# Bird attributes, plant characteristics, and seed dispersal of *Pera glabrata* (Schott, 1858), (Euphorbiaceae) in a disturbed cerrado area

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## Abstract

Several plant characteristics, such as fruit production, nutrient reward, secondary compounds, and fruit color display, affect fruit choice by birds. On the other hand, several bird attributes affect their efficiency as dispersers. Here we investigate the ornithochoric seed dispersal of *Pera glabrata* Schott (Euphorbiaceae) in a cerrado fragment in southeastern Brazil. A set of bird attributes, such as frequency of visits, number of diaspores eaten, time spent foraging, methods of taking and handling the diaspores and agonistic interactions were analyzed in order to infer about the potential of each species to act as a seed disperser. Birds were the unique seed dispersers of these oil-rich diaspores. We observed 414 bird visits during 60 hours of focal observations in five trees from December 1999 to January 2000. Twenty bird species from seven families ate the diaspores of *P. glabrata*, but only 14 species were considered potential seed dispersers because they swallowed the diaspores, increasing the probabilities for the seeds to be defecated and/or regurgitated away from the parent trees. The main potential seed dispersers were: *Turdus leucomelas* (Muscicapidae), *Dacnis cayana* (Emberizidae), *Colaptes melanochloros* (Picidae) and *Elaenia* spp. (Tyrannidae). We did not find any significant seasonal change in the number of visits on the fruiting trees throughout the day. We also did not find any relation between the number of visits per tree and fruit production. The most effective seed dispersers of *P. glabrata* were generalist birds, which have a high visiting rate, high fruit consumption rate, and spend short periods on the plants. The large number of species recorded as potential seed dispersers of *P. glabrata*, being most of them very abundant even in Brazilian disturbed areas, may guarantee seed dispersal of this plant in small fragments and regenerating areas.

*Keywords:* cerrado, frugivory, fragmentation, ornithochory, seed dispersal.

## Características dos propágulos, atributos das aves, e a dispersão das sementes de *Pera glabrata* (Schott, 1858) (Euphorbiaceae) numa área degradada de cerrado

## Resumo

As diferentes espécies de plantas apresentam características que podem influenciar na atração das aves frugívoras, como a quantidade de frutos produzidos, o valor nutritivo dos frutos, a presença de compostos secundários e o *display* de cores. Por outro lado, diversos estudos têm demonstrado que as espécies de aves que consomem frutos não apresentam a mesma eficiência como dispersores das sementes. Embora estudos sobre a frugivoria e dispersão de sementes sejam de grande importância para a realização de planos de manejo e recuperação de áreas degradadas, pouco tem sido pesquisado sobre o assunto no cerrado brasileiro. Neste trabalho são apresentados aspectos da frugivoria e dispersão ornitocórica das sementes de *Pera glabrata* Schott (Euphorbiaceae) num fragmento de cerrado do sudeste do Brasil. Atributos das aves, como freqüência de visitas, número de diásporos consumidos, tempo de permanência sobre as plantas, métodos de captura e mandibulação dos diásporos, bem como interações antagônicas, foram analisados para se inferir sobre o potencial de cada espécie para atuar como dispersora das sementes. As aves foram os únicos potenciais dispersores dos diásporos. Em 60 horas de observações focais, realizadas entre dezembro de 1999 e janeiro de 2000, foram registradas 414 visitas de 20 espécies de aves pertencentes a sete famílias. No entanto, apenas 14 destas espécies foram consideradas como potenciais dispersores. Os principais potenciais dispersores foram *Turdus leucomelas* (Muscicapidae), *Dacnis cayana* (Emberizidae), *Colaptes melanochloros* (Picidae) e *Elaenia* spp. (Tyrannidae). O número de visitas não diferiu significativamente entre os diferentes intervalos de hora do dia. Não foi encontrada correlação significativa entre o número de visitas e o número de frutos presentes em cada árvore. As aves

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generalistas foram as principais potenciais dispersoras de *P. glabrata*, tendo apresentado altas taxas de visitação, alto consumo de diásporos, e permaneceram sobre as plantas durante curtos períodos de tempo. Muitas das espécies de aves observadas são bastante abundantes mesmo em ambientes antrópicos, o que deve garantir a dispersão das sementes de *P. glabrata* em pequenos fragmentos e em áreas que se encontram em estágio de recuperação.

## 1. Introduction

Seed dispersal is a key element in plant demography and survival (Herrera et al., 1994; Wenny and Levey, 1998; Tabarelli et al., 1999; Passos and Oliveira, 2002), and it is well known that most Neotropical tree and shrub species attract birds and mammals to disperse their seeds (Jordano, 1992; Pinheiro and Ribeiro, 2001).

Several plant characteristics, such as fruit production, nutrient reward, secondary compounds, and fruit color display, affect the fruit attractiveness of birds (Izhaki, 2002). On the other hand, a set of bird attributes determine their efficiency as dispersers, such as gape size, time spent foraging, gut retention time, fruit handling behavior, among others (Pratt and Stiles, 1983; Wheelwright, 1985; Foster, 1987; Levey, 1987; Wenny and Levey, 1998). Moreover, the interactions between frugivorous birds and fruits may be affected by habitat disturbance (Howe, 1984; Pizo, 1997; Galetti and Aleixo, 1998; Tabarelli et al., 1999) and it is paramount to understand the seed dispersal system of vascular plants in natural ecosystems.

Forest fragmentation, for instance, may alter the composition of bird seed-disperser assemblages and the relative contribution of some species as dispersers (Pizo, 1997; Cardoso and Tabarelli, 2000), which can ultimately modify the demography and spatial distribution of the plant populations (Howe, 1984; Tabarelli et al., 1999). Bird-dispersed trees that produce large fruits with large seeds usually depend on a small guild of large-bodied primarily frugivorous birds to disperse their seeds (Howe, 1993). However, large frugivorous birds such as trogons, toucans and cotingas, are among the first species to disappear in disturbed habitats (Willis, 1979; Ribon et al., 2003), resulting in the decline of the recruitment with specialized seed dispersal systems (Cardoso and Tabarelli, 2000). On the other hand, opportunist birds are expected to provide effective dispersal for generalist plant species that by virtue of extended seed dormancy, resistance of seeds or seedlings to density-dependent mortality, or gap colonization strategy, demand requirements that can be found in a wide variety of dispersal agents (for a revision see Howe, 1993). Therefore, plant and disperser characteristics are predicted to determine the effectiveness of seed dispersal in disturbed habitats (Francisco and Galetti, 2001, 2002a, 2002b).

Studies on frugivory and seed dispersal in small remnants may provide valuable information, pointing out plant species that would have their seeds dispersed in such disturbed areas, assisting in the choice of plants to be used in reforestations, especially in locations where

the large and specialized frugivorous animals were extinct (Pizo, 2004).

Although the interaction between fruits and birds has been intensively studied in Neotropical forests (Howe, 1977; Wheelwright, 1985; Foster, 1987, 1990; Galetti and Stotz, 1996; Pizo, 1997; Wenny and Levey, 1998; Passos and Oliveira, 2002), there is little information on seed dispersal by birds in other biomes, such as the Brazilian cerrado (Motta-Junior and Lombardi, 1990; Francisco and Galetti, 2001; Cazetta et al., 2002; Francisco and Galetti, 2002a, 2002b). Here we investigate the ornithochoric seed dispersal of *Pera glabrata* Schott (Euphorbiaceae) in a cerrado fragment in southeastern Brazil. A set of bird attributes, such as frequency of visits, number of diaspores eaten, time spent foraging, methods of taking and handling the diaspores and agonistic interactions were analyzed in order to infer about the potential of each species to act as a seed disperser.

## 2. Material and Methods

### 2.1. Study site

We studied the seed dispersal system of *P. glabrata* in a cerrado fragment that belongs to the campus of São Carlos Federal University, in São Paulo state, southeastern Brazil (21° 58' S and 47° 52' W). The area has 124.68 ha of cerrado vegetation, 3.60 ha of gallery forests, 93.84 ha of *Eucalyptus* spp. plantations with dense *cerrado* understory and 222.73 ha of *Eucalyptus* spp. plantations with no understory (Paese, 1997). This area is disturbed, being sporadically affected by *Eucalyptus* logging and occasional fires. However, this study site is known to have 223 bird species (Motta-Junior and Vasconcellos, 1996) and 33% of all species are known to eat fruits (Willis, 1979; Motta-Junior, 1990).

### 2.2. Pera glabrata Schott

*Pera glabrata* is a tree about 8 m high which is distributed in the cerrado, gallery forests and semi-deciduous forests in Brazil (Lorenzi, 1998), being also commonly found in disturbed and secondary habitats (personal observation). The fruits are round dehiscent capsules on which one to three black ellipsoid seeds are covered by a red oily aril, attractive to many bird species (Galetti and Pizo 1996). Seed production is irregular, not occurring every year (Lorenzi, 1998).

### 2.3. Focal observations

We observed five adult trees that produced about 2,800, 4,300, 9,600, 18,000 and 35,800 fruits when we

started the study in December 1999. Fruit production was estimated by direct counting. We counted the fruit production at the beginning of the fruit season, just before the fruits started opening their capsules. All of the studied trees were located in the cerrado, alongside the borders of the gallery forests. These plants were at least 30 m apart from other *P. glabrata*.

Our study was carried out from December, 1999 to January, 2000, totalling 60 h of focal observations. On each focal day, we spent 12 hours (from 6:00 AM to 6:00 PM) per tree. For each bird visit on *P. glabrata*, we recorded the species observed, number of diaspores eaten, time when the birds arrived at the fruiting tree, time spent foraging, methods of taking and handling fruits and agonistic interactions between the individuals (Pizo, 1997).

The number of diaspores eaten and the time the birds spent foraging were determined when we had the complete observation of the whole behavior, i.e. from their arrival up until the departure from the fruiting tree (Motta-Junior and Lombardi, 1990; Francisco and Galetti, 2001, 2002a, 2002b). We calculated the relative percentage of fruit consumption for each species by: 1) multiplying the mean number of fruits consumed per visit by the total number of visits; 2) dividing this value by the sum of the values obtained for all the species; and 3) multiplying the result by 100.

We considered agonistic encounters when we observed the birds fighting or chasing other individuals. We used Willis (1979) and Motta-Junior (1990) to classify the diet of the species, and Motta-Junior and Vasconcellos (1996) to determine the migratory status of the species in the study site. Data from the weight of the birds were obtained from Marini et al. (1997) and Sick (1997). Taking and handling behavior was categorized according to Moermond and Denslow (1985).

### 2.4. Statistical analyzes

We used the non-parametric Kruskal-Wallis test to assess hourly differences in the number of visits and to compare the time spent foraging, as well as the number of diaspores eaten by the different bird species. Spearman rank correlation was used to test for correlation between: the number of fruits per plant and the number of visits; the time spent foraging and the number of diaspores consumed; and bird body mass and the number of diaspores eaten, which were then verified using the mean values of weights of the birds and the mean number of fruits consumed by each species. All of the analyses were performed using the software BIOESTAT 2.0 (Ayres et al., 2000). Those species with three or less complete observations were not included in the analyses.

## 3. Results

We found ripe fruits of *P. glabrata* from November 1999 to February 2000 in the study area. Fruit length was $10.89 \pm 1.37$ mm (mean $\pm$ SD) and width $11.36 \pm 0.53$ mm (n = 10). The diaspore (aril + seed) length was $5.70 \pm 0.64$ mm, width $4.38 \pm 0.59$ mm, and weight $0.03 \pm 0.01$ g.

Seeds represented $58.7 \pm 10.3\%$ of the weight of the diaspores (n = 17). A positive correlation between the length and diameter of the seeds was found (Spearman rank correlation test, $r_s = 0.62$, p = 0.0071).

In 60 hours of observations, we recorded 20 bird species, belonging to seven different families, eating the diaspores (Table 1). Fourteen species swallowed the diaspores, increasing the probabilities for the seeds to be defecated and/or regurgitated away from the parent trees (Table 2). We recorded 414 bird visits and a mean of $6.9 \pm 6.7$ (n = 60) visits per hour. The total observation period seemed to be enough to sample the main visitors of *P. glabrata*, since the maximum number of species was reached after 41 hours.

The pale-breasted thrush, *Turdus leucomelas* (Vieillot, 1818) (Muscicapidae) was the main potential seed disperser, consuming 16.6% of all diaspores observed, followed by the blue dacnis, *Dacnis cayana* (Linnaeus, 1766) (Emberizidae) (16.2%) and the green-barred woodpecker, *Colaptes melanochloros* (Gmelin, 1788) (Picidae) (13.6%). Other species comprised 44.2% of the diaspores consumed. Generalist species were responsible for the removal of 61.5% of all diaspores, followed by typical insectivores (24.9%), seed predators (9.4%), nectarivores (2.6%) and primarily frugivores (1.6%). Non-dispersers comprised 17.3% of all diaspores removed. Three species, the variegated flycatcher, *Empidonomus varius* (Vieillot, 1818) (Tyrannidae) and the red-eyed vireo, *Vireo olivaceus* (Linnaeus, 1766) (Vireonidae) were considered migratory in the study area (Table 1) and were responsible for the consumption of 9.5% of the diaspores.

Birds presented variable behavioral categories to take the diaspores of *P. glabrata*, and 18 species used more than two different categories (Table 2). We found no hourly difference in the number of visits when all of the species were analyzed together (Kruskal-Wallis: KW = 14.24, p = 0.22), as well as when the most frequent species, such as *D. cayana* (KW = 7.64, p = 0.74), elaenias, *Elaenia* spp. (Tyrannidae) (KW = 14.88, p = 0.18), *T. leucomelas* (KW = 12.04, p = 0.36) and *V. oliveceus* (KW = 7.84, p = 0.72) were individually analyzed.

No correlation was found between the number of fruits from each plant and the number of visits ($r_s = 0.80$, p = 0.13). The different bird species did not differ in the time they spent on the plants (KW = 15.53, p = 0.16).

The number of fruits consumed differed significantly among the bird species (KW = 27.43, p = 0.004), however, no significant correlation was found between the weight of the different species and the mean number of fruits consumed ($r_s = 0.47$, p = 0.12). The time spent on plants and the number of fruits consumed were positively correlated for *Elaenia* spp. ($r_s = 0.65$, p = 0.021), *D. cayana* ($r_s = 0.80$, p = 0.0072), *V. olivaceus* ($r_s = 0.95$, p = 0.0001) and *Z. capensis* (Statius Muller 1776) ($r_s = 0.82$, p = 0.015). For *T. leucomelas*, sayaca tanager, *Thraupis sayaca* (Linnaeus 1766) (Emberizidae) and burnished-buff tanager, *Tangara cayana* (Linnaeus, 1766)

**Table 1.** Diet, migratory status, number of visits, number of diaspore taken, time spent on plants and number of visited plants by birds visiting *Pera glabrata*. Phylogenetic sequence follows Sick (1997).

| Species | Visit number | Diet[a] | Status[b] | N[c] | Diaspore taken[d] | Time spent on plants[e] | Number of visited plants |
|---|---|---|---|---|---|---|---|
| **Seed dispersers** | | | | | | | |
| PICIDAE | | | | | | | |
| *Colaptes melanochloros* | 14 | INS | R | 4 | 13.75 ± 6.29 | 101.25 ± 33.21 | 3 |
| TYRANNIDAE | | | | | | | |
| *Elaenia* spp. | 73 | ONI | R | 12 | 2 ± 1.28 | 48.5 ± 31.45 | 5 |
| *Myiarchus ferox* | 2 | INS | R | 2 | 2.5 ± 0.70 | 59.5 ± 36.06 | 1 |
| *Myiarchus tyrannulus* | 14 | INS | R | 4 | 5.5 ± 1.29 | 110.25 ± 55.72 | 4 |
| *Empidonomus varius* | 13 | INS | M | 4 | 2.5 ± 4.36 | 46.5 ± 64.16 | 3 |
| PIPRIDAE | | | | | | | |
| *Antilophia galeata* | 7 | FRU | R | 4 | 3.25 ± 1.70 | 41.75 ± 27.53 | 1 |
| CORVIDAE | | | | | | | |
| *Cyanocorax chrysops* | 3 | ONI | R | 3 | 8.66 ± 8.50 | 102.0 ± 121.74 | 1 |
| MUSCICAPIDAE | | | | | | | |
| *Turdus leucomelas* | 45 | ONI | R | 10 | 5.5 ± 5.25 | 95.6 ± 77.96 | 4 |
| *Turdus amaurochalinus* | 11 | ONI | R | 4 | 8.5 ± 6.60 | 70.25 ± 78.41 | 1 |
| VIREONIDAE | | | | | | | |
| *Vireo olivaceus* | 47 | ONI | M | 10 | 3.0 ± 1.94 | 43.7 ± 40.86 | 4 |
| EMBERIZIDAE | | | | | | | |
| *Ramphocelus carbo* | 3 | ONI | R | 2 | 0.5 ± 0.70 | 13.5 ± 6.36 | 2 |
| *Thraupis sayaca* | 24 | ONI | R | 6 | 1.66 ± 1.86 | 70.33 ± 57.10 | 5 |
| *Tangara cayana* | 17 | ONI | R | 6 | 1.83 ± 2.63 | 62.33 ± 39.18 | 4 |
| *Dacnis cayana* | 91 | ONI | R | 10 | 4.2 ± 2.53 | 60.0 ± 28.12 | 5 |
| **Pulp eaters** | | | | | | | |
| VIREONIDAE | | | | | | | |
| *Cyclarhis gujanensis* | 3 | INS | R | 2 | 4.0 ± 2.82 | 61.5 ± 2.12 | 1 |
| EMBERIZIDAE | | | | | | | |
| *Parula pitiayumi* | 3 | INS | R | 1 | 4 | 97 | 3 |
| *Coereba flaveola* | 5 | NEC | R | 3 | 7.33 ± 2.08 | 395.33 ± 134.67 | 3 |
| *Nemosia pileata* | 5 | INS | R | 2 | 4.5 ± 0.70 | 52.5 ± 2.12 | 3 |
| *Piranga flava* | 2 | ONI | R | 1 | 15 | 98 | 1 |
| *Zonotrichia capensis* | 28 | SE | R | 8 | 4.75 ± 4.13 | 109.75 ± 77.30 | 3 |

[a]FRU = frugivore; ONI = omnivore; INS = insectivore, SE = seed eaters, NEC = nectar eaters; [b]R = resident; M = migrant; [c]Number of observations with complete data on fruit consumed and time spent on plants; [d]Mean number of consumed fruits; and [e]Mean time spent on plants (s).

(Emberizidae), no significant correlations were found ($r_s$ = 0.54, p = 0.104; $r_s$ = 0.30, p = 0.56 and $r_s$ = 0.73, p = 0.10, respectively).

Although few agonistic encounters were observed, intra-species encounters (n = 9) predominated over inter-species encounters (n = 2). The intra-species encounters were observed with *Elaenia* spp. (n = 3), *T. leucomelas* (n = 4), *D. cayana* (n = 1) and the rufous-browed peppershrike, *Cyclarhis gujanensis* (Gmelin 1789) (Vireonidae) (n = 1), and the inter-species encounters occurred between *Elaenia* spp. and the brown-crested flycatcher, *Myiarchus tyrannulus* (Statius Muller 1776) (Tyrannidae) (n = 1), and between *D. cayana* and *V. olivaceus* (n = 1).

## 4. Discussion

### 4.1. Plant characteristics and bird attractiveness

Most plants whose seeds are dispersed by birds have diaspores that are conspicuously colorful (Van der Pijl, 1982; Willson and Thompson, 1982; Willson and Melampy, 1983), their display of colors probably

**Table 2.** Foraging behavior of birds visiting *Pera glabrata*.

| Species | Methods of taking fruits[a] | | | | Handling methods[b] | |
|---|---|---|---|---|---|---|
| | **Hanging** | **Picking** | **Reaching** | **Stalling** | **SW** | **M** |
| *Colaptes melanochloros* | - | 44 | 11 | - | x | - |
| *Elaenia* spp. | - | 19 | 4 | 1 | x | - |
| *Myiarchus ferox* | - | 5 | - | - | x | - |
| *Myiarchus tyrannulus* | - | 9 | - | 12 | x | - |
| *Empidonomus varius* | - | 8 | - | 2 | x | - |
| *Antilophia galeata* | - | 8 | 4 | 1 | x | - |
| *Cyanocorax chrysops* | - | 9 | 16 | - | x | - |
| *Turdus leucomelas* | - | 49 | 8 | - | x | - |
| *Turdus amaurochalinus* | - | 33 | 1 | - | x | - |
| *Cyclarhis gujanensis* | - | 7 | 1 | - | - | x |
| *Vireo olivaceus* | 1 | 24 | 10 | 2 | x | - |
| *Parula pitiayumi* | - | 3 | 1 | - | - | x |
| *Coereba flaveola* | - | 19 | 3 | - | - | x |
| *Nemosia pileata* | - | 7 | 2 | - | - | x |
| *Piranga flava* | - | 12 | 3 | - | - | x |
| *Ramphocelus carbo* | - | 1 | - | - | x | - |
| *Thraupis sayaca* | - | 8 | 2 | - | x | - |
| *Tangara cayana* | - | 4 | 6 | 1 | x | - |
| *Dacnis cayana* | - | 32 | 10 | - | x | - |
| *Zonotrichia capensis* | - | 29 | 9 | - | - | x |

[a]Hanging (bird's entire body and legs stay under the perch with the ventral side up); Picking (the bird takes the fruits close to their perching without assuming special positions); Reaching (the bird extends its body out or down from the perch); Stalling (the bird captures the fruit while flying, pausing briefly in front of the fruit) (Moermond and Denslow, 1985); e [b]SW = Fruits are swallowed whole; M = Fruits are mashed and the seeds are dropped on parental plants.

having evolved to attract the attention of the dispersers (Ridley, 1930; Van der Pijl, 1982). Many species of plants, including *P. glabrata*, have displays with two or more colors, in such a way that the coloration of the mature diaspore contrasts with the coloration of the non-mature ones or with accessory structures (such as capsules or pedicels), increasing the attraction to the dispersers (Willson and Thompson, 1982; Fuentes, 1995).

*P. glabrata* presents a visible color contrast, created by the red aril that partially covers the black seed, which contrasts with the dark brown dry fruit. The large number of bird visits to plants of this species suggests that such a display is quite efficient in attracting dispersers, in addition to demonstrating that its oily arils are an important food resource for the birds.

The number of fruits can influence the number of bird visits, because plants with fewer fruits may be less visible or may not guarantee a sufficient energy return (Foster, 1990). For *P. glabrata*, the absence of a correlation between the number of fruits and the number of visits by birds suggests that other factors besides the number of fruits may be influencing the frequency of visits to individual plants, such as geographic location, presence of bird territories, or proximity to other fruit-

ing plants, co-specific or not (Levey et al., 1984; Foster, 1990).

*4.2. Bird attributes and dispersal*

The success of the dispersal by the different species of birds may depend on their fruit-handling behavior (Levey, 1987; Traveset, 1994). In this study, the species observed swallowing the diaspores were considered to be potential seed dispersers.

As previously demonstrated by Levey (1987), some birds of the sub-family Thraupinae (Emberizidae) can act as dispersers of small fruits whose seeds cannot be easily removed from the pulp. However, they can remove the pulp of larger fruits and let the seeds fall on the plants. Our observations reinforce this hypothesis. Although *T. sayaca*, *T. cayana* and *D. cayana* have not acted as dispersers of the propagules of *Copaifera langsdorffii* (Desf. 1821) (Caesalpiniaceae) (Motta-Junior and Lombardi, 1990) and *Didymopanax macrocarpum* (Cham. and Schltdl, 1826) (Araliaceae) (Francisco and Galetti, unpubl.), the widths of which are 9.6 and 7.86 mm, respectively, they did prove to be potential dispersers of the small propagules of *P. glabrata* (4.38 mm), swallowing them whole and increasing the possibility of the seeds being regurgitated and/or defecated far from the parent plants, and avoiding the disproportionate mortality rates

from predation and competition in these locales (Janzen, 1970; Connell, 1971).

The probability of a bird swallowing a fruit whole may be limited by its gape width in relation to the size of the fruit (Wheelwright, 1985; Mazer and Wheelwright, 1993). Although species such as *Z. capensis*, hepatic tanager, *Piranga flava* (Vieillot, 1822) (Emberizidae) and hooded tanager, *Nemosia pileata* (Boddaert, 1783) (Emberizidae) are probably able to swallow the propagulas of *P. glabrata*, these birds handle the seeds to extract the aril, letting them fall on the plants. This is probably due to behavioral aspects, since these species are not specialists in the consumption of fruit, which are included in their diet only occasionally. The ease of extracting the aril, which is loosely attached to the seed, may have also contributed, since *N. pileata* was observed swallowing the fruits of *Myrsine lancifolia* (Ruiz and Pav. 1825) (Myrsinaceae) whole, whose width is approximately 4 mm but has pulp that is firmly attached to the seed (Francisco and Galetti, 2001).

Thirty-six (16.14%) of the 223 bird species registered in the study area are migratory, staying in that area during the months from September to April, which coincides with the fruiting season of *P. glabrata*. Among them, *V. olivaceus* made an important contribution to the dispersion of *P. glabrata*, as also previously observed for *Cabralea canjerana* (Vell., 1843) (Meliaceae) in an Atlantic Forest fragment in southeast Brazil (Pizo, 1997). Important contribution of migratory species for seed dispersal was also reported by *Guarea glabra* (Vahl, 1807) in Panama (Howe and De Steven, 1979), and this may confer an advantage to the plant due to the increased number of potential dispersers.

Information regarding the variation in the number of visits to the plants at different times of the day can contribute to the choice of the most appropriate time to conduct observations, as well as reveal the periods of frugivore activity. Variations in the number of visits throughout the day were previously recorded by Howe (1977) and Kantak (1981). The uniform distribution of the visits throughout the day, as well as the low number of antagonistic encounters, demonstrates the absence of temporal competitive exclusion among the birds that composed the guild of species that consumed *P. glabrata*, as well as the absence of preferential times among the species for foraging.

The different species of birds can remain on the plants just long enough to eat, or they may prolong their visits in such a way that the seeds of the fruits consumed pass through the digestive tract and are eliminated on the same plants (Pratt and Stiles, 1983; Wheelwright, 1991). The lack of a correlation between the length of stay on the plants and the number of fruits consumed for species such as *T. leucomelas*, *T. sayaca* e *T. cayana* suggests that these birds remain on the plants longer than would be necessary only to feed themselves. Nevertheless, the periods the birds remained on the plants were, on average, shorter than

three minutes, diminishing the number of seeds eliminated over the adult plants.

### 4.3. Birds and aril interactions in the cerrado

Previous studies on frugivory and seed dispersal in the Brazilian cerrado (Motta-Junior and Lombardi, 1990; Francisco and Galetti, 2001; Cazetta et al., 2002; Francisco and Galetti, 2002a, 2002b) have shown that arils may constitute an important feeding resource for birds in this ecosystem. It can be demonstrated by the high number of bird visits on plants and high rates of propagule consumption, not only by primarily frugivorous birds, but also by generalists and some primarily insectivorous species, which probably complement their diets with fruits, especially in periods of insect scarcity. In this same study area, the average number of visits per hour of birds consuming diaspores (in 60 h focal observation periods) was $3.31 \pm 4.42$ for *Myrsine lancifolia* (Myrcinaceae) (Francisco and Galetti, 2001), $5.8 \pm 5.7$ for *Ocotea pulchella* (Martius 1830) (Lauraceae) (Francisco and Galetti, 2002a), $4.01 \pm 4.88$ for *Davilla rugosa* (Poir. 1812) (Dilleniaceae) (Francisco and Galetti, 2002b) and $31.3 \pm 19.49$ for *Didymopanax macrocarpum* (Araliaceae) (unpubl.). The total number of bird species recorded consuming fruits on these plants was 35, which represents 15.7% of the species occurring in this area.

The number of bird species consuming *P. glabrata* fruits (20 species) was the largest one, compared to the other plants previously analyzed in the study area, which suggests that its oil-rich arils may constitute an important feeding resource, especially because its fruiting period coincides with the breeding season of most resident and migratory species.

It has been long recognized that forest fragmentation may affect faunal and flora interactions (Saunders et al., 1991). For instance, in the Brazilian Atlantic forest, a remarkable decline from largest to smallest fragments in the relative number of Myrtaceae, Lauraceae, Rubiaceae and Sapotaceae trees (Tabarelli et al., 1999) was found, which are among the most important plant families for frugivore birds in this ecosystem (Galetti and Pizo, 1996). This alteration on richness and abundance of vertebrate dispersed trees will ultimately result in disperser diversity decline, and vice-versa (Tabarelli et al., 1999).

Oil-rich arils are typical of plants with specialized seed dispersal systems (Howe, 1993). However, the propagules of *P. glabrata* are small and can be dispersed by small and generalist birds. Although most of the large and specialized frugivores are already extinct in the studied fragment, the generalist birds presented high frequencies of visits, high rates of consumption, and short stays on the plants, increasing the chances of the seeds being regurgitated and/or defecated far from the parent trees, where predation rate and competition are lower (Janzen, 1970; Connell, 1971).

The large number of species recorded as potential seed dispersers of *P. glabrata*, being most of them very abundant even in Brazilian antropic locations (Zimmerman,

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1996; Krugel and Behr, 1999), may guarantee seed dispersal of this plant in small fragments and regenerating areas. The Brazilian cerrado is considered one of the six most important hot spots on earth, and a significant portion of this area is represented by small fragments and human dominated areas (Cavalcanti, 1988; Myers et al., 2000). Restoration plans in the cerrado must emphasize the maintenance of bird-plant interactions in order to reconstruct self-sustainable ecosystems. We suggest that the characteristics presented by *P. glabrata* make this plant adequate for use in managed reforestations.

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