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INTERAÇÕES ENTRE FORMIGAS, FRUTOS E SEMENTES EM UM FRAGMENTO DE MATA ATLÂNTICA NO SUL DA BAHIA – BRASIL

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Dissertação apresentada para obtenção de título de mestre em Ecologia e Conservação da Biodiversidade, à Universidade Estadual de Santa Cruz

Área de concentração: Ecologia e Conservação de Comunidades, Ecossistemas e Paisagens

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Ilhéus-BA, 17/02/2011

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"Se não houver frutos, valeu a beleza das flores;

se não houver flores, valeu a sombra das folhas;

se não houver folhas, valeu a intenção da semente."

Henfil

e se não houve dispersão...

valeu a intenção das formigas!

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Sumário

RESUMO

As interações entre formigas e diásporos (i.e. unidade de dispersão que pode ser tanto o fruto quanto a semente) não mirmecocóricos são muito comuns em florestas tropicais, o que se deve principalmente à abundância de frutos e da mirmecofauna. As formigas coletam os diásporos no solo ou os removem das fezes dos dispersores primários, geralmente vertebrados, podendo desempenhar um papel importante como dispersoras secundárias destes diásporos. Nesta segunda fase da dispersão, as formigas podem afetar a sombra de sementes, influenciando no recrutamento e na distribuição espacial das espécies vegetais. No presente estudo as interações formiga-diásporo foram investigadas em um importante remanescente de Mata Atlântica localizado no sul da Bahia. Foram demonstrados alguns dos efeitos que estas interações podem causar nas partes envolvidas. As formigas interagiram com diásporos de diversos tamanhos. Frutos maiores foram consumidos sem serem removidos. Os frutos menores por sua vez, foram tanto removidos quanto consumidos no local. A atividade de limpeza realizada pelas formigas pode aumentar a germinação de algumas espécies vegetais. As formigas removem rapidamente os diásporos disponíveis no solo, diminuindo a chance destes serem predados por vertebrados. A utilização de mais de um dispersor garante á planta maior chance de sucesso no recrutamento de novos indivíduos. Por outro lado, para as formigas, a grande diversidade de frutos carnosos disponíveis no solo pode oferecer nutrientes importantes para sua dieta.

Palavras-chave: Mirmecofauna, dispersão de sementes, diásporos não mirmecocóricos

ABSTRACT

Interactions between ants and diaspores (i.e. dispersal unit that can be the fruit or seed) nonmyrmecochorous are very common in tropical forests, because of fruits and ants abundance. Ants can collect diaspores from the forest floor or remove them from feces of primary dispersers, mainly vertebrates. Ants can develop a role as secondary seeds dispersers of species primarily dispersed by vertebrates. In phase two of seed dispersal, ants may affect seed shadow, influencing recruitment and spatial distribution of plant species. In this study we investigated ant-diaspore interactions in Atlantic Rain forest remnant in southeastern Bahia. We demonstrated some of the effects of these interactions to the involved species. Ants interacted with a great number of diaspores presenting different sizes. Large diaspores were consumed in the local and without removal. The small diaspores can be removed by ants but also be consumed in the place. Ant cleaning activity can enhance seed germination of some plant species. Ants rapidity removed available diaspores from the forest floor, decreasing the chance of seeds be predated by vertebrates. Plants dispersed by more than one dispersal agent may guarantee better chances in the recruitment of news individuals. For ants, a great diversity of fleshy fruits available on the forest floor may offer important nutrients for their diet.

Key words: Mirmecofauna, seed dispersal, diaspores nonmyrmecochorous

INTRODUÇÃO

A dispersão de sementes é um passo essencial no ciclo de vida das plantas para o recrutamento de novos indivíduos (Howe & Smallwood, 1982). Ao longo do processo coevolutivo, os animais tornaram-se peça chave na dispersão de sementes que possui efeitos relevantes na densidade demográfica e dinâmica populacional das plantas (Jordano & Godoy, 2002). O processo de dispersão pode ser constituído de uma etapa ou mais etapas. A presença de mais de um agente dispersor (e.g. primário e secundário) torna o sistema de dispersão mais complexo, porém pode garantir à planta um maior sucesso de recrutamento (Vander Wall & Longland, 2004).

Na dispersão primária de sementes por formigas, ou mirmecocoria, as plantas mirmecocóricas apresentam um apêndice conhecida como elaiossomo, rico em lipídios, proteínas e açúcares, e usado pelas formigas como recurso alimentar e como suporte para carregar a semente até o ninho, onde é consumido por larvas e operárias (Beattie, 1985; Bennett & Krebs, 1987; Handel & Beattie, 1990). Cerca de 90 % das espécies vegetais mirmecocóricas se concentram em regiões áridas como os desertos australianos e a região dos fynbos sul africanos onde tal interação prevaleceu como uma boa estratégia evolutiva para as plantas (Westoby & Hughes, 1991). Dentre as vantagens da mirmecocoria para as espécies vegetais destacam-se a dispersão direcionada, o escape de predadores e a remoção do elaiossomo que pode aumentar a germinação das sementes (Beattie, 1985). Embora as vantagens desse mutualismo para as formigas ainda não seja muito explorada, aparentemente o elaiossomo pode influenciar nas resões sexuais das colônias (Morales & Heithaus, 1998).

Em florestas tropicais, as interações entre formigas e diásporos (i.e. unidade de dispersão que pode ser tanto o fruto quanto a semente) não mirmecocóricos são muito comuns, porém só ganharam mais evidência nas duas últimas décadas. (Levey & Byrne, 1993; Pizo et al., 2005). As formigas podem coletar diásporos no solo após sua queda da planta mãe ou ainda removê-los das fezes dos dispersores primários, geralmente vertebrados. As interações formiga-diásporo têm sido comumente observadas e estudadas na Mata Atlântica. Em parte, isso se deve à grande quantidade de frutos e sementes encontrados no chão da mata e também à rica e abundante comunidade de formigas que forrageiam em serrapilheira (Medeiros & Morretes, 1997; Pizo & Oliveira, 1999).

Pesquisadores interessados nos possíveis benefícios da dispersão de sementes não mirmecocóricas por formigas vêm testando hipóteses, sobre as vantagens dessa relação, geralmente aceitas nos estudos de mirmecocoria (Levey & Byrne, 1993; Howe & Miriti, 2004). A dispersão direcionada de diásporos não mirmecocóricos realizada pelas formigas, pode propiciar a deposição das sementes em um local mais adequado à germinação. Geralmente no lixo do formigueiro, apresenta mais nutriente devido à presença de restos de presas e materiais orgânicos descartados pela colônia, e proporcionar à semente maior proteção contra predadores e patógenos (Passos & Oliveira, 2004). Estas interações podem ainda aumentar o sucesso de estabelecimento das sementes, principalmente nos ambientes onde os solos apresentam poucos nutrientes, à exemplo da Caatinga (Leal & Oliveira, 1998).

Um fator muito relevante para que a dispersão secundária de espécies vegetais não-mirmecocóricas ocorra é a relação entre o tamanho da formiga e o tamanho do diásporo (Ness et al., 2004). Nos ambientes tropicais onde há uma grande diversidade de frutos, geralmente o tamanho do diásporo e a distância percorrida pela formiga são inversamente correlacionadas (Christianini et al., 2007). Diante da variação do tamanho corpóreo que se encontra nas operárias de espécies de formigas, na maioria dos estudos observa-se uma concentração de sementes depositadas a pequenas distâncias e poucas sementes dispersas a maiores distâncias (Gómez et al., 2005). As maiores distâncias de dispersão de espécies não mirmecocóricas são observadas, sobretudo, para as formigas da subfamília Ponerinae, que além de estarem entre as maiores formigas da família também forrageiam a maiores distâncias em relação ao formigueiro (Passos & Oliveira, 2003). Além do tamanho do diásporo as características químicas do diásporo podem influenciar na seleção deste pelas formigas. Apesar da grande variedade de componentes nutricionais existentes nos frutos carnosos explorados pelas formigas, predomina a preferência por aqueles que possuem maior quantidade de lipídios (Pizo & Oliveira, 2001), que são também nutrientes comuns nos elaiossomos dos diásporos mirmecocóricos.

Dentre os ambientes neotropicais estudados é na Mata Atlântica que as interações formiga-diásporo parecem ocorrer com mais freqüência e também envolver o maior número de espécies (Dalling et al., 1998; Leal & Oliveira, 1998; Pizo et al., 2005; Christianini et al., 2007). Mesmo assim, ainda são poucos os trabalhos que comparam os padrões das interações em regiões distintas no mesmo ecossistema. Nesse sentido a própria variação natural na composição local tanto de espécies de formigas quanto de espécies vegetais pode implicar na observação de padrões de interações ainda não descritos, tanto para a comunidade local quanto para o bioma como um todo.

1.1 Área de Estudo

O estudo foi conduzido na Reserva Biológica de Una (151100 S, 391030 W), situada no município de Una e aproximadamente a 40 km ao sul de Ilhéus (Figura 1). A unidade de conservação foi criada em 1980, inicialmente com 11.400 ha e, após algumas ampliações atualmente totaliza uma área de 18.200 ha (ICMBio). As coletas do presente estudo foram realizadas na porção leste da reserva, próxima à sede do Maruim, totalizando uma amostragem de 20 % do total da reserva.

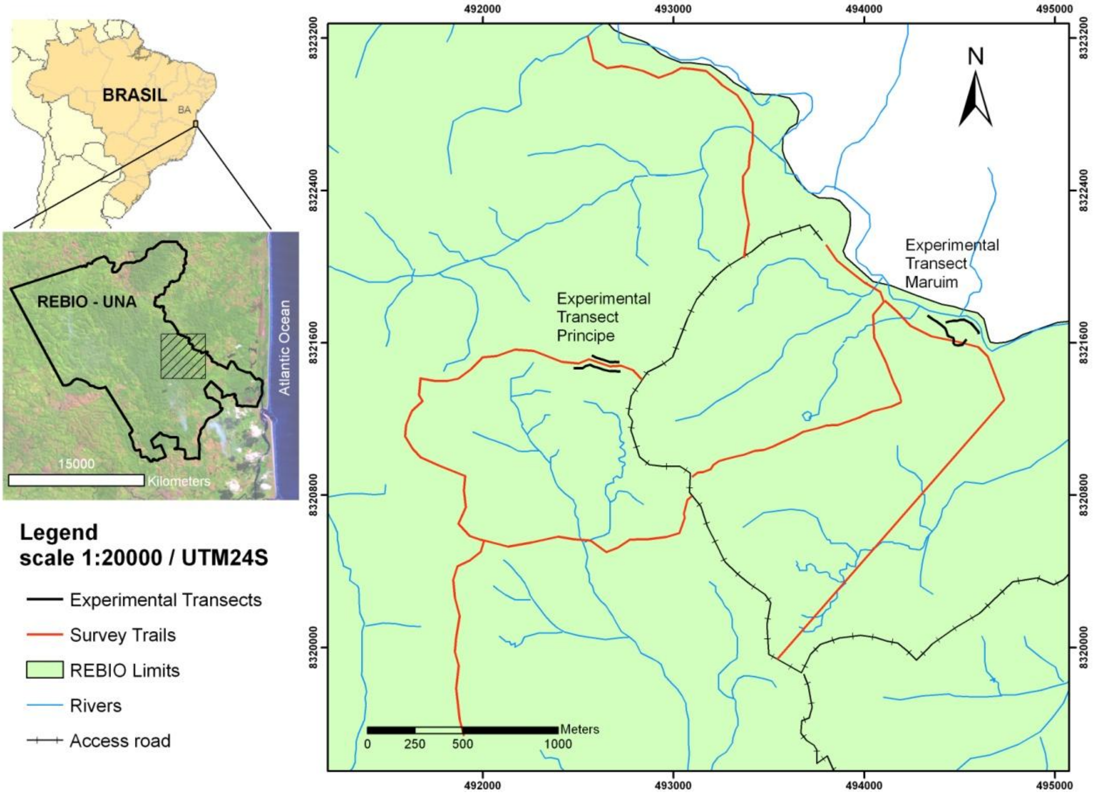

Figura 1. Localização da Reserva Biológica de Una no município de Una ao sul do município de Ilhéus, sul da Bahia, Brasil. No destaque a área total abrangida pelo estudo onde as linhas vermelhas representam trilhas utilizadas para amostragem das interações formiga-diásporo mensais. Em linhas pretas estão os transectos utilizados para as amostragens sistemáticas das interações e para os experimentos de remoção.

O clima da região segundo a classificação de Köpen, é do tipo Af, quente e úmido, com precipitações médias anuais de 2000 mm/ano, média anual de 24 °C, com pouca sazonalidade (Mori & Boom, 1983), podendo ter de um a dois meses secos com apenas 5 % da precipitação anual (Roeder, 1975).

O tipo de solo que predomina na área de estudo (i.e porção leste próxima à faixa litorânea) é Podzólico arenoso, com baixa fertilidade, onde se desenvolve a floresta de Tabuleiro (Amorim et al., 2008). Formada por um mosaico de tipos de vegetação, a paisagem é composta por remanescentes de floresta madura, florestas secundárias iniciais a avançadas, capoeiras e cabrucas (Mariano Neto, 2004). A vegetação da reserva apresenta grande diversidade e taxas relativamente altas de endemismos. Das 420 espécies vegetais estudadas por Thomas et al. (1998), 28% foram consideradas endêmicas da Mata Atlântica Bahia - Espírito Santo e 7,4 % representam espécies da disjunção Bahia -Amazônia. As famílias vegetais mais ricas na área são Myrtaceae, Leguminosae, Sapotaceae, Lauraceae, Chrysobalanaceae e Euphorbiaceae. Nas áreas secundárias as famílias mais abundantes são Melastomataceae, Malpighiaceae e Cecropiaceae (Mariano Neto, 2004).

Um estudo preliminar da comunidade de formigas da Reserva Biológica de Una revelou 183 espécies, o que deve representar apenas um terço de toda a mirmecofauna esperada para a Reserva (Delabie et al., 1997). Myrmicinae é a subfamília mais rica em espécies, seguida de Dolichorerinae e Ponerinae.

REVISÃO BIBLIOGRÁFICA

1. Mutualismo e dispersão de sementes por formigas

Considerado um dos grupos animais mais abundantes do mundo, as formigas (Hymenoptera: Formicinae) estão presentes em quase toda extensão terrestre com exceção dos pólos (Hölldobler & Wilson 1990). Estima-se que existam entre 25.000 e 30.000 espécies, porém apenas 12.500 espécies de formigas foram descritas até o momento (Lach et al., 2010)sendo responsáveis por cerca de 10 a 15% de toda a biomassa dos ecossistemas terrestres (Beattie & Hughes, 2002). Acredita-se que na floresta amazônica formigas e cupins representem aproximadamente 30 % de toda a biomassa animal (Fittkau & Klinge, 1973). Dentro das comunidades, as formigas desempenham papéis ecológicos importantes como competidores, predadores, presas, decompositores, mutualistas, jardineiros e engenheiros do solo (Lach et al., 2010).

As interações entre formigas e plantas são consideradas bastante antigas e apresentam diferentes relações de custo-benefício (Delabie et al., 2003). Isso se deve ao fato de tais interações terem evoluído ao longo de um contínuo entre o antagonismo, como no caso da herbivoria, e o mutualismo, a exemplo da dispersão (Rico-Gray & Oliveira, 2007). Devido ao hábito onívoro da maioria da mirmecofauna, as interações planta-formiga geralmente são facultativas e dificilmente envolvem coevolução interespecífica. Consequentemente, a diversidade de formigas interagindo com certa espécie vegetal pode variar significativamente em curtas distâncias geográficas (Whitney, 2002).

Ao longo da evolução da mirmecocoria, podem ter ocorrido o desenvolvimento de adaptações anatômicas, químicas e fenológicas especiais nas plantas, potencializando a atratividade para as formigas e com isso aumentando a eficiência na dispersão de sementes (Bennett & Krebs, 1987). As espécies vegetais tipicamente dispersas por formigas possuem um apêndice na testa da semente chamado de elaiossomo. Segundo Dunn *et al* (2007), devido ao fenômeno de convergência evolutiva, o elaiossomo é observado em mais de 3.000 espécies de plantas inseridas em 80 famílias. Esse apêndice é composto por ácidos gordurosos similares aos encontrados em invertebrados considerados presas, que atraem principalmente formigas onívoras (Hughes & Westoby, 1992; Levey & Byrne, 1993). Estudos recentes constataram que o uso de elaiossomo na alimentação pode aumentar a taxa de produção de indivíduos sexuados na colônia, sendo este o principal benefício da utilização desse recurso pelas formigas (Bono & Heithaus, 2002).

O processo de dispersão de espécies mirmecocóricas inicia quando as formigas coletam as sementes utilizando o elaiossomo como suporte, carregando-as até o ninho onde o mesmo é utilizado de alimento por larvas e adultos (Beattie, 1985). Após consumo do elaiossomo a semente é descartada intacta no lixo do formigueiro onde geralmente germina e se desenvolve até se tornar um indivíduo adulto (Bennett & Krebs, 1987). As subfamílias Formicinae, Myrmicinae, Ponerinae e Dolichoderinae são as principais envolvidas nessa interação (Beattie & Hughes, 2002). Para a planta, a remoção das sementes com elaiossomo pelas formigas pode de ser a principal etapa da mirmecocoria e peça-chave para o sucesso desse mutualismo (Garrido et al., 2009).

Cerca de 90% das espécies vegetais mirmecocóricas se concentram nos fynbos Sul Africanos e nas áreas dominadas por vegetação esclerófila da Austrália; outras pequenas parcelas encontram-se nas zonas áridas da América do Norte (Berg, 1981). Predominantemente, observa-se que as espécies vegetais adaptadas para a dispersão por formigas encontram-se em ambientes mais secos e com solos mais pobres. Westoby et al. (1991) acreditam que para a planta custa menos produzir sementes com elaiossomo do que com frutos carnosos adaptados para a dispersão por vertebrados.

Ao longo de algumas décadas, diversos pesquisadores têm proposto benefícios da mirmecocoria para as plantas. Os estudos sugerem algumas hipóteses a respeito das vantagens desse mutualismo: (1) escape de predação, já que os ninhos geralmente se encontram próximos às áreas de forrageio (Vasconcelos & Bruna, 2007), as formigas podem rapidamente coletar essas sementes e levá-las para o ninho, permitindo que as sementes fiquem fora do alcance de predadores (Beattie, 1985). A remoção do elaiossomo também evita a ação de patógenos e de alguns insetos predadores, podendo aumentar a taxa de germinação (Pizo & Oliveira, 1999); (2) escape de competição parental, pois a remoção das sementes pelas formigas, mesmo que por curtas distâncias, pode reduzir essa competição; além disso, em ambientes com pouca fertilidade no solo, a qualidade do sítio onde a semente será depositada pode ser determinante no sucesso de recrutamento (Boyd, 2001; C. Gómez et al., 2005); (3) dispersão direcionada, pois o padrão de dispersão das sementes geralmente está relacionado ao padrão de distribuição dos ninhos das formigas que podem apresentar um substrato rico em nutrientes e favorecer o recrutamento da semente; como os ninhos estão sempre mudando de local as sementes têm um padrão aleatório de dispersão (Lach et al., 2010); (4) escape de fogo, pois a vegetações de áreas secas tem períodos de alta susceptibilidade a queimadas, que podem fazer parte da dinâmica ecológica local; uma vez dentro do ninho das formigas, as sementes têm mais chances de escapar do fogo (Leal et al., 2007);

2. Interações entre formigas e frutos não mirmecocóricos

As formigas em sua maioria são onívoras e consomem diversos recursos provenientes das plantas como néctar, pólen, exsudatos, folhas, sementes e frutos (Hölldobler & Wilson, 1990). Desta forma, a falta de elaiossomo não é um fator que limita a interação entre formigas e diásporos (i.e. unidade de dispersão que pode ser tanto o fruto quanto a semente) fora dos ambientes esclerófilos.

As florestas neotropicais são conhecidas por apresentarem alta diversidade de organismos e sistemas complexos de interações inter e intra-específicos (Chazdon et al., 2009). Nesses ambientes cerca de 80% das espécies vegetais possuem frutos carnosos que são primariamente dispersos por vertebrados (Gautier-Hion et al., 1985). Com exceção de algumas regiões secas do neotrópico (e.g. caatinga e cerrado) que apresentam uma maior quantidade de espécies mirmecocóricas, nas regiões úmidas são mais raras as plantas adaptadas para a dispersão por formigas (Pizo & Oliveira, 2000; Leal et al., 2007).

Considerando todas as espécies vegetais adaptadas para a dispersão de sementes por formigas no mundo, apenas 0,2 % se concentram na região neotropical (Rico-Gray & Oliveira, 2007). Ainda assim, as interações entre formigas e diásporos nos solos das florestas são muito freqüentes, resultantes principalmente da diversidade e abundância de formigas de serrapilheira (Vasconcelos et al., 2008) e também da grande quantidade de frutos carnosos que caem no solo ao longo do ano (Clark et al., 2004; Martini & Santos, 2006). As formigas interagem com diásporos que caem naturalmente da planta-mãe, que são derrubados por frugívoros ou ainda das fezes dos dispersores primários (Passos & Oliveira, 2004; Christianini & Oliveira, 2009). Na maioria dos casos, as formigas podem atuar como dispersores secundários e beneficiar o recrutamento desses diásporos de forma semelhante ao que acontece com sementes com elaiossomo (Levey & Byrne, 1993; Passos & Oliveira, 2004; Guimarães Jr et al., 2007).

3. Dispersão secundária e diplocoria

A dispersão de sementes é um passo fundamental para as espécies vegetais, já que determina os locais do estabelecimento de novos indivíduos. Em teoria, plantas têm mais chance de obter sucesso no recrutamento de novos indivíduos se uma maior quantidade de sementes for direcionada para locais adequados (Wenny, 2001) o que se constitui em um dos maiores benefícios provenientes destas interações com formigas (Hanzawa et al., 1988). Apesar da dispersão de sementes por frugívoros ser fundamental para as espécies vegetais nas florestas tropicais, o destino das sementes após serem defecadas ou regurgitadas geralmente é desconhecido. Por outro lado, a dispersão secundária dessas sementes por formigas podem levá-las a sítios mais propícios para germinação (Christianini & Oliveira, 2010). Desta forma, dispersão secundária de sementes por formigas pode influenciar a viabilidade, sobrevivência e distribuição das sementes de espécies não mirmecocóricas, resultando em alterações na distribuição espacial das plantas no ambiente e até na diversificação das comunidades vegetais (Roberts & Heithaus, 1986; Lengyel et al., 2009).

Na maioria dos estudos, a dispersão direcionada realizada pelas formigas pode proporcionar às sementes um local mais adequado, geralmente no lixo do formigueiro, que apresenta mais nutriente devido à presença de restos de presas e materiais orgânicos descartados pela colônia, além de estarem mais protegidas contra predadores e patógenos (Passos & Oliveira, 2004). O que pode aumentar o sucesso de estabelecimento da semente, principalmente nos ambientes onde os solos apresentam pouco nutrientes como é o caso de ambientes de caatinga (Leal & Oliveira, 1998).

A chave para que a dispersão secundária de espécies não-mirmecocóricas ocorra, é a relação entre tamanho da formiga e tamanho da semente (Ness et al., 2004). Geralmente a distância percorrida pela formiga e o tamanho da semente têm sido correlacionadas positivamente (Christianini et al., 2007). Diante da variação do tamanho corpóreo encontrada nas operárias de espécies de formigas, o que se observa na maioria dos estudos é uma concentração de sementes depositadas a pequenas distâncias e poucas sementes dispersas a distâncias maiores (Gómez et al., 2005). Sobretudo as formigas da subfamília Ponerinae responsáveis pelas maiores distâncias entre a planta matriz e a semente dispersada (Passos & Oliveira, 2003). Por outro lado, observa-se que, apesar da grande variedade de frutos explorados pelas formigas, há uma evidente preferência por aqueles que possuem maior quantidade de lipídios (Pizo & Oliveira, 2001), que são também nutrientes comuns nos elaiossomos dos diásporos mirmecocóricos.

Sistemas de dispersão compostos de duas etapas e que envolvem diferentes dispersores para cada etapa, são chamados de diplocoria (Vander Wall & Longland, 2004). A dispersão primária por vertebrados seguida da dispersão secundária por formigas podem ser consideradas fases complementares de um mesmo sistema de dispersão (Vander Wall et al., 2005) e como parte da estratégia de regeneração de planta (Christianini & Oliveira, 2010). Dispersões a longas distâncias (e.g vertebrados como dispersores) podem beneficiar o crescimento de metapopulações, enquanto que em curtas distâncias (e.g. formigas como dispersores) influenciam a manutenção das subpopulações das espécies vegetais (Schupp et al., 2010).

OBJETIVO GERAL

Investigar interações entre formigas e diásporos ao nível do solo a fim de relacioná-las com o potencial papel das formigas na dispersão de sementes de espécies vegetais não mirmecocóricas da Mata Atlântica do sul da Bahia.

OBJETIVOS ESPECÍFICOS

- Amostrar as espécies vegetais e de formigas envolvidas nas interações formiga -fruto - semente no solo de uma área de Mata Atlântica;

- Identificar os tipos de uso dos diásporos pela comunidade de formigas da área de estudo;

- Testar a contribuição das formigas na remoção de diásporos no solo;

- Testar o efeito do consumo da parte carnosa dos diásporos pelas formigas na germinação de sementes;

- Avaliar, a partir dos benefícios da interação formiga-diásporo, o papel das formigas na dispersão de sementes de algumas espécies vegetais da Mata Atlântica.

Artigo

Interações entre formigas, frutos e sementes em uma floresta de Mata Atlântica do nordeste do Brasil

Interactions between ants, fruits and seeds in an Atlantic Rain forest in the northwestern Brazil.

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Abstract

Ant-diaspore interactions are a widespread phenomenon in tropical habitats that usually are beneficial for both organisms involved: ants use energy resources, as sugar and lipids, and diaspores can be cleaned or removed to favorable places to seedling development. The nature of this non-myrmecochory diaspore exploitation varies according to ant species and fruit and seeds characteristics. In this context, we did the first ant-diaspore interactions study in an Atlantic Forest fragment of northeastern Brazil. These interactions were sampled monthly during one year through a transect that cross the study area. In complementary experiments, eight diaspores were supplied during a 24 hours period and our objective was to 1) investigate ant foraging strategies through systematic sampling of interactions; 2) predator-avoidance hypothesis testing through ant and vertebrate removing rates comparison and 3) verify if cleaning by ants improve rates of seed germination. After 43 km walked we found 80 interactions involving 30 ant and 27 plant species. During systematic samples 43 ant species were recorded. Within the diaspores choose for systematic samples,, those classified as small (<0.15 g) were more consumed and removed. Smaller diaspores probably have more chance to avoid predators through ant removing, than large ones. Seed cleaning by ants benefited germination of *Pera glabrata*. Ants foraging habits may affect the fate of some primarily dispersed by vertebrate diaspores and have an important role as secondary seed dispersers in northeastern Lowland Atlantic Forest.

Key words: ant behavior, secondary seed dispersers, mirmecofauna

Resumo

Interações entre formigas e diásporos são um fenômeno generalizado em ambientes tropicais e geralmente são de caráter benéfico para ambos os organismos envolvidos: formigas utilizam recursos energéticos, tais como açúcares e lipídios e diásporos podem ser limpos ou mesmo removidos para locais mais favoráveis ao desenvolvimento da plântula. A natureza desta exploração de diásporos não mirmecocóricos varia de acordo com a espécie de formiga e das características dos frutos e sementes. Nesse contexto, estudamos as interações entre formigas e frutos carnosos em um fragmento de Mata Atlântica no Brasil. Estas interações foram amostradas mensalmente durante um ano em transectos que cortam a área de estudo. Em experimentos complementares, diásporos de oito espécies vegetais foram disponibilizados ao longo de um período de 24 horas e utilizados para 1) investigar as estratégias de forrageio das formigas a partir de amostragens sistemáticas das interações; 2) testar a hipótese de escape do predador a partir da comparação entre taxas de remoção realizadas por formigas e vertebrados e 3) verificar se a limpeza por formigas aumenta a taxa de germinação das sementes. Após 43 km percorridos nos transectos foram registradas 80 interações envolvendo 30 espécies de formigas e 18 espécies vegetais. Na amostragem sistemática foram registradas 43 espécies de formigas. Dos tipos de diásporos selecionados para os experimentos, houve maior consumo e remoção daqueles considerados pequenos (<0,15 g). Os diásporos menores também mostram ter mais chances para escapar de possíveis predadores em comparação com os maiores. A limpeza das sementes por formigas beneficiou a germinação de *Pera glabrata*. Os hábitos de forrageio das formigas podem afetar o destino de algumas plantas primariamente dispersas por vertebrados e terem um papel importante como dispersoras secundárias da Mata Atlântica do nordeste do Brasil.

Palavras-chave: comportamento de formiga, dispersor secundário, mirmecofauna

Introduction

Seed dispersal is a critical life cycle period, where plants try to maximize the recruitment of new individuals and reach new environments for colonization (Howe, 1982). During evolution processes, animals became an important key in seed dispersal, impacting positively on demography and population dynamic of plants (Jordano et al, 2007). In tropical forests almost 80 % of the plants present fleshy diaspores, but there is a huge variation in color, size, shape and nutritional contents. These characteristics arose after a complex web of evolutive interactions and are results of selection for traits maximizing dispersal by vertebrates, mainly mammals and birds (Gautier-Hion et al., 1985). Fleshy fruits can reach the forest floor naturally, falling from parent trees directly or after be carried by frugivores.

Once in forest floor, diaspores become available for ground-dwelling ants that exploit them in different ways, according with each type of forage strategy. This exploitation can result in a negative, positive or even neutral influence for seed fate (Wenny, 2000). The myrmecochory syndrome plants are adapted for primary seed dispersal by ants (Beattie, 1985). Most of ant-diaspore interactions in tropical forests are opportunistic, usually involving generalist ants (Bernstein, 1975; Levey & Byrne, 1993). Benefits of myrmecochory include avoidance of predators, avoidance of competitors and increase of dispersal distance (Rico-Gray & Oliveira, 2007). In nonobligate associations, ant-diaspores interactions can also benefit groups. The high abundance and diversity of fleshy diaspores (i.e unit of dispersal, fruit or seed) and also of ground-dwelling ants, turn interactions between them especially common in lowland rain forest (Pizo & Oliveira, 2000).

In the last years, researches revealed that interactions between ants and fleshy diaspores in tropical forests bring benefits quite similar to those found in true myrmecochory (Pizo & Oliveira, 2000). Ants interacting with diaspores primarily dispersed by vertebrates may rearrange vertebrate seed shadow, rescue seeds from predator attack (i.e granivores or fungi) under the parental tree and enhance germination activity through seed cleaning (Roberts & Heithaus, 1986; Guimarães Jr & Cogni, 2002; Ohkawara & Akino, 2004; Passos & Oliveira, 2004; Christianini & Oliveira, 2009). Ants can also contribute to development and genetic diversity maintaining in plant populations, when they carry seeds to safe sites, which are not necessarily their nest (Horvitz, 1981; Kalisz et al., 1999). Similar to myrmecochory, diaspore traits, such as seed size and nutritional content, can influence the interaction between ants and non-myrmecochorous diaspores (Christianini et al., 2007; Hughes & Westoby, 1992). Omnivorous ants are known to select food according to nutrient deficiencies (Fowler et al., 1991). Thus, they use efficiently foraging strategies to optimize a complementary nutrition (Lach et al., 2010). The relationship between removal rates and diaspores characteristic, as size, may indicate the type of foraging strategy used by ants (Hughes & Westoby, 1992). Thus small diaspores have more chance to be dispersed by ants than large ones due to limitation on removal by workers size (Kaspari, 1996). Otherwise, without this removal by ants, some diaspores are more prone to predation by rodents and ground-dwelling bird, considered the main seed predators in tropical forest floor (Mendoza & Dirzo, 2007).

In this context, we were mainly interested in: (1) describe ant-diaspore interactions occurring in a remnant of tropical lowland rain forest in Una Biological Reserve; additionally, through experimental approach (2) evaluate whether diaspore traits influence ant forage activity; and (3) test if removal of seeds by ants enhances avoidance of predators, as well if (4) seed cleaning by ants benefits seed germination.

Methods

STUDY AREA. – Interactions between ants and fruits were studied from October 2009 to September 2010, at Una Biological Reserve (Rebio Una), municipio of Una in southern Bahia, Brazil (15º11'00"S; 39º10'30"W). The climate belongs to the Af type (hot, moist tropical forest) according Köppen's classification, with average precipitation of 2000mm.yr^{-1}, with no marked seasonality and mean annual temperature around 24°C (Mori & Boom, 1983). The total protected area in the Reserve comprises 18,100 ha, and the dominant vegetation type is classified as Lowland Atlantic Rain Forest (Oliveira-Filho and Fontes, 2000) growing in low fertility soil. Una Biological Reserve landscape is composed by a mosaic of different stages of forest growth (Amorim et al., 2008). Our study was conducted in the eastern part of the Reserve, which represents almost 20 % of the total area. We concentrated our effort in secondary and advanced forest, the two most representative forest stages of regional landscape (Mariano Neto, 2004).

SURVEY OF ANT-DIASPORE INTERACTIONS. - We conducted monthly observations from October 2009 to September 2010. The walks occurred during the period of morning, once per month, and observations of ant-fruit-seeds interactions were made following opened trails crossing areas with different stages of vegetation succession. Fallen diaspores were searched in both sides of the trail (c. one meter). Interactions were recorded each time ants were observed exploiting a diaspore. The interaction was classified in four categories according to the ant behavior: removing the diaspore (R), collecting parts of the pulp (P), consuming pulp parts in the local (C) or in contact with the surface apparently collecting liquids (L). Both ants and diaspores were collected for further identification. Voucher specimens were deposited in the Laboratório de Mirmecologia, CEPEC-CEPLAC collection [CPDC] (Agosti et al., 2000) and in the CEPEC Herbarium, respectively.

SYSTEMATIC SAMPLINGS – ANT FORAGING PATTERNS. – In order to record more ant-diaspore interactions and specially to investigate patterns of diaspores use by the ant community in the forest ground, we also conducted systematic samplings. The diaspores primarily dispersed by vertebrates, *Byrsonima sericea* DC. (Malpighiaceae), *Euterpe edulis* Mart.(Arecaceae), *Henriettea succosa* (Aubl.) DC. (Melastomataceae), *Miconia prasina* (Sw.) DC. (Melastomataceae), *Pera glabrata* (Schott) Baill. (Euphorbiaceae), *Psychotria* sp. (Rubiaceae), *Tapirira guianensis* Aubl (Anacardiaceae) and *Trichilia* sp., were used in experiments. We selected the species due to their morphological characteristics and fruit availability. Systematic samplings occurred in different months of the year according to the fruiting season for each species, between the months of February and August. We set up the experiments on a trail in secondary forest since the majority of the studied plant species are typical of this type of habitat. The only exception was *E. edulis*, endemic and threatened palm of Atlantic rain forest that occurs mainly in advanced secondary and old growth forests. Systematic samples of *E. edulis* were conducted on advanced secondary forest. For each species, fruits were set up on sampling stations in groups of five and separated by 10 m – intervals, along a trail. The diaspores were placed on white filter paper (Pizo and Oliveira 2000) and protected by a wire cage (20 x 20 x10 cm, 1.5 cm mesh) closed on the top and sides (Roberts & Heithaus, 1986) and staked on the ground. The number of sample stations varied between three and 10 according to fruit availability. All experiments started 11:00 AM and lasted 24 hours until the same period of next day. The sampling stations were checked for interactions and ant collecting at 2 hours intervals. Ant behavior were classified in the same four categories used in transects surveys. During each observation period, we counted the number of diaspores totally consumed or removed, and specimens of interacting ants were collected. Every time that was possible, ants carrying diaspores were followed to the nest or till disappearance in the leaf litter. In these cases we registered the distance the diaspores were carried by ants.

We also sampled the ant community in the same place where experiments were installed in order to compare with those interacting with diaspores. In September 2009 we performed a broad ant survey through application of three distinct methodologies in ten sample points, 20 m apart, distributed over a 200 m transect. Ground-dwelling ants were sampled using Winkler extractor and Pitfall traps (Bestelmeyer et al., 2000) and we also sampled arboreal community once some of these ants forage in leaf litter. For Winkler extraction, at each sample point 1 m^2 of leaf litter was sifted and deposited in a cotton bag; at the laboratory the material was placed in mini-Winkler sacks for 72 hours. For the Pitfall collection, we used plastic cups of 100 ml with 50 ml moist with ethanol/detergent solution and left in the field for 24 hours. To collect arboreal ants, one treelet or shrub (CAP ≤ 20 cm) was chosen in each sample point. The vegetation was beaten to dislodge ants onto a sheet under the tree and they were collected manually.

DIASPORE REMOVAL: ANTS VS VERTEBRATES. – To investigate the contribution of ants on the removal of fallen diaspores in the forest ground and test the avoidance predator hypothesis, we conducted exclusion experiments on the forest floor at Una Biological Reserve. A transect was established with sample stations apart from each other at 25 m intervals, warranting independence between sampled points. Each sample station was constituted by a pair of exclusion treatments. To vertebrate exclusion, 10 fruits were set up on a white filter paper and protected by a wire cage (20 x 20 x10 cm, 1.5 cm mesh), closed on the top and sides (Roberts & Heithaus, 1986) and staked on the ground, giving access only to ants. Other invertebrates that had access to fruits protected by the wire cages were not capable to remove fruits. Ant exclusion, consisted of fruits set up on transparent plastic dishes that had in the border an insect-trapping glue (Tanglefoot©), allowing access only for vertebrates. Both treatments were distant 20 cm apart from each other and checked after 24 hours. The fruits moved more than 20 cm or missing were considered removed, and ants found interacting with diaspore on the spot were collected. Here we followed a similar methodology used by Hughes & Westoby's (1990) with adaptations. The treatment with vertebrate exclusion was previously tested in the study site using sunflower seeds and vertebrates did not present any distinct behavior between treatments in reason to the Tanglefoot© on the transparent plastic dishes' border.

GERMINATION TESTS – As seed cleaning by ants could influence on seed germination, and consequently seed establishment (Passos & Oliveira, 2003), test on seed germination was conducted to evaluate ant effect. Up to 100 fruits from 1-5 plants of *Euterpe edulis, Pera glabrata* and *Tapirira guianensis* were collected and seeds were divided in two groups for each species. In the first group the flesh part of the fruit was removed (simulating the cleaning by ants) and in the second the fruits were left intact (i.e. with the flesh part). For all species cited above we followed the same experimental design, using seeds of each treatment in germination boxes divided in 128 individual spaces filled with vermiculite. The experiment was monitored at 1 week intervals until seed germination (radicle protrusion) or presenting signals of decay. The experiment was maintained in the greenhouse of Universidade Estadual de Santa Cruz, under regular conditions of humidity.

DATA ANALYSIS. - To test foraging strategy hypotheses we used simple linear regression. These analyses tested the relationship between diaspore sizes with: number of removed diaspores, number of diaspores exploited by ants, number of diaspores exploited by ants per hour and number of ant species attracted per diaspore species. For diaspores removal, the number of removed fruits per treatment was compared through a Willcoxon test for paired samples. Seed germination rates between treatments for each species of germination test were compared by performing Chi-square tests. All analysis were performed in R software (R Development Core Team, 2009).

Results

MONTHLY SURVEY OF INTERACTIONS – After 43 km of transect sampling, an average of 3.5 km per month, between advanced and secondary forests, 80 interactions between ants and diaspores were recorded. The ants were represented by 30 species distributed in four subfamilies. Myrmicinae was the subfamily with a greater number of species (N = 25), recorded in 85% of interactions (Table 1). The subfamilies Dolichoderinae, Formicinae, and Ponerinae were involved in three, seven and two records of interactions, respectively. The genera *Pheidole* was the more speciose with 9 species, and participated in 30% of the interactions recorded (24 out of 80). The ant *Wasmannia auropunctata*, known as an opportunistic species and abundant in disturbed areas (Delabie et al., 2007), was the most frequent species, being recorded in 19 interactions. Recruitment and ant behavior were different depending on ant species and diaspore characteristics.

Ants of the Dolichoderinae and Formicinae subfamilies, as well as small myrmicines of the genera *Solenopsis* and *Wasmannia*, did not remove diaspores of any size. The behavior of these ants consisted in consuming the diaspore in place and apparently collected liquids on fruit surface. Interactions between ants of the subfamily Myrmicinae and fruits/seeds normally involved worker recruitment with two or more nestmate exploring the resource. Many Myrmicinae of the genera *Atta*, *Mycetarotes*, *Pheidole* and *Sericomyrmex* had similar behavior, in which most of the interactions were the consumption of fleshy parts of fruits in place, but could also remove small diaspores (≤ 0.3 g).

The Ponerinae *Pachycondyla concava* was the larger ant recorded interacting with diaspores during surveys but it is also considered a predator. These ants were observed removing diaspores with size range from 0.1 to 0.6 g.

TABLE. 1. Ant species (in alphabetic order of subfamily) recorded exploiting fallen diaspores during monthly surveys and shared species of systematic samples in Una Biological Reserve, Bahia, Brazil. Category of ant behavior:

apparently collecting liquids from fruit surface (L); consumed fleshy part on the spot (C); removed portions of fleshy part to the nest without seeds (P); removal of entire diaspore (R). The names of plant species are available on Table 2 bellow.

Ant species	Ant behavior	Plant species	N of interections in monthly surveys	N of interactions in sistematic samples
Dolichoderinae				
1. *Dorymyrmex* sp. 1	L, C	1, 9, 15	3	-
Formicinae				
3. *Brachymyrmex heeri*	L, C	7, 9, 15, 25	4	1
4. *Nylanderia fulva*	C	9, 12, 13, 15	1	5
6. *Nylanderia* sp.	L, C	9, 15	2	2
Mymicinae				
7. *Atta cephalotes*	R	18	1	-
10. *Crematogaster limata*	L, C	6, 9, 11, 14	3	1
11. *Crematogaster* sp.	C	4	1	-
15. *Megalomyrmex* sp. 1	L, C	6, 17	2	-
16. *Megalomyrmex* sp. 2	L	9	1	-
17. *Mycetarotes parallelus*	R	28	1	-
18. *Mycocepurus smithi*	C	5, 7, 12	2	1
20. *Pheidole bruesi*	L, C	8, 10, 12-14	2	3
22. *Pheidole obscurithorax* Naves	C, P, R	4, 8, 9	11	-
23. *Pheidole synarmata*	C, R	4, 8, 9	4	-
25. *Pheidole* sp. 1	C	3, 9, 15	1	2
26. *Pheidole* sp. 2	C	20	1	-
29. *Pheidole* sp. 7 gr *fallax*	C, R	9, 15	2	1
30. *Pheidole* sp. 8 gr *diligens*	C	1, 24	1	1
31. *Pheidole* sp. 10 gr*flavens*	C, R	4, 13	1	1
32. *Pheidole* sp. 11 gr *diligens*	C	3, 12	1	1
37. *Sericomyrmex* sp. 1	R	9, 27	1	1
38. *Sericomyrmex* sp. 2	C, R	1, 3, 8, 9, 12, 13, 24	4	7
39. *Sericomyrmex* sp. 3	P	9, 10	1	1
40. *Solenopsis geminata*	L	2	1	-
41. *Solenopsis* sp. 1	L, C	9, 15, 19	3	-
42. *Solenopsis* sp. 2	L, C	3, 9, 15, 26	2	5
45. *Solenopsis* sp. 6	L, C	2, 13	1	1
48. *Trachymyrmex* sp. 3	C	9, 12	1	2
49. *Wasmannia auropunctata*	L, C	1, 3, 5, 7-9, 12, 13, 15, 16, 20, 22, 24	19	9
Ponerinae				
51. Pachycondyla concava	C, R	6, 9, 23	2	1
TOTAL			80	46

We identified 18 plant species in 12 families involved in ant-plant interactions. The diaspores of another nine species of trees, scrubs, epiphytes and hemiepiphyts remained undetermined (Table 2). Melastomataceae and Clusiaceae were the families with the highest number of species and together their diaspores were responsible for 48% (39/80) of interactions. The diaspores of *Henriettea succosa* (Melastomataceae) were registered in 18 interactions involving nine different ant species. In general, fruits of *H. succosa* (1.8 g), was directly consumed on place, but as this fruit bears small seeds, medium-large ants were observed removing pieces of the pulp containing seeds. *Byrsonima sericea* (Malpighiaceae) and *Pera glabrata* (Euphorbiaceae) were also highly explored by ants, with eight records of interactions each. Fruits and seeds were less frequently observed in advanced secondary forest than in secondary forest and, for this reason, the interactions recorded in this study were more abundant in the latter. Diaspore sizes ranged from 0.01 g to 500 g, but most of them weighed around 1 g, in average. All large diaspores were observed in advanced secondary forest while medium-small ones were more common in secondary forest.

TABLE 2. Plant diaspores used by ants during monthly surveys and systematic samplings in Una Biological Reserve, Bahia, Brazil. Plants followed by an asterisk had interactions recorded only in systematic samplings.

Plant species	**Ant numbers**	**Growth form**	**Months**
Anacardiaceae			
1. *Tapirira guianensis*	1, 2, 13, 24, 30, 38, 49	Tree	Jun.-Aug.
Arecaceae			
2. *Elaeis guianensis*	40, 45	Tree	Mar.
3. *Euterpe edulis*	25, 32, 34, 38, 42, 49, 52	Tree	May-Jun.
Chrysobalanaceae			
20. *Licania* sp.	26, 49	Tree	Dez.
Clusiaceae			
4. *Clusia nemorosa*	11, 22, 23, 31	Tree	Jan.-Mar.
5. *Tovomita* sp.	18, 49	Tree	Apr.
6. *Rheddia gardneriana*	10, 15, 51	Tree	Apr.
7. *Vismia guianensis*	3, 18, 49	Tree	Sep.
Euphorbiaceae			
15. *Pera glabrata*	1, 3-6, 13, 25, 29, 35, 36, 41-43, 49	Tree	Jul.-Sep.
Malpighiaceae			
8. *Byrsonima sericea*	2, 20, 22, 23, 38, 44, 49, 53	Tree	Mar.-Apr.
Melastomataceae			
9. *Henriettea succosa*	1, 3-6, 8-10, 12, 14, 16, 22, 23, 25, 27-29, 34, 37-39, 41, 42, 46-49, 51, 52	Tree	Nov.-Oct.
10. *Tibouchina* sp.	20, 39	Tree	Sep.
11. *Miconia hypoleuca*	10	Shrub	Sep.
12. *Miconia prasiana**	2, 4, 13, 14, 18-20, 32, 33, 38, 48, 49, 50, 53	Tree	Mar.-May

Meliaceae			
13. *Trichilia* sp.*	4, 20, 21, 31, 38, 45, 49	Shrub	Apr.
Moraceae			
14. *Ficus hirsuta*	10, 20	Tree	Jan.
Rubiaceae			
16. *Psychotria* sp.*	13, 24, 49	Shrub	May
Rutaceae			
17. *Hortia* sp.	15	Tree	Feb.
Sapindaceae			
27. *Cupania* sp.	37	Tree	Sep.
Undetermined			
18. Indet. 1	7	Epiphyte	Oct.
19. Indet. 2	41	Epiphyte	Dez.
21. Indet. 3	22	Hemiepiphyte	Jan.
22. Indet. 4	49	Shrub	Mar.
23. Indet. 5	51	Hemiepiphyte	Apr.
24. Indet. 6	30, 38, 49	Tree	Apr.-May
25. Indet. 7	3	Tree	May
26. Indet. 8	42	Tree	Sep.
28. Indet. 9	17	Epiphyte	Sep.

SYSTEMATIC SAMPLINGS – ANT FORAGING PATTERNS – During systematic samplings we recorded 43 ant species of four subfamilies. Myrmicinae had 36 species, Formicinae and Ponerinae had four each and Ectatomminae a single one (Table 4). Although systematic sampling with *E. edulis* was the only one that occurred in advanced secondary forest, all the ants recorded in interactions were also recorded with other diaspores in secondary forest. Comparing with monthly surveys, up to 55 % (24 out of 43) of ant species occurred only in the experiment (i.e. for shared species see Table 1). Diaspore sizes were divided into categories as large, medium and small raging from 0.04 g in *P. glabrata* to 1.85 g in *H. succosa*
(Table 3).

TABLE. 3. Morphological characteristics of plant species diaspores studied in systematic samples and diaspore removal experiments in Una Biological Reserve, Bahia, Brazil.

Diaspore species	**Weight (g)**	**High (cm)**	**Length (cm)**	**Size categories**	**N of seeds per fruit**
Byrsonima sericea	0.53	0.84	0.83	M	1
Euterpe edulis	1.77	1.38	1.34	L	1
Henriettea succosa	1.85	1.51	1.60	L	>50
Miconia prasina	0.12	0.52	0.60	S	>50
Pera glabrata	0.04	0.40	0.70	S	3
Psychotria sp.	0.14	0.31	0.61	S	4
Tapirira guianensis	0.50	0.87	1.13	M	1
Trichilia sp.	0.38	0.76	1.08	M	1

Size categories: Large (L); Medium (M); Small (S).

The same ant patterns observed in monthly surveys were observed in systematic samplings: the genus *Pheidole* was the most speciose, with 15 species and *W. auropunctata* the commonest species. We also registered one cricket (Order: Orthoptera) consuming diaspores of *T. guianensis* and also one millipede (Family: Spirostreptidae) consuming *H. succosa* during experiments, but removal were observed only by ants.

The number of ant species exploiting diaspores ranged from 3 in *Psychotria* sp. (Rubiaceae) to 23 in *H. succosa* (Melastomataceae). *M. prasina* and *P. glabrata* also were considered rich in ant interactions (Table 4) while the remaining diaspores presented between 6 and 7 ant species. The presence of aril in *P. glabrata* (Euphorbiaceae) seeds was considered an *a priori* indicative of high attractiveness to ant foraging behavior and contrary to our expectations, these diaspores were attended only by 10 ant species. Probably the high number of *P. glabrata* diaspores removed (50 %) in the first four hours of systematic sampling reduced the chances of being exploited by other ant species.

H. succosa had the greatest number of interaction events recorded (86) and ant exploitation were made mainly by *Pheidole* sp. 1 and three *Sercomyrmex* species. *Sericomyrmex* spp. was responsible for a high rate of pulp consumption by piecemeal removal. Opportunistic seed removal were also observed when pulp pieces of *H. succosa* bearing a seed was carried by ants.

Despite distinct patterns of ant behavior observed, the number of interaction events was quite similar between *B. sericea* (43), E. *edulis* (41) and *P. glabrata* (41). Diaspores of *P. glabrata* that were not removed were attended by small ants such as *Pheidole* sp. 10 group *flavens, Wasmannia auropunctata and Solenopsis* sp. 2, which consumed the aril or collected liquids from its surface. *Pheidole bruesi* and *Wasmannia auropunctata* were responsible for 50 % of all interactions recorded with *B. sericea.* Similarly, almost 75 % of all *E. edulis* diaspore interactions had only three ant species: *Pheidole* sp. 1, *Solenopsis* sp. 2 and *Wasmannia auropunctata.* Myrmicines were always the leading ants in seed cleaning activity, and the commonest ant behavior was the local consumption of pulp parts. None Formicinae was observed interacting with *B. sericea, E. edulis, Psychotria* sp. or *T. guianensis*.

TABLE 4. Ants interacting with diaspores during systematic samplings in Una Biological Reserve, Bahia, Brazil. The number of plant species is followed by the month of experiment between parentheses. Values inside cells indicate number of observation periods which events of ant-diaspore interactions were registered (max value=12).

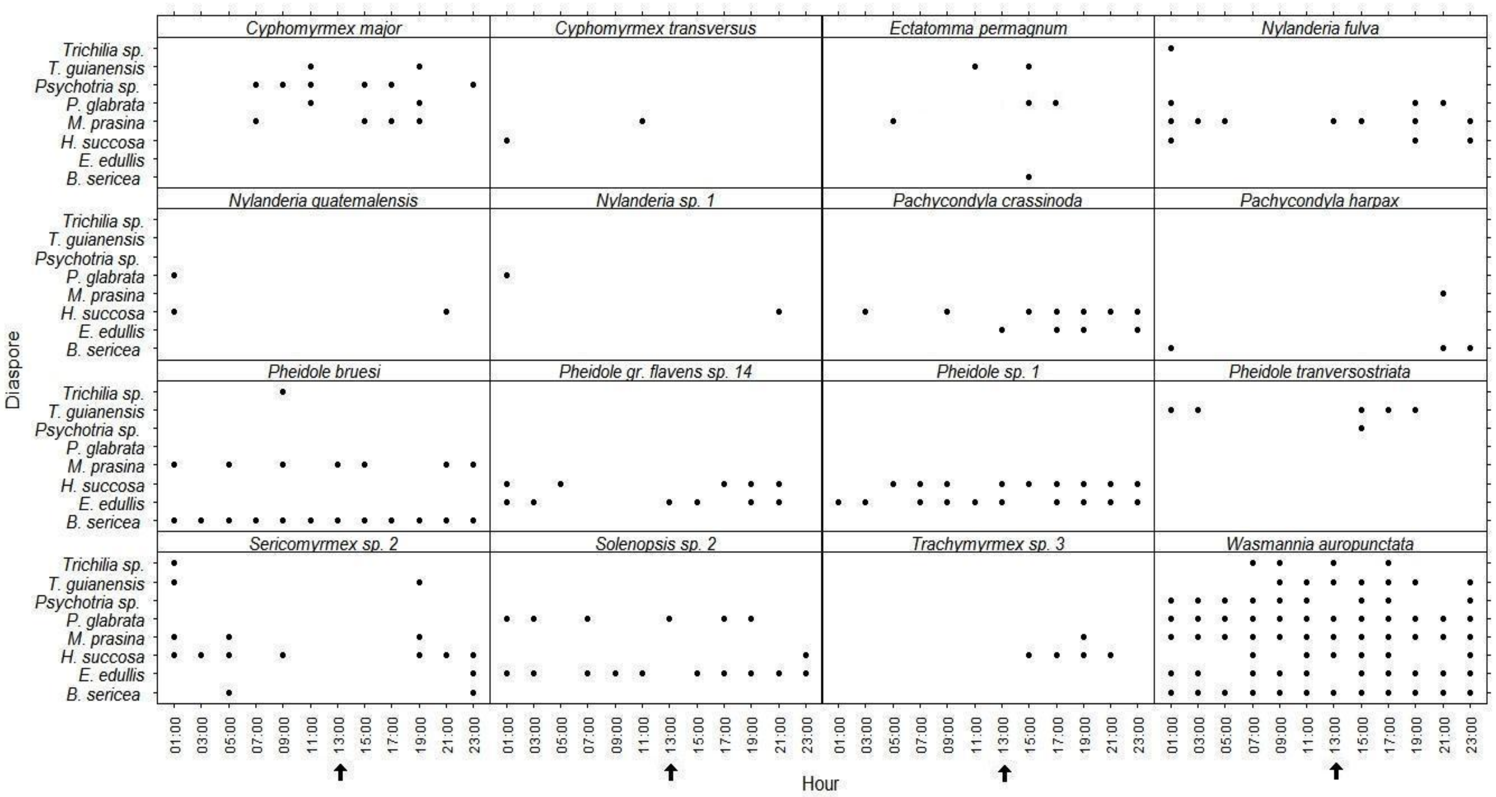
Ant species	Ant behavior	Byrs (May)	Eute (May)	Hens (Feb.)	Micp (Apr.)	Perg (Aug.)	Psyc (May)	Tapg (Aug.)	Tric (Apr.)
Ectatomminae									
Ectatomma permagnum	C/R	1	-	-	1	2	-	2	-
Formicinae									
Brachymyrmex heeri	L	-	-	1	-	-	-	-	-
Nylanderia fulva	C	-	-	3	7	3	-	-	1
Nylanderia guatemalensis	C	-	-	2	-	1	-	-	-
Nylanderia sp. 1	L/C	-	-	1	-	1	-	-	-
Myrmicinae									
Carebara urichi	C	-	-	2	-	-	-	-	-
Crematogaster brasiliensis	C	-	-	1	-	-	-	-	-
Crematogaster limata	C	-	-	3	-	-	-	-	-
Pheidole bruesi	C	12	-	-	7	-	-	-	1
Pheidole fimbriata	C	-	-	-	-	-	-	-	5
Pheidole pubiventris	C	4	-	-	-	-	-	-	-
Pheidole transversostriata	C/R	-	-	-	-	-	1	6	-
Pheidole sp. 1	C	-	10	9	-	-	-	-	-
Pheidole sp. 3	C	-	-	1	-	-	-	-	-
Pheidole sp. 4 gr *diligens*	C/R	-	-	3	-	-	-	-	-
Pheidole sp. 7 gr *fallax*	C/R	-	-	-	-	2	-	-	-
Pheidole sp. 9	L/C	-	-	-	-	-	-	1	-
Pheidole sp. 10 *gr flavens*	C	-	-	-	-	-	-	-	1

Pheidole sp. 11 gr *diligens*	C/R	-	-	-	6	-	-	-	-
Pheidole sp. 13 gr *diligens*	C	-	-	-	1	-	-	-	-
Pheidole sp. 14 gr *flavens*	L/C	-	6	5	-	-	-	-	-
Pheidole sp. 15 gr *flavens*	C	-	-	-	-	10	-	-	-
Pheidole sp. 17 gr *flavens*	C	-	-	-	-	1	-	-	-
Solenopsis sp. 2	L	-	10	1	-	6	-	-	-
Solenopsis sp. 3	L	-	-	-	-	1	-	-	-
Solenopsis sp. 5	L	9	-	-	-	-	-	-	-
Solenopsis sp. 6	L/C	-	-	-	-	-	-	-	3
Wasmannia auropunctata	C/L	12	10	6	12	12	9	7	4
Myrmicinae (Attini)									
Cyphomyrmex hamulatus	C	-	-	1	-	-	-	-	-
Cyphomyrmex major	C	-	-	-	4	2	6	2	-
Cyphomyrmex transversus	C	-	-	1	1	-	-	-	-
Mycocepurus smithii	C	-	-	-	1	-	-	-	-
Myrmicocrypta sp.	C	-	-	-	1	-	-	-	-
Sericomyrmex sp. *1*	C/P	-	-	8	-	-	-	-	-
Sericomyrmex sp. *2*	C/P	2	1	7	3	-	-	3	1
Sericomyrmex sp. *3*	C/P/R	-	-	10	-	-	-	-	-
Trachymyrmex relictus	C/P/R	-	-	2	-	-	-	-	-
Trachymyrmex cornetzi	C/P	-	-	3	-	-	-	-	-
Trachymyrmex sp. *3*	C/P	-	-	4	1	-	-	-	-
Ponerinae									
Odontomachus haematodus	C/R	-	-	-	1	-	-	-	-
Pachycondyla crassinoda	P/R	-	4	7	-	-	-	-	-
Pachycondyla harpax	C/P/R	3	-	-	1	-	-	-	-
Pachycondyla concava	P/R	-	-	5	-	-	-	-	-
Total species richness		7	6	23	14	11	3	6	7
Total number of interaction events		43	41	86	47	41	16	21	16

Legend of ant behavior: collecting liquids from fruit surface (L); consuming fleshy part on the spot (C); removing portions of fleshy part to the nest (P); removing the entire diaspore (R).

The recruitment of worker ants for diaspore exploitation was higher in Myrmicinae, especially *Pheidole, Sericomyrmex*, *Solenopsis, Trachymyrmex* and *Wasmannia* where the number of workers range from 10 to > 50 in each sampling point. Ants in the genus *Pheidole* were the most common observed in diaspore exploitation, but at the same time 11 out of 15 species were exclusively recorded in only one plant species. Furthermore, some of them (5 out of 11) attended a specific diaspore in only one period of observation in systematic sampling. Generalists myrmicines, such as *Solenopsis* and *Wasmannia,* attended to diaspores by consuming fleshy parts or collecting liquids on place. These ant behaviors, especially liquid gathering were also observed in Formicinae ants. Additionally, some species of *Solenopsis* used to cover the diaspores with soil and leaf litter before consumption. *Ectatomma permagnum* workers were able to carry individually diaspores of *P. glabrata* and *M. prasina*. The joint effort of two workers was enough to remove diaspores of a heavier seed, *B. sericea*. The largest ant in the study site, *Pachycondyla crassinoda,* attended only the larger diaspores of *H. succosa* and *E. edulis*. *P. crassinoda* was the only ant that could remove an entire *H*. succosa fruit, but the distance of removal did not exceeded 18 cm. We compared foraging activity between ant species exploiting diaspores more than two plant species (Figure 1). In general the ant activity was lower between 7:00 h and 11:00 h in the 24 hours experiment. The exceptions were the ants *Cyphomyrmex major* and *E. permagnum*. We identified five species of ants with preferential nocturnal activity: *Nylanderia* sp., *Nylanderia guatemalensis*, *Pachycondyla harpax* and *Sericomyrmex* sp. 2. Nine out of 16 ant species expended less than two hours (i. e. period for the first observation time) to discover the diaspores placed experimentally. Continuous exploitation of diaspores occurred with myrmicine ants *Pheidole* sp. 1, *Pheidole bruesi*, *Solenopsis* sp. 2, *Wasmannia auropunctata* and *Pachycondyla crassinoda*.

FIGURE 1. Exploitation of the different diaspores by shared ant species in a temporal scale of 24 hours. The experiments were conducted along different days. Arrows mark the initial time of observations made during systematic samplings with interval of 2 hours in Biological Reserve of Una, Bahia, Brazil.



Rates of diaspore consumption and/or removal along the 24 hours of experiment were very different between diaspore species (Figure 2). Results indicated that small diaspores were more cleaned and removed than large ones. Ant species richness did not influenced rates of consumption/ removal in *P. glabrata* and *M. prasina*. We considered as consumed each diaspore unit that were totally cleaned by ants. Diaspores of *E. edulis*, *T. guianensis* and *Trichilia* sp. were not removed and all of them persisted almost intact after 24 hours, with only few pieces consumed.

We did not find statistical support when relating diaspore size with the number of diaspore exploited by ants and with number of ant species attracted per diaspore species. Although the diaspore size seemed to be related with the rate of diaspore removal ($r^2 = 0.33$, N= 8, F= 3.1, P = 0.133) our data are not strong enough to support this relationship.

Ant community samplings in the whole study area totalized 124 ant species distributed in six subfamilies: Dolichoderinae, Ectatomminae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmecinae. Ants interacting with diaspores represented 45% (54 out of 124) of the sampled ant community.

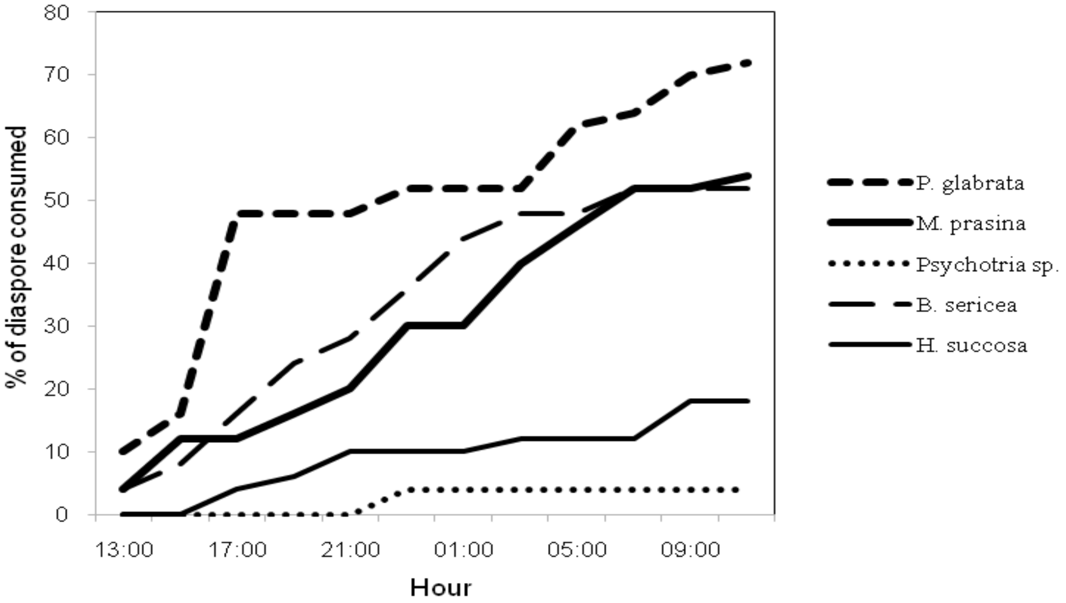


FIGURE 2. Rates of diaspore consumption by ants through 24 hours of systematic samplings in the Biological Reserve of Una, Bahia, Brazil.

DIASPORE REMOVAL: ANTS VS VERTEBRATES – Mean of diaspores removal by vertebrates and ants were low in our observations. Ants removed more diaspores of *P. glabrata*, *M. prasina*, *H. succosa* and *Psychotria* sp. than vertebrates, but the difference was statistically significant only in *M. prasina* and *P. glabrata.* In both cases removal by ants was higher (Table. 4). Predated seeds of *P. glabrata* were found in some spots of ant exclusion supporting the hypothesis that vertebrates tend to be more seed predators than dispersers in the forest grounds. Thus, among the plant species used, *P. glabrata* and *M. prasina* diaspores should have more chance to avoid predators and fungi attack by ant removing.

TABLE 4. Morphological parameters of diaspores used in systematic samplings and results of removal experiments conducted in Una Biological Reserve, Bahia, Brazil. N is the number of replicates used in removal experiments for each diaspore species.

			Number of diaspores removed (mean ± SD)		
Diaspore species	**Size categories**	**N**	**Vertebrates exclusion**	**Ants exclusion**	**P**
Byrsonima sericea	M	6	0.6 ± 0.5	0.6 ± 0.5	ns
Euterpe edulis	L	10	0.0 ± 0.0	0.0 ± 0.0	ns
Henriettea succosa	L	14	0.6 ± 0.8	0.0 ± 0.0	ns
Miconia prasina	S	10	3.3 ± 3.8	0.3 ± 0.6	0.03
Pera glabrata	S	10	4.8 ± 4.1	1.6 ± 3.3	0.05
Psychotria sp.	S	5	2.2 ± 4.3	0.4 ± 0.5	ns
Tapirira guianensis	M	10	0.0 ± 0.0	0.1 ± 0.3	ns
Trichilia sp.	M	10	0.0 ± 0.0	0.1 ± 0.3	ns

Legend of size categories: Large (L); Medium (M); Small (S).

SEED CLEANNING BY ANTS: GERMINATION TESTS. – Germination test was possible only for three out of the eight species choose for the experiments (Table 5). The remove of fleshy part in diaspore increased seed germination only for *P. glabrata* ($\chi2_{=}$ 32.57; P<0.001). Seed cleaning did not affect germination for *T. guianensis* and *E. edulis.*

TABLE 6. Germination tests results. Treatment: seeds without fleshy part cleaned manually; Control:seeds with fleshy part. χ^2 = test value and P = value of test significance.

	Number of seeds sowed		**Number of seeds germinated**			
Plant species	**Treatment**	**Control**	**Treatment (%)**	**Control (%)**	χ^2	P
Euterpe edulis	80	80	15 (18.75)	18 (22.5)	0.308	ns
Pera glabrata	128	128	22 (17.18)	0	32.57	< 0.001
Tapirira guianensis	168	167	54 (32.33)	54 (32.33)	0.344	ns

Discussion

In the present study we corroborate with studies that found a great proportion of ant community interacting with fruits and seeds on the forest floor. In our study this ant assemblage was higher than was expected. Once diaspores are available on the ground, ants exploited them in different ways and can be an important seed rescue for small diaspores. Although all of diaspores used in the experiments are primarily dispersed by vertebrates, ants showed a strong signature of preferences for some species.

SURVEY OF ANT-DIASPORE INTERACTIONS. –We recorded 30 ant species interacting with seeds of 27 species of trees, shrub, epiphytes and hemiepiphytes in the forest floor, bringing a total of 80 ant-diaspore distinct combinations. Despite the lower number of interactions in this study, when compared to a southeastern remnant that found 886 ant-plant interactions (Pizo & Oliveira, 2000), we recorded a higher proportion of ant species by diaspore. As the number of interactions depends on the local density of each organism (Pizo et al., 2005), our results are probably related with a limited diaspore species availability during sampling periods. According to studies of plant phenology in the Una Biological Reserve, a great number of plant species had a small fruit season and are not available regularly along the year. Therefore, a low percentage of mature fruits available per month and had an average of 1.8 % in advanced secondary forest and 3 % in secondary forest (Santos, 2008). Otherwise, maybe an increase in sample effort can overcome the small number of interactions records.

Most of the interactions recorded in this study occurred in secondary forest and had diaspores of *H. succosa* and *M. prasina* as the most consumed by ants. Melastomateceae species are dominant in secondary forest of the studied area while *Miconia* is the most representative genera (Martini & Santos, 2006; Pessoa, 2008). Both species produce fruits continually along the year (Pessoa, 2008) and are very important in the food diet of the endemic species golden-headed lion tamarin *Leontopithecus chrysomelas* (Primates: Callitrichidae) one of the primary seed dispersers in Una Biological Reserve (Cardoso, 2008; Catenacci, et al 2009).

Myrmicinae are the most frequent ants interacting with fallen diaspores in tropical forests, followed by Ponerinae and Formicinae (Rico-Gray & Oliveira, 2007). Our study showed similar pattern: these subfamilies predominated in ant exploitations to diaspores. The genus *Pheidole* was responsible for a large part of interactions in monthly surveys but it does not mean that these ants are good seed dispersers. Contribution of *Pheidole* in seed dispersal is ambiguous due to the fact that this genus can be considered primarily seed harvest and predator (Hölldobler & Wilson, 1990), but can also act as secondary seed dispersers (Levey & Byrne, 1993; Pizo, 2008).

During monthly surveys, individuals of *Pheidole obscurithorax* Naves, *Pheidole synamarta*, *Pheidole* sp. 7 *fallax* group and *Pheidole* sp. 10 *flavens* group, were responsible for 50% of diaspore removal records. We also found intact seeds on refuse pile of *P. obscurithorax.* Thus the world more speciose ant genus and the more diverse in all the forest habitats in the Neotropics (Wilson, 2003), probably occupying an important ecological niche/role in neotropical forests as plant diaspore dispersers (Pizo, 2007).

SYSTEMATIC SAMPLINGS – ANT FORAGING PATTERNS. – Community studies of interactions between ants and fruits in Brazilian ecosystems had showed a great number of ant exploiting diaspores. As example, 27 species were found in Cerrado (Christianini et al., 2007) and 17 species in Caatinga (Leal et al., 2007). In the Atlantic Forest domain this number was higher, with 36 ant species observed in sandy plain forest and 48 in lowland forest (Pizo, Passos, & Oliveira, 2005). Ants exploiting diaspores in our study showed the greatest diversity between all studies already done in Atlantic forest, with 54 ant species representing 43 % of the assemblage in the sampled area. To our knowledge, is the higher proportion of ant assemblage interacting with diaspores.

Myrmicines belongs to the largest of all ant subfamilies and encompass a variety of foraging behaviors (Hölldobler & Wilson, 1990). In the literature, Myrmicinae always contributes with the higher number of ant species interacting with fruits and seeds in tropical forests (Pizo et al., 2005; Christianini et al., 2007; Leal et al., 2007). These generalist ants exploit diaspores of different sizes and traits as showed here, although small to medium diaspores have more chance to be removed by them. The leaf-cutter ants of the genera *Atta* and *Acromyrmex* are known to their herbivory activities, but are recorded in many seed interactions too, in which these ants carry and disperse diaspores at long distances, and in some environment they are the most important secondary seed dispersers (Dalling & Wirth, 1998; Leal & Oliveira, 2000; Milesi & Casenave, 2004). Although we did not record any Attini during systematic samples, other six Attini species belonging to the genera *Sericomyrmex* (3 spp.) and *Trachymyrmex* (3 spp.) attended fallen diaspores and also were recorded carrying seeds. Corroborating these observations and following Mehdiabadi & Schultz (2009), the use of parts of plants, such as fruits and seeds is mainly known in the most derived ant agriculturists that practice “generalized higher agriculture” (*Sericomyrmex* and *Trachymyrmex*) and “leafcutter agriculture” (*Acromyrmex* and *Atta*). Nevertheless, several other Attini genera practicing “lower agriculture” can collect fruit flesh or seeds too as one of the numerous resources they can use (Mehdiabadi & Schultz, 2009).

The high frequency of *Wasmannia auropunctata* interacting with all plant species tested, probably results from its high abundance in disturbed areas, mainly due to their ability and successful behavior for colonize new habitats (Delabie & Fowler, 1990). For instance, *W. auropunctata* can even affect abundance and richness of local ants in their natural habit. As this species used to feed on extrafloral nectar and on honeydew excreted by Homoptera, these abundant sources of carbohydrates may contribute to the maintenance of dense populations of *W. auropunctata* in disturbed areas (Wetterer & Porter, 2003).

Beside the abundance, dietary preferences should explain the intensity forage activity of *W. auropuntacta* observed, in which the intense cleaning activity may benefit great number of carbohydrates-rich diaspores species. *W. auropunctata* is also world known as invasive ant, and its presence in exotic environment can influence ecological function of local ant community (Walker, 2006). Recently, studies showed that exotic argentine *Linepithema humile* may develop a role as seed disperser, surrogating Australians native ants in the dispersal system of some native plants (Gomez & Oliveras, 2003; Rowles & O'Dowd, 2009). Thus, knowledge about role of *W. auropunctata* in it native habitat can bring some light over the lack of information about the influence of this species in invaded environments (Rico-Gray & Oliveira, 2007).

Ant behaviors observed in our study were very similar with those found by other researchers. Independent of plant species, most of the diaspore was discovered during the first hours of experiment, but after that period, the ants tended to spend more time on some diaspores than on others (Pizo & Oliveira, 2001), although some results were unexpected by us. The larger fruit used in the experiments, *H. succosa,* attracted a higher number of ants than the small ones, *M. prasina* and *P. glabrata*. Small seeds of *H. succosa* allowed even small ants to carried them. In the other side, the small diaspores of *Psychotria* sp. attracted only three ant species, this can be due to the low nutritional values of this species (Lach et al., 2010). Time expended by ants to diaspore discovery did not differ between plant species used. This first step of interaction generally is not affected by diaspore size (Pizo & Oliveira, 2001), while the second step (i.e. ant foraging behavior) should be influenced both by seed size and chemical characteristics (Bernstein, 1975).

Although chemical analyses were not performed for the diaspores in question, others studies can give support to our results. For example, some Melastomateceae tend to be lipid-poor while most Euphorbiaceae have aril lipid-rich (Pizo & Oliveira, 2000; Christianini et al., 2007; Leal et al., 2007; Catenacci, 2008). Thus, different to the expected about exploitation patterns in ant-diaspores, the large, sugar rich diaspores of *H. succosa* (Melastomataceae) attracted more ant species than the small arilate diaspores of *Pera glabrata* (Euphorbiaceae) (Rico-Gray & Oliveira, 2007). Probably, the higher rate of removal in the first four hours reduced the chance of other ants discovery diaspores. Another diaspore evaluated, *Euterpe edulis,* is a key species for many frugivores in Atlantic forest, attracting a variety of vertebrates, including birds and mammals (Galetti et al., 1999). Thus we expected that its diaspores should attract a great number of ant species (Pizo & Oliveira, 2000). Instead of that, in our study, the number of interactions between *E. edulis* diaspores and ant species were low. Furthermore, seed cleaning behavior showed not benefit the germination and ants were not able to remove its diaspores, demonstrating a low potential for interactions with ants in our study area.

Given the abundance, and ant behavior, we consider that myrmicines species *Pheidole, Sericomyrmex* and *Trachymyrmex,* as well *E. permagnun* (Ectatomminae) and *Pachycondyla* spp. (Ponerinae) should play an important role as seed disperses in the study area. These ants are cited as secondary seed dispersers in other studies, (Pizo et al., 2004; Martins et al., 2006; Christianini et al., 2007).

The ant assemblage was composed mainly by generalists, typically ground dwellers. Within then, *Crematogaster* spp. and *Odontomachus haematodus* can occur both in leaf litter and in suspended soils (Lach et al., 2010). Pseudomyrmecinae was the only subfamily sampled in ant community that had no observed interactions with diaspores. This absence is explained by the fact that this subfamily is typically arboreal with only rare species nesting on the ground in the forests of these regions (Delabie et al., 2007).

DIASPORE REMOVAL: ANTS VS VERTEBRATES. - After their fall on the forest ground, the fruits are vulnerable to a range of predators and fungi attack (Hughes & Westoby, 1990; Ohkawara & Akino, 2004). The hypothesis of predator avoidance is one of the possible benefits of the interaction between ants and myrmecochorous seeds (Hughes & Westoby, 1990; Gove et al., 2007). In tropical forests small rodents and some birds are considered more important as seed predators than dispersers of fallen diaspores (Hulme, 1997). According to DeMattia et al. (2004) small rodents and ants are the main predators of small seeds (< 1 g) in tropical forest while large mammals predate large ones. Even with some evidence of seed predation by ants, literature supports that most of diaspore removing by ants benefits plants species through escape from seed predators (Roberts & Heithaus, 1986; Manzaneda et al., 2005). In our study small diaspores were the most removed by ants, as in other studies, with the exception of *H. succosa* that presented the small seeds removed (Beattie, 1985; Kaspari, 1996; Servigne & Detrain, 2008). Removal rates of diaspores by vertebrate were discreet and probably the level of seed predation of the plants studied is low, but differences between removal rates in *P. glabrata* and *M. prasina* support the predator avoidance hypothesis. Maybe ants play an important role as seed dispersers of these plants.

SEEDS CLEANNING BY ANTS: GERMINATION TEST. – Only a fraction of interactions between ants and fleshy diaspores on the forest floor resulted in their removal due to size limitation. Thus the main ant contribution to plant cycle were the consumption of fleshy parts of the diaspores (i.e seed cleaning) and the germination tests were performed to evaluate the beneficial of these interactions. Although it was expected that seed cleaning by ants increased germination rates, this influence was observed only for *P. glabrata*. Non-myrmecochorous species of Euphorbiaceae, primarily dispersed by birds, presented an aril that is an equivalent structure to the elaiossome, with very similar functional and nutritional characters (Passos & Oliveira, 2003; Francisco et al., 2007). Even without evidence of benefits of seed cleaning by ants in germination tests, cleaning behavior can act as an antifungal treatment in seeds (Ohkawara & Akino, 2004). Cleaning of fleshy parts by ants tended to influence more seed germination of arillates seeds than non-arillate (Pizo & Oliveira, 2001; Christianini et al., 2007), thus results of germination test with P. glabrata corroborated this aspect, as found in the above cited studies.

Conclusion

Our results bring out the highest number of ants exploiting diaspores in Brazilian Atlantic Rain Forests. Ou study was also the first to evaluate ant-fruit-seed interactions in northeastern lowland forests and shows differences in relation with these interactions in southeast lowland forests. The 12 scan samples made during 24 hours of systematic samplings, allowed us to explore ant activity most of the role period, and have the chance to record nocturnal species more accurately. Ant exploitation to diaspores in tropical forest, even only through seed cleaning may give some advantage to the plants in comparison with those not attended. Because dispersal distance of some pioneer seeds could be irrelevant for seed bank dynamics, as well the small diaspores of *Miconia* sp. and the large ones of *H. succosa*, typical of secondary forest, could be benefited by the secondary seed disperser role of the ants in our study area. We suggest that further studies in Una Biological Reserve must consider more complex dispersal mechanisms such as diplochory. Secondary seed dispersal by ants can be an important stage in disperse system for species such as *Pera glabrata*, *Miconia prasina* and *Henriettea succosa*, but our data supports only an weak, or no effect on seed fate of another plant species, such as the threatened palm *Euterpe edulis.* The understanding of the role of ants in communities affected by the effects of habitat fragmentation is a complex question that also requires ant functional information in further studies. Studies involving interactions of ants with others organism could enhance information about this important question for conservation of genetical and ecological resources.

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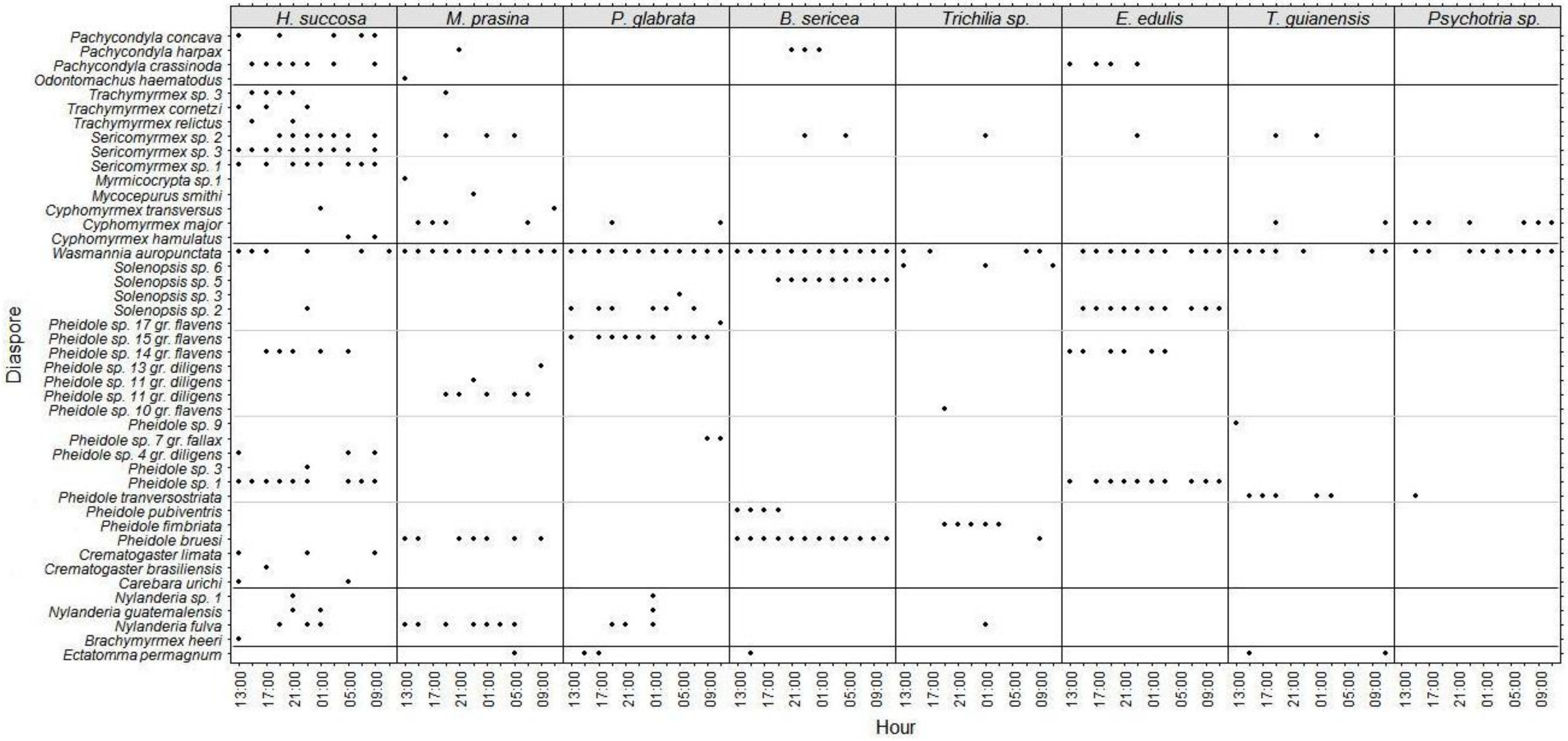
APPENDIX 1. Use of eight different diaspores species by ants during 24 hours . Ant exploitation diaspores were conducted in different days for each diaspore species and the initial time for all was at 13:00 hours. Observations were made during systematic samplings with interval of 2 hours. Biological Reserve of Una, Bahia, Brazil. Black lines separate Ant subfamilies in this order: Ponerinae, Myrmicinae (Atinne), Mymicinae, Formicinae and Ectatomminae.



CONSIDERAÇÕES FINAIS

Uma parte considerável da comunidade de formigas de serrapilheira interage com frutos e sementes nos solos. Nosso estudo revelou a maior riqueza de espécies de formigas em interações com frutos na Mata Atlântica. Por outro lado, é possível reconhecer que não foi possível observar mais interações formiga-diásporo devido à baixa quantidade de frutos encontrados nas áreas que amostramos.

Os possíveis benefícios resultantes do forrageio das formigas nos diásporos observados por nós foram: 1) consumo da parte carnosa do diásporo sem a predação das sementes (Figura 1); 2) remoção rápida dos diásporos (Figura 2), evitando o contato com os vertebrados possíveis predadores; 3) aumento da germinação após limpeza das partes carnosas dos diásporos.

Apesar das formigas explorarem uma variedade de espécies vegetais, ficou evidente que algumas são preferencialmente mais utilizadas por elas, como por exemplo os diásporos de *Henriettea succosa*, *Miconia prasina* e *Pera glabrata* Segundo os nossos resultados, espécies vegetais que possuem diásporos menores que 2 g têm mais chances de serem beneficiadas pela remoção por formigas.

Estudamos principalmente as espécies vegetais que ocorrem em áreas secundárias e com base nos achados deste trabalho, sugerimos que as formigas desempenhem a função de dispersoras secundárias das espécies descritas à cima. A ocorrência da dispersão secundária nos ambientes em regeneração pode auxiliar no recrutamento de espécies vegetais importantes neste processo. Em ambientes perturbados a existência de sistemas de dispersão com muitas etapas pode ajudar a garantir que o processo não será interrompido na ausência de um dos dispersores.

Figura 1

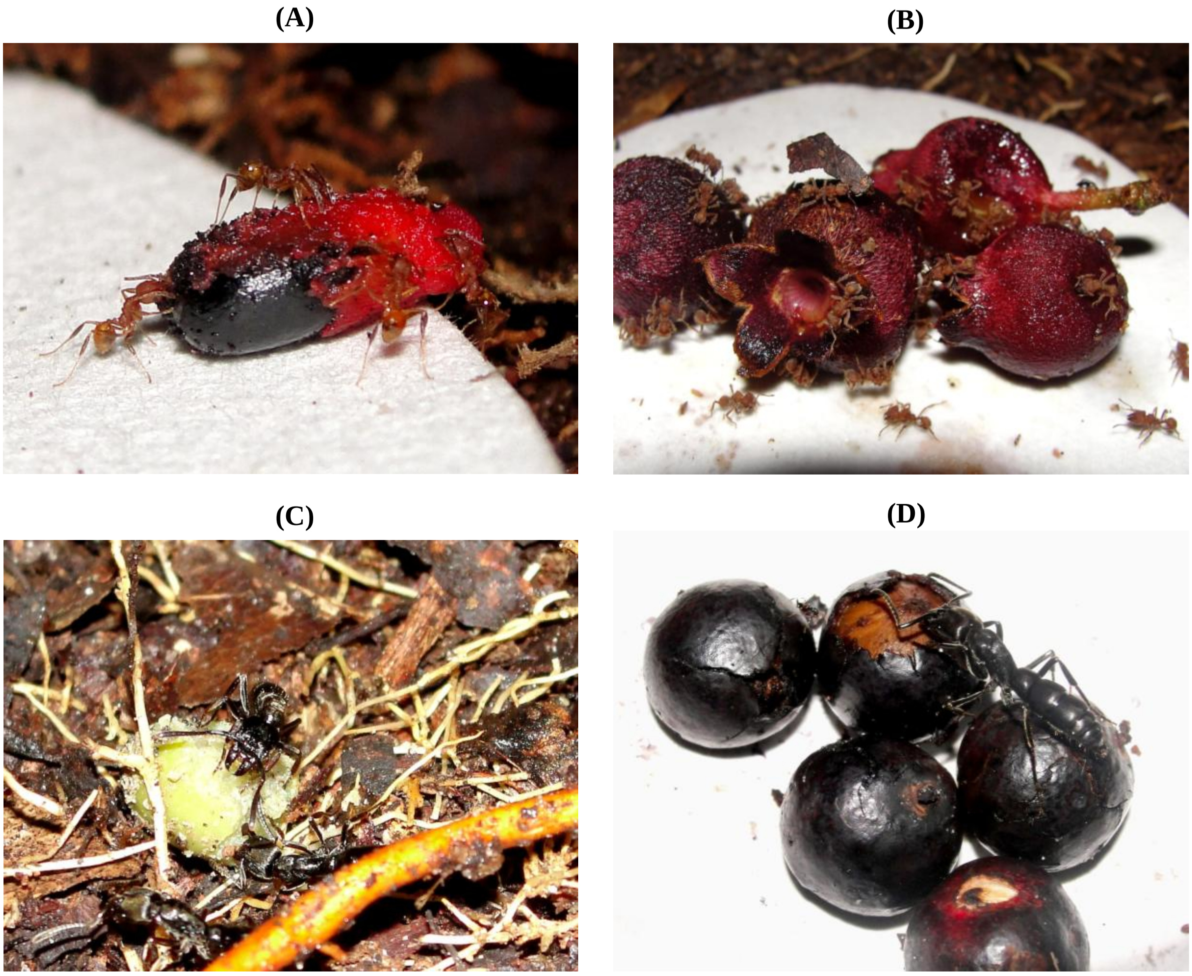


Figura 1. Exemplos de formigas consumindo as partes carnosas dos diásporos. (A) Operárias de *Pheidole* sp. 17 grupo *flavens* (Myrmicinae) consumindo o diásporo de *Pera glabrata* (Euphorbiaceae); (B) Operárias de *Sericomyrmex* sp. 2 (Myrmicinae:Attinae) consumindo o diásporos de *Henriettea succosa* (Melastomataceae); (C) Operárias de *Pachycondyla harpax* (Ponerinae) consumindo diásporo de *Byrsonima sericea* (Malpighiaceae); (D) *Pachycondyla crassinoda* (Ponerinae) consumindo o diásporo de *Euterpe edulis* (Arecaceae).

Figura 2

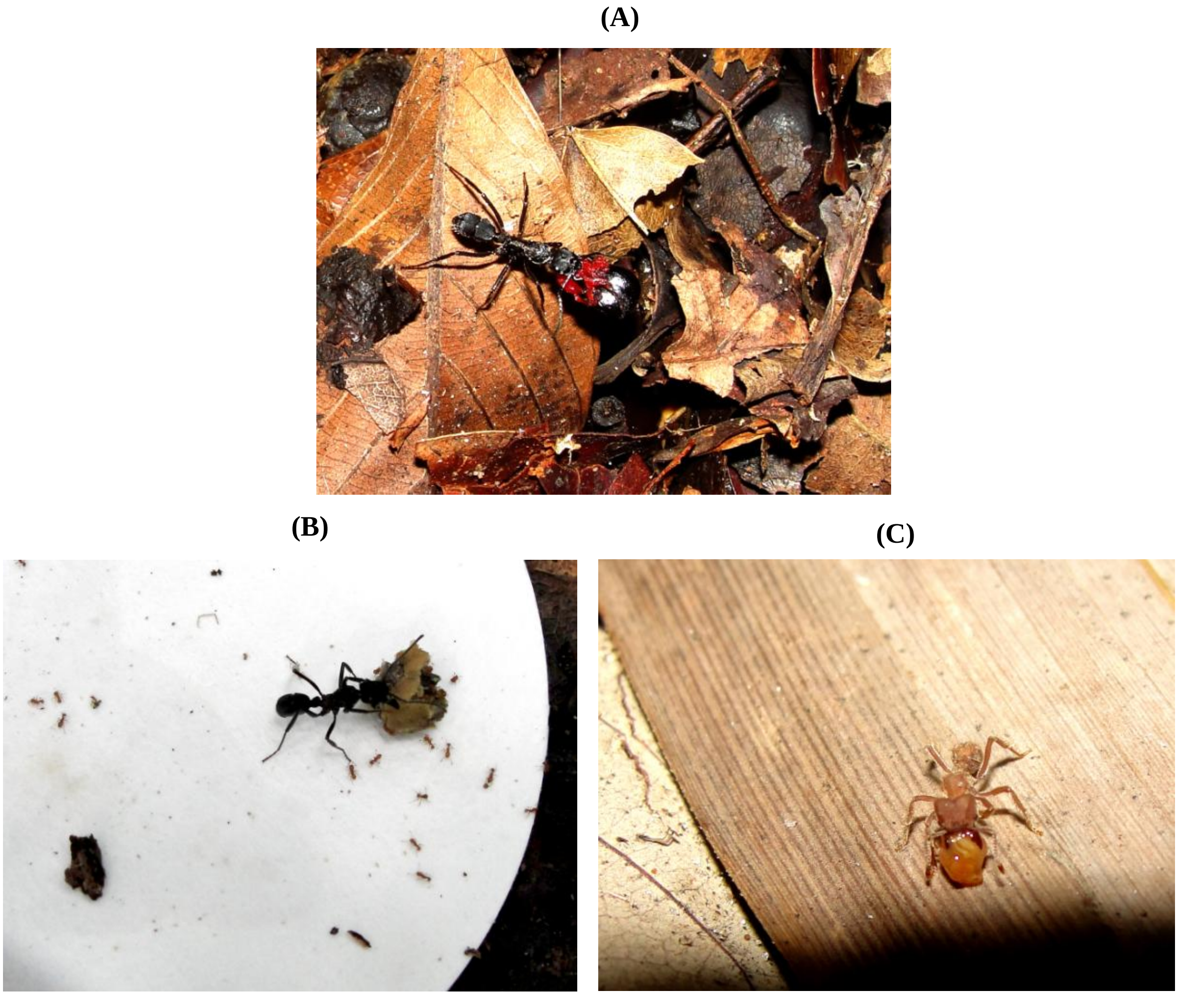


Figura 2. Exemplos de formigas removendo os diásporos. (A) Operária de *Ectatomma permagnun* (Ectatomminae) removendo o diásporo de *Pera glabrata* (Euphorbiaceae); (B) Operária de *Ectatomma permagnun* (Ectatomminae) removendo o diásporo de *Byrsonima sericea* (Malpighiaceae); (C) Operária de *Sericomyrmex* sp. 2 (Myrmicinae:Attinae) removendo semente de *Henriettea succosa* (Melastomataceae).

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