hood), damage the plant with their rasping-sucking mouthparts and frequently kill the new shoots. Because of this behavior, *P. ichini* is being considered as a biological control agent for *S. terebinthifolius* in Florida, where the past introduction of this plant is causing nowadays the loss of Florida natural vegetation (Cuda *et al.* 2008).

Liothrips – The single individual found in *P. tomentosa* accounted for the high diversity of thrips in this plant. This is one of the largest genera in the Thysanoptera with about 230 species (approximately 15 in Brazil), all leaf-feeding (Mound & Marullo 1996). In Hawaii *Liothrips urichi* Karny is a biological control agent against the weed *Clidemia hirta* (L.) D. Don (Melastomataceae) but predators like *Pheidole megacephala* (Fabricius) (Formicidae) and *Montandoniola moraguesi* (Puton) (Anthocoridae) reduces thrips effectiveness in controlling weed plants (Reimer 1988). In Brazil Varanda & Pais (2006) noted that *Liothrips didymopanax* Del-Claro & Mound (1996) was the main herbivore on *Didymopanax vinosum* (Cham. & Schltdl.) Seem. (Apiaceae) throughout the year in Cerrado causing necrosis and twisting of young leaves and these thrips were not affected by leaf defenses like the toughness and tannins. *Liothrips* are also implicated with galls (Monteiro 2002). This genus was registered in five plants in Southern Brazil (Pinent *et al.* 2005) and we showed that Malpighiaceae is not a host for this thrips.

***Haplothrips gowdeyi* (Franklin 1908)** – The single individual of this species was found in the flowers of *B. campestris*. Unlike the dark color of *Pseudophilothrips* and *Liothrips*, *H. gowdeyi* is brown in color and micropterous. This species is probably African in origin, judging from its frequency in collections from that continent. However it is now widespread around the tropics and one of the most common flower thrips in Caribbean (Mound & Marullo 1996). In Brazil it was found coexisting with three species of *Frankliniella* in chrysanthemum (*Dendrathera grandiflora* Tzvelev) crops in greenhouses (Carvalho *et al.* 2006) and it seems to be common for *H. gowdeyi* to be associated with other thrips species, particularly *Frankliniella* (Annadurai & Velayudhan 1986). In nectarine (*Prunus persica* var. *nuscipersica* (L.) Batsch) *H. gowdeyi*, together with other thrips, was responsible for causing

damage to flower's ovary and fruits (Hickel & Ducroquet 1998, Pinent *et al.* 2008); In maize the predator *Orius insidiosus* (Say) was found positively associated with *H. gowdeyi* and other two thrips species (Silveira *et al.* 2005). The significance of this co-occurrence of *H. gowdeyi* with other thrips species was not analyzed and deserves further attention.

6.2 Thrips community and host plant preferences

Studies of thrips communities are very rare and usually researchers focus on only one or a few species of thrips (Agrawal *et al.* 1999, Seal *et al.* 2006), the exception accounting for pest thrips in crops where more than one species is involved (see Carvalho *et al.* 2006, Dreistadt *et al.* 2007). In an inventory conducted in Southern Brazil, Pinent *et al.* (2005) found three coexisting thrips species in *Banisteriopsis metallicolor* (A. Juss.) O Donell & Lourteig. (Malpighiaceae) and most diversity occurred in Asteraceae, recognizably to host several thrips species (Mound 2005). Furthermore in Pinent *et al.* (2005) the only Malpighiaceae present, from 72 plants analyzed, was *B. metallicolor* which hosted three species of thrips. This contrasts with our findings in the present study since the least number of thrips species found in a Malpighiaceae was six and the maximum was ten species, indicating the great importance of these plants in Brazilian Savanna as pool of thrips diversity, relative to other biomes.

The coexistence of many thrips species in a same microhabitat is quite common and may involve partitioning of resources like food, shelter and places to oviposit (Hickel & Ducroquet 1998, Pulliam 2000, Sakai 2001, Silveira *et al.* 2005, Pinent *et al.* 2008). Malpighiaceae flowers are a homogeneous habitat; their flowers are very similar either in structure as in food resources offered for thrips like pollen and floral tissues (Del-Claro *et al.* 1997). The ways in which species within ecological communities partition available resources among themselves is a major determinant of the diversity of coexisting species. All else being equal, a community with more resource sharing, or greater niche overlap, will clearly support more species than one with less niche overlap (Pianka 1974).

Heterothrips peixotoa was the most abundant thrips in all plants and may be considered the species to make the best use of Malpighiaceae flowers, being a stronger competitor relative to other species. Generally in communities of thrips, species of the genus *Frankliniella* are the most abundant accounting in some cases for more than 90% of the species sampled (Pearsall & Myers 2001, Carvalho *et al.* 2006) demonstrating either a good adaptation to its habitat, high reproductive rates and better invasive and competitive behavior than the other species (Morse & Hoddle 2006). However, in Malpighiaceae the situation is

opposite; *H. peixotoa* was the main herbivore in relation to the other thrips in all Malpighiaceae studied, its dominance was constant and not exceeded by any other species. Usually the dominance of species varies over time so allowing many species to coexist. Cho *et al.* (2000) studied the spatial and temporal occurrence of three thrips species on tomato and concluded that thrips shared the same space on the plants (upper and lower plant strata) but on foliage, the thrips feeding resources, *Frankliniella fusca* (Hinds) was predominant while few *F. tricolor* (Fitch) and *F. occidentalis* were observed. This dominance changed as the season progressed and *F. occidentalis* became dominant one month later.

Most cases of interspecific competition are indirect interactions between species mediated by the influence of one species in the limiting resources of another species (Pulliam 2000). In relation to reproduction, by avoiding sites already crowded with eggs of *H. peixotoa*, females of other species might be forced to oviposit on other plants or in resources of lower nutritional quality for their offspring thus bringing about a density-dependent regulation of population size (Jaenike 1990).

In Malpighiaceae, except for *H. peixotoa*, the dominance of thrips species changed over time depending on the plant, and the causes may be in the ecology and host ranges of the species. For instance, *F. condei* was well represented in all plants except in *Byrsonima intermedia*. This plant flowers in October in the beginning of the rainy season in the same occasion that *Hancornia speciosa* Gomez (Apocynaceae) starts blooming. This Apocynaceae is a major host of *F. condei* and large populations are found within its flowers until January, when flower production ceases (Alves-Silva & Del-Claro unpubl data). Moreover *F. condei* was also found in abundance in *Tocoyena formosa* (Schum. & Schlecht) Schum (Rubiaceae) and *Himatanthus obovatus* (Müll. Arg.) Woodson (Apocynaceae) (pers. obs). All these species share the similarity of large white flowers with long tubular corolla and presence of scent. The low numbers *F. condei* in *Byrsonima intermedia* may be explained by the high invasive and the potential of this thrips to occupy new available microhabitats. Such statement was corroborated by the fact that in *B. campestris*, the following plant in the chain of Malpighiaceae sequential flowering, *F. condei* was abundant as at this period the other host plants mentioned above do not produce flowers. Changes in host plants may be important in determining which plant an insect will or will not choose. The simplest but perhaps most common reason why certain plants are not preferred by a given herbivore may be related to phenologies (Barbosa 1988). The overlapping of flowering between *Byrsonima intermedia* and *H. speciosa* and the preference of *F. condei* for the latter is a reflection of the thrips species lifestyle, a specific response to a specific set of selective forces. *Frankliniella condei*

host changing puts Malpighiaceae as major hosts in part of the year and minor hosts in other. Also, in this context Malpighiaceae has a significant importance in the maintenance of species such as *F. condei* which change their hosts according the availability of other resources in time and space.

6.3 Resource and predators

Apparently *Heterothrips* species in Malpighiaceae are also common in other parts of the world. In Costa Rica several species of *Heterothrips* were found in the flowers of common *Byrsonima* and other species of Malpighiaceae (Mound & Marullo 1996). The conservative aspect of floral morphology in all Malpighiaceae, with five petals and sepals forming a chamber, may have profound implications on thrips occupation in the flowers. For example, to leaf-mining or bud-boring insects, plant anatomy rather than plant phytochemistry or phylogenetic relationships may determine host range (Powell 1980). Not only *H. peixotoa*, but all thrips species may benefit of living under the sepal chambers. This microhabitat offers escape from predators and also protection against environment (Del-Claro *et al.* 1997, Mound & Terry 2001) indicating that both bottom-up and top-down forces are important in structuring thrips communities (see Hunter & Price 1992). There is a wide acceptance that thrips populations are limited by bottom-up forces (food or resource) (Mound 2005) but enemy free space may be also a selecting force to make Malpighiaceae suitable for thrips living.

In field observations *Pseudophilothrips* were the species most susceptible to predation. In some occasions *Pseudophilothrips* stayed for long periods on the petals and its contrasting dark color on this surface was very conspicuous. It could either expose the individuals to predators as well as provoke desiccation through direct sun exposition. However no predator attack to these thrips was observed and desiccation presumably did not take place because these thrips species possesses a tough cuticle which may minimize the effects of sunlight and heat. The most likely predators, jumping and crab spiders, did not spend their efforts on *Pseudophilothrips*, possibly because thrips are low rewarding resources (Charnov 1976, Pyke *et al.* 1977) or because their long setae along the body are defense mechanisms against predators, the same strategy used by caterpillars (see Hare & Eisner 1993). Observations indicated that predators played a negligible role in controlling all thrips populations, not only *Pseudophilothrips*. Natural enemies of thrips are not well known and besides some Hemiptera and Hymenoptera (Dreistadt *et al.* 2007) in crops and greenhouses little is known about thrips predators in natural ecosystems.

According to Morse & Hoddle (2006) most resident natural enemies that attack thrips are generalist predators and even those which presents some degree of specificity, such as hymenopteran parasitoids that attack thrips eggs, (*Megaphragma* spp.) (Steyn *et al.* 1993, Bernardo & Viggiani 2002, Tamo *et al.* 2002) and larvae (*Ceranisus* spp.: Eulophidae) (Castineiras *et al.* 1996) generally inflict low levels of mortality (Hessein & Mcmurtry 1988). But the most likely factor affecting the susceptibility to natural enemies is the life cycle of thrips. Usually, eggs are laid inside plant tissues; there are two free-living larval instars; two or three pupal stages that pupate within protective cracks on branches or in soil, buried beneath the host plants; and winged vagile adults (Mound & Marullo 1996). Under such conditions, a guild of generalist natural enemies would need to be simultaneously available in several distinct habitats (e.g., arboreal to attack thrips larvae and adults exposed on leaves, and subterranean to attack pupal stages in the soil) to minimize the number of life stages benefiting from refuge in natural enemy free space. In addition, the “boom and bust” ecology, patchy distribution of high-density populations, and occurrence of life stages that occupy widely varied niches make invasive thrips an unstable resource for resident natural enemies (Morse & Hoddle 2006). Obrist *et al.* (2005) have shown that pupal and prepupal thrips, which are restricted in their mobility, were killed most successfully by *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) whereas older larvae and winged adults were more likely to escape the attacks of predator and caught less successfully.

The behavior of both predator and prey is a crucial factor influencing predation and in Malpighiaceae. The fluctuation of thrips populations along the year, the movements between plants, the concealed habitats under the sepals, the small size and the flying-at-any-disturbance behavior of these insects makes them hard to find and to capture by predators. Parasitoids of thrips are species-specific (Triapitsyn 2005) and to succeed in Malpighiaceae, parasitoids would have to be able to enter the tiny chambers where thrips live and be lucky to find the certain species to parasitize, like the genera *Frankliniella* and *Thrips* (Tagashira & Hirose 2001) but our observations showed no other arthropod species than thrips inside flower chambers. The last but not less important to be mentioned is the defensive behavior of some thrips in the form of anal exudates or volatile unpleasant odors (Tschuch *et al.* 2002).

In Malpighiaceae ants are the main predators of thrips and Fernandes *et al.* (2005) showed that in *Byrsonima crassifolia* (Linnaeus) H. B. K. (Malpighiaceae) ants exerted strong influences on the structure, composition, and dynamics of phytophagous insect communities, including thrips, diminishing the damages of these insects through the herbivory (see Del-Claro *et al.* 2006). Ants observed in our study were too big to enter the flower chambers to

prey on thrips and foraged rather on the leaves in order to get the nectar from extrafloral nectaries. The impact of natural enemies may favor host specialization in phytophagous insects but as a single host does not produce flowers all along the year, thrips are forced to look for other flowering plants. The similarity between habitats may facilitate the occupation because previous learning may maximize the use of this new habitat and save energy which otherwise would be spent to know and explore this new habitat (Jaenike 1990). Therefore the conservative aspect of flowering Malpighiaceae is so important either in providing food as well as enemy free spaces (Del-Claro *et al.* 1997). So it is common to find so many thrips and often the same species in sequential flowering Malpighiaceae.

6.4 Polyphagy

Sequential flowering Malpighiaceae offer a predictable and useful microhabitat for thrips maintenance along the year because the different plants bloom in a series that allow thrips to migrate between hosts where it can find food and protection. However, not all species of thrips migrate from plants. Of all the thrips species common to the five Malpighiaceae, only *H. peixotoa* abundantly infested all plant species, while *Frankliniella condei* and *Scutothrips nudus* also occurred in all plants, but in low abundance sometimes.

The higher *H. peixotoa* abundancy shows that this species is able to feed and develop successfully on all five plant species, suggesting that it is a Malpighiaceae generalist herbivore. *Peixotoa tomentosa* and *B. laevifolia* presented the higher rates of *H. peixotoa* infestation, indicating that these two plants are the major hosts while the other three plants are placed as minor ones. The other thrips species in which the approach major/minor hosts are suitable were *F. condei* and *S. nudus* since adult and immature of these species occurred in all plants. Their indexes of dominance shows that for *F. condei* its major hosts were *Banisteriopsis malifolia* and *B. campestris* while for *S. nudus* the major host was *B. malifolia*. All these three thrips species may be considered polyphagous as herbivorous species tend to have this designation simply on the basis of incidence records from numerous plant species (Zalucki *et al.* 1986). Polyphagy is a main ecological feature for these thrips because it allows the migration from plants whenever there are resources available so population can persist in time and space in a variety of hosts. In this view, sequential flowering Malpighiaceae serve as a predictable reservoir of food in which thrips may continue to make use of, independently of the flowering species. This statement is according to Mound & Teulon (1995) who consider polyphagous organisms to evolve local 'preferences' to suite local plant species availability.

That may be the reason why we found great diversity of thrips in Brazilian Savanna Malpighiaceae and thrips are so successful in exploring these plants.

According to Milne & Walter (2000) polyphagy in thrips represents a survival mechanism against periodic stressful conditions but may also mean an adaptation for a species to exploit a diversity of sporadically and unpredictable abundant hosts opportunistically. Such an adaptation can be considered a functional equivalent of the other mechanisms used by various thrips species to span unfavorable periods, namely aestivation and diapause (Ananthakrishnan 1993, Van Houten *et al.* 1995, Nakao 1998). Thrips in our study breed throughout the year and do not overwinter so Neotropical sequential flowering provides habitats and food so thrips do not need to enter the diapause.

6.5 Seasonality and phenology

Despite its uniqueness, thrips movements and maintenance in different seasons along the year has not caught the attention of thysanopterologists and there are few data available on it. The first and most time consuming study was conducted by Davidson & Andrewartha (1948) who recorded *Thrips imaginis* Bagnall, 1926, population during 14 years in two varieties of roses in Australia. They concluded that thrips populations come and go from flowers more or less in waves and this may be due to inherent gregariousness of the species. Also, the species were more common in the localities where flowers were abundant and were highly influenced by weather; the population was high in summer and low in winter. Relations with rain, moisture and temperature were considered to increase thrips populations. More recently Leite *et al.* (2002) did not observe relation between *Scirtothrips manihoti* Bondar, 1924 population on cassava (*Manihot esculenta* Crantz var. Cacao) with rainfall, temperature and relative humidity. Thrips populations were rather controlled by senescence of the plant and predators than environmental factors. On *Brassica oleracea* L. var. *acephala*, *Thrips tabaci* Lind. populations tended to increase as the mean temperature increased while heavy rain and high humidity were deleterious to these insects (Leite *et al.* 2005). In *Prunus persica* var. *nuscipersica* (L.) Batsch thrips are associated with years of dry winter (Hickel & Ducroquet 1998). In Brazilian Savannah thrips were related negatively with relative humidity. However, since we analyzed five different host plants thrips might be related primarily with a particular host and not with the climate solely. Data shows that both climate and host are apparently responsible for thrips population rates given that thrips were more abundant in *P. tomentosa* and *B. laevifolia*. These plants flowers in wet season when the rains are rare and relative

humidity is low. In cerrado vegetation rains may be a strong force reducing small herbivores abundance (Del-Claro & Oliveira 2000).

6.6 The importance of sequential flowering and major hosts

Since a high proportion of plants expend their reproductive energy in single brief annual pulses, the animal community dependent on flower resources can be expected to follow the cyclicity of flowering and be reduced during the intervening periods, like pollinators such as bees, butterflies and also thrips attracted to their foraging plants (Appanah 1993, Mound & Terry 2001). For instance, in temperate zone the staggered annual flowering, instead the sequential flowering, seems to be common. It comprises a progression of annual population patterns in a sequence of species that extends for only part of the year. For example, in a lowland tropical forest at La Selva, Costa Rica, beetle pollinated species flower in a staggered sequence for part of the year (Young 1986). During the non flowering interval or gap the beetles are dormant (Newstrom *et al.* 1994). Marquis & Braker (1994) discussed that in tropical forests host plant seasonality is one of the main forces structuring the herbivores communities. In the present study, the seasonal variation and sequential flowering of Malpighiaceae followed by thrips species migration suggest that it is also applicable in the tropical savannas.

In Neotropics sequential flowering is common (Frankie *et al.* 1974, Machado & Semir 2006, Marques & Lemos Filho 2008) and considering the level of competition for pollinators during a general flowering the sequential flowering noted so far among trees with close floral affinity may be a much more widespread phenomenon (Appanah 1993). As the five Malpighiaceae in this study are sympatric and flowers are very similar, competition for pollinators would be expected if the species bloomed at the same time. Competitive plant effects will commonly occur when a shared pollinator forages so as to transfer pollen interspecifically, since this will reduce the availabilities of effective pollinator movements, pollen, and stigmatic surfaces to individuals of both species and may thereby limit their reproductive output. Such effects will occur even if each plant species has additional pollinators not shared by the other (Waser 1978). The timing of plant reproductive cycles affects plant–plant interactions such as competition for resources or for pollinators (Newstrom *et al.* 1994). This competition for pollinators has often been suggested as the primary selective force molding flowering schedules (Brody 1997). For associated animal community, sequential flowering plants represent a predictable and continuous source of resources

(Siqueira Filho & Machado 2001). Again, our data suggest that not only plant-pollinator system is influenced by phenology and seasonality, but also plant-herbivore relationships.

Thrips have the capacity to increase their populations rapidly in response to the availability of a massive source of flowers (Bawa & Hadley 1990). Mixed continual flowering patterns have dramatic influence on amplitude peaks of thrips. This pattern has been described for thrips pollinated species in Malaysia. After many years of sporadic light flowering, a staggered but slightly sequential flowering of six *Shorea* (Dipterocarpaceae) species burst into full, high intensity flowering. At this time, the short-lived thrips pollinators had an exponential population explosion (Chan 1981, Appanah 1985). *Shorea* species are thrips major hosts and at other times, when these hosts are not available, other species that flower more frequently at low or intermediate amplitudes maintain the thrips at low population levels (Appanah 1985, Bawa & Hadley 1990, Newstrom *et al.* 1994). Malpighiaceae also present the same features as *Shorea* species such as increasing thrips populations and serve as major hosts for some thrips species, but unlike *Shorea* which flowers only in part of the year, the sequential flowering Malpighiaceae provides habitats for thrips maintenance during the entire year. Moreover, the destination of *Shorea* thrips in the gaps of flowering is unknown whereas for Brazilian savanna Malpighiaceae at least for *H. peixotoa*, *F. condei*, *S. nudus* their whereabouts are known.

Davidson & Andrewartha (1948) noted that *Thrips imaginis* Bagnall populations presented annual fluctuations related to availability of host plants. During the spring, fields and gardens harbored flowering plants which provided favorable situations for *T. imaginis*. During the summer these plants disappeared and the insects died almost completely. The survivors were to be found in restricted local situations scattered thinly throughout the area of distribution of the species, in minor hosts. Therefore major hosts are an essential and limiting factor in maintaining thrips populations and have direct and undoubted implications for conservation efforts in areas where the flora is endangered like Cerrado in Central Brazil (Myers *et al.* 2000). The group of five sequential flowering Malpighiaceae analyzed in this study has not been found elsewhere in plant inventories in cerrado vegetation. Usually these inventories are made in protected reserves and accomplish mostly trees excluding shrubs and vines from analysis and the Malpighiaceae eventually sampled, are mostly *Byrsonima* (Silva *et al.* 2002, Assunção & Felfili 2004). It is really surprising the fact that *Banisteriopsis* and *Peixotoa* are so rare in other Cerrado areas (Urso-Guimarães & Scareli-Santos 2006) as in ours these plants are so abundant. Cerrado biota is not homogeneous, so additional distribution data for different groups of organisms must be collected and organized in a

retrievable way to help conservationists to determine whether there are additional unidentified subareas of endemism (Silva & Bates 2002).

If thrips, particularly *H. peixotoa*, are dependent of sequential flowering to maintain its population along the seasons, the lack of any plant may have strong consequences because thrips would be at least two months without host and thrips adult life span is about one month (Murai & Loomans 2001). The register of this thrips species in plants other than Malpighiaceae (Pinent *et al.* 2005) suggests wider habit exploitation. Also it has been argued that polyphagy should favor risk spreading, with females laying their eggs on many host plants in order to ensure that at least some offspring survive. Such a strategy, if beneficial, could lead to the acceptance of a greater variety of host species for oviposition (Jaenike 1990) and thrips could survive in small number in these minor hosts in the lack of the major ones.

The fact that some species matter more than others becomes especially clear in the case of keystone species which refers to species whose loss has a disproportionate impact on the community when compared to the loss of other species (Mills *et al.* 1993). We still cannot assume Malpighiaceae as keystone species for thrips given that no large scale samplings were made in other plants to compare. Yet most ecosystem processes are driven by the combined biological activities of many species, and it is often not possible to determine the relative contributions of individual species to ecosystem processes (Loreau *et al.* 2001, Naeem 2002, Hooper *et al.* 2005). However our results and our knowledge of thrips occurrence so far, particularly *H. peixotoa*, allow us to propose that the community of these sequential flowering plants have a significant and noteworthy role in thrips time and space maintenance.

It would be useful to learn how thrips community would adapt itself to a change in its staple food resources through availability in time and space. Would the diversity of potential food species be a factor determining whether thrips could remain, feeding on substitutes, or whether they would have to move to other habitats or plants? This approach will be the aim of future studies and may elucidate different aspects of thrips biology and ecology and enrich our knowledge about these minute and ubiquitous insects.

7 CONCLUSION

In this study we showed that sequential flowering Malpighiaceae has an important role in the maintenance of thrips community throughout the year, especially for *H. peixotoa*, the most abundant species in all samplings. The richness and diversity recorded is the highest ever sampled for thrips living in a group of related taxonomic plants, possibly because the conservative aspect of Malpighiaceae flowers provide food resources and protection against

predators. Large flowers support more thrips and the environment may be as important as the plant flowering phenology in maintaining thrips in time and space. Future studies will attain on the damages or benefits of thrips in their hosts as well as their occurrence on other common plants on Brazilian Savanna vegetation.

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