

Seed rain under the canopies of female and male *Myrsine coriacea*, a pioneer tree from the Brazilian Atlantic forest

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Abstract: Isolated pioneer trees have been shown to increase the deposition of animal-dispersed seeds. The effect of gender on seed rain has not yet been investigated, and this study aimed to evaluate whether female and male plants of a pioneer dioecious zoochoric tree differ with respect to the seed rain under their canopies. Seed rain was evaluated for 13 mo, from October 2009 to October 2010, in secondary vegetation of the Atlantic forest in southern Brazil. We used 60 seed traps (0.5 m²): 40 traps under the crowns of 40 *Myrsine coriacea* (Primulaceae) trees (20 male and 20 female individuals) and 20 at sites without trees. We found 365 071 diaspores belonging to 115 morphospecies from 37 families, and 38.3% of the morphospecies were trees, most of them zoochoric. The female trees accumulated a greater number of diaspores and species richness than male trees. The male trees accumulated a higher number of seeds and species than areas without trees. This study shows that sites containing female and male trees of *M. coriacea* and sites without trees differed significantly in terms of seed rain, and there is a gender effect in this dioecious, pioneer tree species because female plants promote an increase in the richness and abundance of diaspores.

Key Words: dioecious trees, natural perches, nucleation, secondary succession, seed dispersal, tropical forest, zoochory

INTRODUCTION

Remnant trees and isolated shrubs or pioneer species in open landscapes represent natural perches and stepping stones for dispersal agents (Guevara *et al.* 1986, Howe *et al.* 2010). Birds and bats seek protection, shade, rest and food in these natural perches and increase the seed rain of the tree species under them (Galindo-González *et al.* 2000). These attributes make these trees ‘regeneration nuclei’ (Guevara *et al.* 1986).

Trees with fleshy fruits attract more seed dispersers (Guevara *et al.* 1986, Slocum 2001), and a greater seed arrival occurs under these canopies than under species that produce dry fruits (Slocum & Horvitz 2000, Vieira & Gandolfi 2006), even during periods when the trees are not producing fruit (Slocum & Horvitz 2000). However, even without attractive food for seed dispersers, trees without fleshy fruits can be important perches and, accordingly, show an increase in seed rain (Carrière *et al.*

2002). These authors found that the increase in seed rain was slightly higher in wind-dispersed plants than in those that produce fleshy fruits. In this context, it is clear that the mechanisms for the attraction of animals are not yet fully understood (Slocum 2001).

Evaluations of the seed rain under the canopies of female and male plants of dioecious and zoochoric species could clarify mechanisms of attractiveness and highlight the importance of the presence of food resources in the deposition of diaspores under these trees. Studies utilizing this approach, i.e. those exploring the effect of gender on seed rain beneath isolated trees, have not yet been developed. Furthermore, this research could determine the importance of each sex as nucleator trees in natural environments.

Importantly, dioecious plants often exhibit sexual differences in life-history traits, such as plant size, growth rate and phenology, which arise from the different costs of reproduction for male and female plants (Forero-Montaña *et al.* 2010, Kuaraksa *et al.* 2012). In tropical forests, dioecy can occur in 27% of tree species, and the dioecious condition is associated with fleshy fruits dispersed by animals at both species and generic levels (Ibarra-Manríquez & Oyama 1992). Some dioecious trees

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are recognized as important pioneer species in secondary succession, such as those belonging to the genera *Cecropia* (Alvarez-Buylla & Martinez-Ramos 1992) and *Myrsine* (Klein 1980).

It is pertinent to assume that, in pioneer vegetation, these trees can act as perches for birds and bats, and in the case of female plants, there is also the provision of food resources. Thus, if the food source is the largest element of attraction for animal dispersal, a significant increase in seed rain under the canopy of female trees in relation to male trees would be expected, and both would cause increases in seed rain compared with sites without trees.

In the context stated above, we predict that the seed rain under the canopies of female trees of *Myrsine coriacea* (Sw.) R. Br. ex Roem. & Schult. (Primulaceae) will be more abundant and more species-rich than that of male trees because female trees offer fleshy fruits as a reward. We also predict that the seed rain under the canopies of these trees will be more abundant and more species-rich than that in sites with only herbaceous vegetation, i.e. areas lacking tree and shrub species.

METHODS

Study area and species

The study was conducted in a 1.8-ha secondary forest fragment in the Atlantic zone (48°48'19"–48°48'25"W, 27°43'46"–27°44'02"S, 290 m asl) adjacent to the state park of Serra do Tabuleiro in the municipality of Santo Amaro da Imperatriz, State of Santa Catarina, Brazil. The climate in the region is classified as humid and mesothermic (Cfa) according to the Köppen system (Castellani & Santos 2005). The average annual temperature is 19 °C. January is the hottest month (mean temperature of 23 °C), and July is the coldest month (mean temperature of 15 °C). The average annual rainfall is approximately 1600 mm. The wettest month is February (average rainfall of 211 mm), and the driest month is June (average rainfall of 68.5 mm) (GAPLAN 1986).

The original vegetation was cut and planted with grass in the 1940s, after which the land was used for pasture until 1990 and was successively cut until 5 y prior to this study (F. M. Brüggemann, pers. comm.). The species present are characteristic of the regeneration process of the Atlantic forest (Klein 1980, 1981) and are interspersed with some invasive species. The physiognomy is predominantly herbaceous, with a predominance of grasses such as *Melinis minutiflora* P. Beauv. and *Andropogon bicornis* L. Trees are sparse, and *Myrsine coriacea* is predominant. There are also isolated trees of *Clethra scabra* Pers., *Miconia cinnamomifolia* (DC.) Naudin and *Tibouchina granulosa* (Desr.) Cogn.

Myrsine coriacea is an evergreen heliophytic tree with great capacity for colonizing areas of the Atlantic forest in the process of secondary succession (Klein 1980, Pinheiro & Carmo 1993, Reitz *et al.* 1979). Its fruits are consumed by several bird species (Pinheiro & Carmo 1993). *Myrsine coriacea* trees have an elongated crown that is not very dense, their height varies from 6 to 12 m, and the trunk varies from 30 to 40 cm in diameter. These trees bloom from May to June, and their fruits ripen from October to December. The fruits are small globose drupes (3–5 mm) that are black-purple when ripe with a very thin pericarp and one seed with a diameter 1 mm smaller than that of the fruit (Lorenzi 2002a, Pascotto 2007).

Seed rain under female trees, male trees and sites without trees

In this paper, the term diaspore is used to describe seeds and fruits together as units of dispersal, and the term seed rain, adopted in this work, corresponds to both seeds and fruits deposited in traps under the crowns of *M. coriacea* and in sites without trees.

Sixty traps were installed to monitor seed rain: 20 under the crowns of 20 female *M. coriacea* trees (one per tree), 20 under the crowns of 20 male trees and 20 in sites with only herbaceous vegetation (referred to as 'without trees'). The area under the crown of each *M. coriacea* tree was divided into four quadrants, and a trap was placed in a randomly chosen quadrant close to the trunk of the tree. The trees chosen for the study were reproductive adults and had no crown overlap with other shrub or tree species. Traps were placed at an average of 5 m away from each other (with a minimum of 3 m), and there was no overlap between species canopies.

Seed traps were made of wood and voile fabric (100% polyester). Each trap was square with an area of 0.5 m² (Hardesty & Parker 2002, Pivello *et al.* 2006) and was positioned 0.5 m above the ground on wooden legs (Holl 1998). The diaspores were collected every 15 d for 13 mo from October 2009 to October 2010, analysed with the aid of a stereoscopic microscope and separated into morphospecies.

The collected diaspores were identified to the level of species, genus or family by comparing them with fruits and seeds of trees collected in the study area and the surrounding forest. The literature was also consulted (Bacchi *et al.* 1984, Barroso *et al.* 1999, Leitão Filho *et al.* 1972, 1975; Lorenzi 2002a, 2002b, 2009) to assist in the identification of diaspores. The diaspores were classified according to dispersal syndrome (van der Pijl 1972): (1) zoochoric, (2) anemochoric, (3) autochoric and (4) indeterminate. Only ripe fruits and seeds were included in the analysis.

The male and female trees of *M. coriacea* selected for the study were measured to determine total tree height, canopy height (from the apex of the canopy to the insertion of the first branch of the trunk) and canopy area (area of the circle generated from the mean radius of the canopy) to assess whether these morphological characteristics differed between the sexes and influenced seed rain.

Data analysis

The abundance of diaspores and richness of seed rain per trap area were compared using analysis of variance (ANOVA) and the post hoc Tukey test using \log_{10} -transformed data (Zar 1996). The species composition of seed rain under male and female trees of *M. coriacea* and in sites without trees was assessed by analysis of similarity (ANOSIM) using R version 2.11.1. The morphological characteristics of male and female trees of *M. coriacea* were compared using a t-test (Zar 1996) with the program Statistica (version 7).

A principal component analysis (PCA) was performed to explore the combined effects of the richness and abundance of the seed rain and the morphological characteristic of the trees (canopy area). A correlation matrix was employed in the PCA (Legendre & Legendre 1998), and the analysis was performed with the standardized measurement data using the program MVSP (version 3.13r).

All of the *M. coriacea* fruits that were deposited by falling naturally (i.e. those without signs of use by fauna) were removed from the analysis; thus, only the diaspores manipulated by animal dispersal agents were included.

RESULTS

Abundance and richness of the seed rain under female trees, male trees and sites without trees

We collected 365 071 diaspores in the 60 traps. Of these, 53% (191 652) were under female trees, 29% (106 533) were under male trees and 18% (66 886) were in sites without trees. The proportion of *M. coriacea* diaspores that were deposited by falling naturally was 8.14% of the total (29 728 diaspores). Excluding this percentage, 335 343 diaspores were employed in the analyses. A total of 115 morphospecies belonging to at least 37 plant families were recorded in the seed rain. Of these morphospecies, 97 were found under female trees, 92 were found under male trees and 57 were found in sites without trees.

The three types of trap site differed significantly with respect to the number of diaspores deposited ($F_{(2,57)} = 13.4$, $P < 0.05$). The average abundance of diaspores

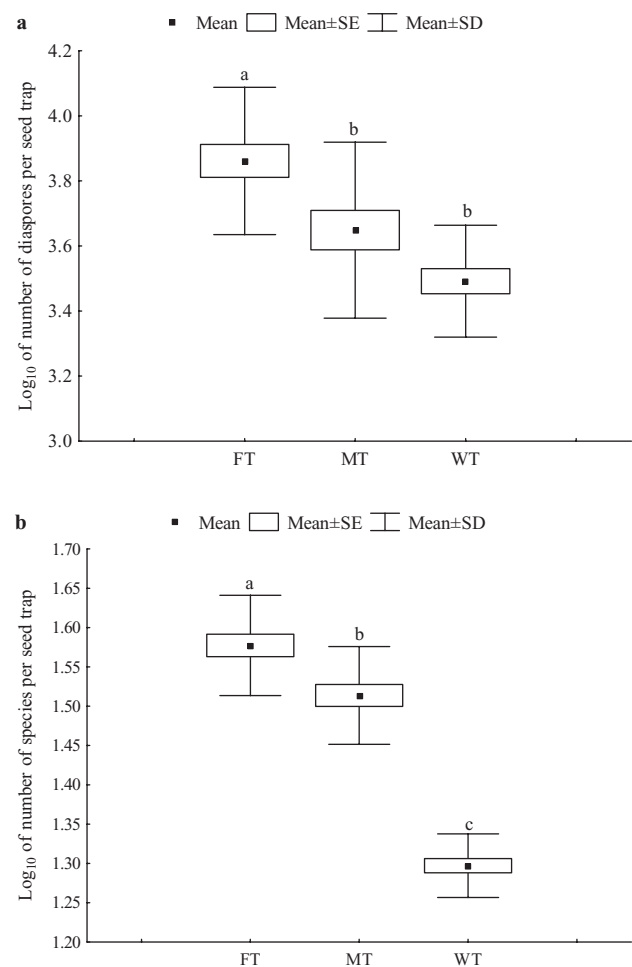


Figure 1. Number of diaspores (a) and richness of species of diaspores (b) deposited under the canopy of the female trees (FT, $n = 20$ seed traps of 0.5 m^2) and male trees (MT, $n = 20$) of *Myrsine coriacea* and at sites without trees (WT, $n = 20$) in secondary vegetation of Atlantic rain forest (Santo Amaro da Imperatriz, State of Santa Catarina, southern Brazil). Same letters indicate no significant differences according to Tukey test, $P < 0.05$.

under female trees differed from the abundance found under male trees and in sites without trees (Figure 1a). We also found significant differences in the richness of species deposited in the three sites ($F_{(2,57)} = 135$, $P < 0.05$), with female trees differing from the male trees and the sites without trees. The male trees also differed from the sites without trees (Figure 1b).

Considering only the diaspores classified as zoochoric, the abundance of diaspores ($F_{(2,57)} = 112$; $P < 0.05$) differed significantly between sites containing trees of *M. coriacea* and sites without trees. The richness ($F_{(2,57)} = 155$; $P < 0.05$) differed significantly among the three types of trap sites (Figure 2a, b). The species richness of diaspores under the canopy of female plants was always higher than that under male trees for both zoochoric diaspores and total seed rain (Figure 1b, 2b).

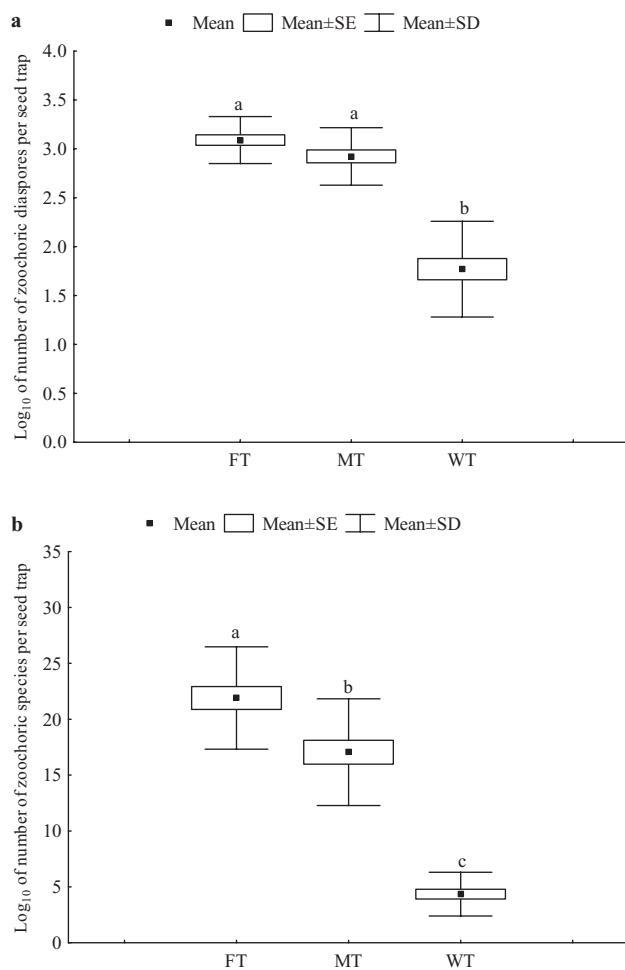


Figure 2. Number of zoochory diaspores (a) and richness of zoochory species (b) under the canopy of the female trees (FT, $n = 20$ collectors of 0.5 m^2) and male trees (MT, $n = 20$) of *Myrsine coriacea* and at sites without plants (WT, $n = 20$) in secondary vegetation of Atlantic rain forest (Santo Amaro da Imperatriz, State of Santa Catarina, southern Brazil). Same letters indicate no significant differences according to Tukey test, $P < 0.05$.

Male and female trees of *M. coriacea* did not differ in total height ($t_{(38)} = 1.1$, $P > 0.05$), canopy height ($t_{(38)} = 1.2$, $P > 0.05$) or canopy area ($t_{(38)} = 1.8$, $P > 0.05$). These reproductive plants presented average heights of approximately 6 m (female 6.2 ± 1.3 m; male 6.5 ± 0.8 m) and canopy areas of $5.7 \pm 2.8 \text{ m}^2$ (female) and $7.8 \pm 4.4 \text{ m}^2$ (male).

In the principal component analysis (Figure 3) involving the parameters of seed rain and the morphological characteristics of the trees, the first two components accounted for 83.7% of the variance (49.1% and 34.6% for the first and the second, respectively). The number of diaspores (0.72) and species richness (0.65) were more highly correlated with the first component, and canopy area (0.90) was more highly correlated with the second component. Most of the female trees sampled were

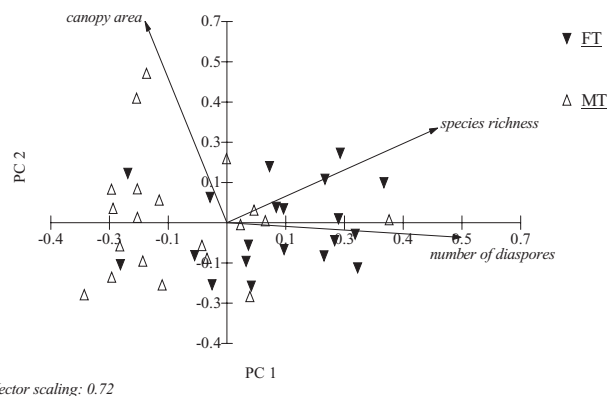


Figure 3. Scatter plot of principal component analysis (PCA) of parameters of seed rain (number of diaspores and richness of species) deposited under the canopy of the female trees (FT) and male trees (MT) of *Myrsine coriacea* and morphological characteristic of the trees (canopy area). (PC1 = 49.0% and PC2 = 34.6%).

positioned closer to the vectors of the number of diaspores and species richness, indicating a positive association with these variables. At the same time, most male tree samples were negatively associated with the seed-rain vectors. Additionally, trees with higher values for canopy area did not show increased arrival of diaspores or greater species richness per trap (Figure 3).

Seed rain composition

A total of 115 morphospecies were recorded in the evaluation of seed rain, belonging to at least 37 plant families. Species with zoochory dispersal composed the greatest percentage of the seed-rain richness (53.9%) followed by those with anemochory (24.3%), autochory (7.8%) and indeterminate dispersal mechanisms (13.9%). In terms of diaspores, the anemochory dispersal syndrome was most abundant (39%) followed by autochory (37%), zoochory (22.2%) and indeterminate dispersal syndromes (1.8%). *Tibouchina* spp. (*Tibouchina granulosa* (Desr.) Cogn., *Tibouchina urvilleana* (DC.) Cogn. and *Tibouchina sellowiana* Cogn.), with autochory seed dispersal, presented the highest number of diaspores, and *Clethra scabra* Pers., with winged seeds, presented the second-highest number of diaspores collected (Appendix 1).

The predominant growth habit was tree (38.3% of species), comprising medium-sized and tall trees, followed by herbs (10.4%), woody shrubs (9.6%), scandent plants (6.1%), epiphytes (0.9%) and indeterminate (34.8%). Among the tree species recorded in the seed-rain analysis, 35 were zoochory, and the species *Miconia cinnamomifolia*, *M. cabussu*, *M. eichleri* and *Cecropia glaziovii* stand out due to the arrival of larger numbers of diaspores, which together accounted for 5% of the total. *Miconia* (six

species), *Ficus* (four species) and *Ilex* (three species) are the most well-represented genera (11% of the total) among the zoochoric trees in terms of species (Appendix 1).

Regarding the composition of the seed rain under the canopies of female trees, male trees and at sites without trees, the samples differed significantly ($R = 0.6$; $P = 0.001$) among the three sites. Samples obtained from under female trees differed from samples obtained from under male trees ($R = 0.1$; $P = 0.007$) and from sites without trees ($R = 0.9$; $P = 0.001$). Samples from male trees also differed from those collected from sites without trees ($R = 0.7$; $P = 0.001$).

DISCUSSION

Abundance and richness of seed rain under female trees, male trees and sites without trees

The results of this study showed that a significant amount of the total seed rain occurred under *M. coriacea* trees (more than 80% of the total), confirming the assumption that *M. coriacea* is an important focus for the deposition of diaspores compared with areas lacking trees and corroborating the hypothesis that isolated trees in the landscape are the sites of the deposition of diaspores (Corlett & Hau 2000, Galindo-González *et al.* 2000, Herrera & García 2009, Slocum 2001, Wilms & Kappelle 2006).

Additionally, the effect of gender on seed rain beneath isolated trees of dioecious species was evident with *M. coriacea*, especially with regard to the species richness of diaspores. Female trees promoted increases in the arrival of zoochoric diaspores and increases in total seed rain under their canopy compared with male trees, confirming our hypothesis. We also observed a greater abundance of seed rain deposited under female trees, with records of 85 119 more diaspores under female trees than under male trees. This tendency was also observed with zoochoric diaspores, with 7213 more. We suggest that the fruits of female trees play a key role in attracting dispersers because male and female trees differ only in the presence of fruit. Thus, the male trees act as a control because they have the same characteristics as the female trees but lack fruits.

The male trees are also a focus of diaspore deposition, as shown by the richer seed rain under male trees compared with sites without trees. This result is relevant because it confirms that the dispersers are visiting male trees, which must also offer features that are attractive to dispersers. In some cases, the importance of non-fruit-producing trees can be comparable to that of fruit-producing trees in the seed dispersal landscape, and non-fruit-producing trees may increase the seed rain although they lack a food source that is attractive to dispersal agents. For example,

Carrière *et al.* (2002) reported an increase in seed rain under the canopy of anemochoric and zoochoric species compared with open field sites far from the trees evaluated. These authors found an average of 17.2 seeds m^{-2} per trap (0.2 m^2) under anemochoric trees, compared with 15.5 seeds m^{-2} under zoochoric trees.

We believe that both female and male *M. coriacea* trees offer points of landing, rest and shelter as well as tree-associated insects (*pers. obs.*) that make them attractive to dispersers. According to Carrière *et al.* (2002), birds with mixed diets may visit the trees to eat items other than fruits. These authors argue that some bird species may visit trees that do not have fleshy fruits to feed on insects. Our findings corroborate the work of these authors and show that trees of *M. coriacea* are attractive to seed dispersers.

Trees with a larger canopy area showed no major increase in diaspores per trap area. This result suggests that the size of reproductive trees is not a factor that influences the abundance and richness of seed rain, although these results were obtained using a standard trap size, which is a procedure that has been employed in other studies evaluating seed rain (Grombone-Guaratini & Rodrigues 2002, Guevara *et al.* 1986, 2004, Herrera & García 2009, Vieira & Gandolfi 2006).

Seed rain composition

Species with the zoochoric dispersal syndrome showed the highest number of species in their seed rain, corroborating other studies performed on isolated trees in tropical forests (Carrière *et al.* 2002, Guevara *et al.* 1986, 2004; Howe & Smallwood 1982). Nearly 40% of the species recorded were trees, and many of these trees had zoochoric fruits, indicating that the arrival of these species may facilitate the future development of tree patches and forest succession. However, many other post-dispersal factors alter recruitment after seed arrival, e.g. seed predation and seedling competition (Duncan & Chapman 1999).

In terms of numbers, the anemochoric dispersal syndrome was the most abundant, confirming a trend in the early stages of succession. According to Pivello *et al.* (2006), the initial species involved in the succession of tropical rain forests are commonly dispersed by wind. This feature is also mentioned by van der Pijl (1972), who indicated that anemochoric dispersal tends to predominate in the early stages of colonization.

The composition of the seed rain was different in each site, suggesting that the arrival of species is modified by the presence and absence of individual trees and by the gender of the same tree species. Thus, we believe that species with diaspores dispersed by animals would benefit from the presence of local trees as perches (Corlett & Hau

2000, Duncan & Chapman 1999, Guevara *et al.* 1986, 2004; Herrera & García 2009).

CONCLUSIONS

Myrsine coriacea trees were shown to be foci of diaspore deposition, as evaluated by their richer and more abundant seed rain compared with sites lacking trees. Female trees showed significantly greater abundance and richness of seed rain compared with male trees. A greater richness of zoochoric diaspores was deposited under the canopy of female plants. Thus, there is a gender effect on seed rain beneath trees of dioecious species. Male trees were important foci of diaspore deposition compared with sites lacking trees. Resources, including landing areas, rest areas, the presence of insects and the presence of fruits, were likely responsible for the attraction of dispersal agents, which deposited a large number of diaspores from many species of trees under the canopy of *M. coriacea*, thus contributing to the process of the arrival of new species and secondary succession in the Atlantic forest.

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LITERATURE CITED

- ALVAREZ-BUYLLA, E. R. & MARTINEZ-RAMOS, M. 1992. Demography and allometry of *Cecropia obtusifolia*, a neotropical pioneer tree – an evaluation of the climax-pioneer paradigm for tropical rain forests. *Journal of Ecology* 80:275–290.
- BACCHI, O., LEITÃO FILHO, H. F. & ARANHA, C. 1984. *Plantas invasoras de culturas no Estado de São Paulo*. Editora da Universidade de Campinas, São Paulo. 309 pp.
- BARROSO, G. M., MORIN, M. P., PEIXOTO, A. L. & ICHASO, C. L. F. 1999. *Frutos e sementes – morfologia aplicada à sistemática de dicotiledôneas*. Editora da Universidade Federal de Viçosa, Viçosa. 443 pp.
- CARRIÈRE, S. M., ANDRÉ, M., LETOURMY, P., OLIVIER, I. & McKEY, D. B. 2002. Seed rain beneath remnant trees in a slash-and-burn agricultural system in southern Cameroon. *Journal of Tropical Ecology* 18:353–374.
- CASTELLANI, T. T. & SANTOS, F. A. M. 2005. Abundância de ramos reprodutivos e produção de sementes em populações de *Ipomoea pes-caprae* (L.) R. Br. na Ilha de Santa Catarina, Brasil. *Acta Botanica Brasílica* 19:251–264.
- CORLETT, R. T. & HAU, B. C. H. 2000. Seed dispersal and forest restoration. Pp. 317–325 in Elliott, S., Kerby, J., Blakesley, D., Hardwick, K., Woods, K. & Anusarnsunthorn, V. (eds). *Forest restoration for wildlife conservation*. International Tropical Timber Organization and The Forest Restoration Research Unit, Chiang Mai University, Thailand.
- DUNCAN, R. S. & CHAPMAN, C. A. 1999. Seed dispersal and potential forest succession in abandoned agriculture in Tropical Africa. *Ecological Applications* 9:998–1008.
- FORERO-MONTAÑA, J., ZIMMERMAN, J. K. & THOMPSON, J. 2010. Population structure, growth rates and spatial distribution of two dioecious tree species in a wet forest in Puerto Rico. *Journal of Tropical Ecology* 26:433–443.
- GALINDO-GONZÁLEZ, J., GUEVARA, S. & SOSA, V. 2000. Bat and bird generated seed rains at isolated trees in pastures in a tropical rainforest. *Conservation Biology* 14:1693–1703.
- GAPLAN. 1986. *Atlas de Santa Catarina*. Aerofoto Cruzeiro S/A, Rio de Janeiro. 173 pp.
- GROMBONE-GUARATINI, M. T. & RODRIGUES, R. R. 2002. Seed bank and seed rain in a seasonal semi-deciduous forest in south-eastern Brazil. *Journal of Tropical Ecology* 18:759–774.
- GUEVARA, S., PURATA, S. E. & VAN DER MAAREL, E. 1986. The role of remnant forest trees in tropical secondary succession. *Vegetatio* 66:77–84.
- GUEVARA, S., LABORDE, J. & SANCHEZ-RIOS, G. 2004. Rain forest regeneration beneath the canopy of fig trees isolated in pastures of Los Tuxtlas, Mexico. *Biotropica* 36:99–108.
- HARDESTY, B. D. & PARKER, V. T. 2002. Community seed rain patterns and a comparison to adult community structure in a West African tropical forest. *Plant Ecology* 164:49–64.
- HERRERA, J. M. & GARCÍA, D. 2009. The role of remnant trees in seed dispersal through the matrix: being alone is not always so sad. *Biological Conservation* 142:149–158.
- HOLL, K. D. 1998. Do bird perching structures elevate seed rain and seedling establishment in abandoned tropical pasture? *Restoration Ecology* 6:253–261.
- HOWE, H. F. & SMALLWOOD, J. 1982. Ecology of seed dispersal. *Annual Review of Ecology and Systematics* 13:201–228.
- HOWE, H. F., URINCHO-PANTALEON, Y., PEÑA-DOMENE, M. & MARTÍNEZ-GARZA, C. 2010. Early seed fall and seedling emergence: precursors to tropical restoration. *Oecologia* 164:731–740.
- IBARRA-MANRIQUEZ, G. & OYAMA, K. 1992. Ecological correlates of reproductive traits of Mexican rain forest trees. *American Journal of Botany* 79:383–394.
- KLEIN, R. M. 1980. Ecologia da flora e vegetação do Vale do Itajaí (continuação). *Sellowia* 32:165–389.

- KLEIN, R. M. 1981. Fisionomia, importância e recursos da vegetação do Parque Estadual da Serra do Tabuleiro. *Sellowia* 33:5–57.
- KUARAKSA, C., ELLIOTT, S. & HOSSAERT-MCKEY, M. 2012. The phenology of dioecious *Ficus* spp. tree species and its importance for forest restoration projects. *Forest Ecology and Management* 265:82–93.
- LEGENDRE, P. & LEGENDRE, L. 1998. *Numerical ecology*. (Second edition). Elsevier, Amsterdam. 853 pp.
- LEITÃO FILHO, H. F., ARANHA, C. & BACCHI, O. 1972. *Plantas invasoras de culturas no Estado de São Paulo*. Volume 1. Hucitec, São Paulo. 291 pp.
- LEITÃO FILHO, H. F., ARANHA, C. & BACCHI, O. 1975. *Plantas invasoras de culturas no Estado de São Paulo*. Volume 2. Hucitec, São Paulo. 306 pp.
- LORENZI, H. 2002a. Árvores brasileiras – Manual de identificação e cultivo de plantas arbóreas nativas do Brasil. (Quarta edição). Volume 1. Instituto Plantarum, Nova Odessa. 368 pp.
- LORENZI, H. 2002b. Árvores brasileiras – Manual de identificação e cultivo de plantas arbóreas nativas do Brasil. (Segunda edição). Volume 2. Instituto Plantarum, Nova Odessa. 368 pp.
- LORENZI, H. 2009. Árvores brasileiras – Manual de identificação e cultivo de plantas arbóreas nativas do Brasil. (Primeira edição). Volume 3. Instituto Plantarum, Nova Odessa. 384 pp.
- PASCOTTO, M. C. 2007. *Rapanea ferruginea* (Ruiz & Pav.) Mez. (Myrsinaceae) como uma importante fonte alimentar para as aves em uma mata de galeria no interior do Estado de São Paulo. *Revista Brasileira de Zoologia* 24:735–741.
- PINHEIRO, A. L. & CARMO, A. P. T. 1993. Contribuição ao estudo tecnológico da Canela-azeitona, *Rapanea ferruginea* (Ruiz e Pav.) Mez, uma espécie pioneira. I. Características anatômicas da madeira. *Ciência Florestal* 1:121–145.
- PIVELLO, V. R., PETENON, D., JESUS, F. M., MEIRELLES, S. T., VIDAL, M. M., ALONSO, R. A. S., FRANCO, G. A. D. C. & METZGER, J. P. 2006. Chuva de sementes em fragmentos de floresta atlântica (São Paulo, SP, Brasil), sob diferentes situações de conectividade, estrutura florestal e proximidade da borda. *Acta Botanica Brasilica* 20:845–859.
- REITZ, R., KLEIN, R. M. & REIS, A. 1979. *Madeiras do Brasil: Santa Catarina*. Lunardelli, Florianópolis. 320 pp.
- SLOCUM, M. G. 2001. How tree species differ as recruitment foci in a tropical pasture. *Ecology* 82:2547–2559.
- SLOCUM, M. G. & HORVITZ, C. C. 2000. Seed arrival under different genera of trees in a neotropical pasture. *Plant Ecology* 149:51–62.
- VAN DER PIJL, L. 1972. *Principles of dispersal in higher plants*. (Second edition). Springer-Verlag, Berlin. 160 pp.
- VIEIRA, D. C. M. & GANDOLFI, S. 2006. Chuva de sementes e regeneração natural sob três espécies arbóreas em uma floresta em processo de restauração. *Revista Brasileira de Botânica* 29:541–554.
- WILMS, J. J. A. M. & KAPPELLE, M. 2006. Frugivorous birds, habitat preference and seed dispersal in a fragmented Costa Rican montane oak forest landscape. *Ecological Studies* 185:309–324.
- ZAR, J. H. 1996. *Biostatistical analysis*. (Fourth edition). Prentice-Hall, Englewood Cliffs, NJ. 662 pp.

Appendix 1. Diaspores collected in the seed rain in secondary vegetation of Atlantic rain forest (Santo Amaro da Imperatriz, State of Santa Catarina, southern Brazil) ranked by abundance of diaspores. Syndromes: ane = anemochoric, auto = autochoric and zoo = zoochoric; Habits: 1 = herbs, 2 = woody shrubs, 3 = medium-sized trees, 4 = scandent plants, 5 = tall trees, 6 = epiphytes and 7 = indeterminate.

Species	Family	Diaspores	Syndromes	Habits	Number of diaspores
<i>Tibouchina</i> spp.	Melastomataceae	seed	auto	3	134 809
<i>Clethra scabra</i> Pers.	Clethraceae	fruit/seed	ane	3	44 470
<i>Myrsine coriacea</i> (Sw.) R. Br. ex Roem. & Schult.	Primulaceae	fruit/seed	zoo	3	35 351
<i>Vernonia</i> sp. 1	Asteraceae	fruit	ane	1	19 403
<i>Piptocarpha tomentosa</i> Baker	Asteraceae	fruit	ane	3	17 259
<i>Miconia sellowiana</i> Naudin	Melastomataceae	fruit/seed	zoo	2	14 361
<i>Urochloa</i> sp. 1	Poaceae	seed	ane	1	14 283
<i>Miconia cinnanomifolia</i> (DC.) Naudin	Melastomataceae	fruit/seed	zoo	5	14 011
<i>Calea</i> sp.	Asteraceae	fruit	ane	1	12 519
<i>Andropogon bicornis</i> Forssk.	Poaceae	seed	ane	1	11 811
<i>Baccharis</i> sp. 1	Asteraceae	fruit	ane	2	8174
<i>Leandra</i> aff. <i>aurea</i> (Cham.) Cogn.	Melastomataceae	fruit/seed	zoo	2	7840
<i>Baccharis</i> sp. 2	Asteraceae	fruit	ane	2	6874
Morphospecies sp. 1	indeterminate	seed	ind	7	5929
<i>Paspalum</i> sp.	Poaceae	seed	ane	1	2612
<i>Miconia cabussu</i> Hoehne	Melastomataceae	seed	zoo	5	1510
<i>Cecropia glaziovi</i> Sneathl.	Urticaceae	seed	zoo	3	1412
<i>Vernonia discolor</i> (Spreng.) Less.	Asteraceae	fruit	ane	3	1330
<i>Miconia eichleri</i> Cogn.	Melastomataceae	seed	zoo	3	1110
<i>Mikania sericea</i> Hook. & Arn.	Asteraceae	fruit	ane	4	1034
<i>Ficus</i> cf. <i>luschnathiana</i> (Miq.)	Moraceae	seed	zoo	5	960
<i>Asteraceae</i> sp. 1	Asteraceae	fruit	ane	7	825
Morphospecies sp. 3	indeterminate	seed	ind	7	691
<i>Casearia sylvestris</i> Sw.	Salicaceae	seed	zoo	3	571
<i>Rubus</i> sp. 1	Rosaceae	seed	zoo	7	551
<i>Ilex dumosa</i> Reissek	Aquifoliaceae	seed	zoo	3	549
<i>Asteraceae</i> sp. 2	Asteraceae	fruit	ane	7	384
Morphospecies sp. 27	indeterminate	seed	zoo	7	358
<i>Miconia fasciculata</i> Gardner	Melastomataceae	seed	zoo	3	315
<i>Poaceae</i> sp. 1	Poaceae	seed	ane	7	308
<i>Ilex</i> sp. 1	Aquifoliaceae	fruit/seed	zoo	3	281
<i>Leandra australis</i> (Cham.) Cogn.	Melastomataceae	fruit	zoo	2	259
<i>Clusia criuva</i> Cambess.	Clusiaceae	seed	zoo	3	229
<i>Alchornea</i> spp.	Euphorbiaceae	seed	zoo	5	176
<i>Tibouchina granulosa</i> (Desr.) Cogn.	Melastomataceae	fruit	auto	3	169
<i>Dodonaea viscosa</i> Jacq.	Sapindaceae	fruit/seed	ane	2	162
<i>Myrcia splendens</i> (Sw.) DC.	Myrtaceae	fruit/seed	zoo	3	137
<i>Hedyosmum brasiliense</i> Miq.	Chlorantaceae	seed	zoo	3	119
Morphospecies sp. 2	indeterminate	seed	zoo	7	114
<i>Schefflera actinophylla</i> (Endl.) Harms	Araliaceae	seed	zoo	3	107
Morphospecies sp. 9	indeterminate	seed	ind	7	97
<i>Amaioua guianensis</i> Aubl.	Rubiaceae	seed	zoo	3	93
<i>Cordia monosperma</i> (Jacq.) Roem. & Schult.	Boraginaceae	seed	zoo	4	91
<i>Rubus brasiliensis</i> Mart.	Rosaceae	seed	zoo	4	85
<i>Psychotria hastisepala</i> Müll. Arg.	Rubiaceae	seed	zoo	1	77
<i>Mimosa bimucronata</i> (DC.) Kuntze	Fabaceae	fruit	auto	3	75
<i>Davilla rugosa</i> Poir.	Dinelliaceae	fruit/seed	zoo	4	73
<i>Pinus</i> sp.	Pinaceae	seed	ane	5	70
<i>Poaceae</i> sp. 3	Poaceae	seed	ane	7	65
<i>Asteraceae</i> sp. 4	Asteraceae	fruit	ane	7	64
Morphospecies sp. 16	indeterminate	seed	zoo	7	61
<i>Symplocos</i> sp. 1	Symplocaceae	fruit/seed	zoo	2	59
<i>Schinus terebinthifolius</i> Raddi	Anacardiaceae	seed	zoo	2	59
<i>Ficus</i> sp. 3	Moraceae	seed	zoo	5	51
<i>Scleria melaleuca</i> Rchb. ex Schltld. & Cham.	Cyperaceae	seed	auto	1	48
Morphospecies sp. 4	indeterminate	seed	zoo	7	48
<i>Tibouchina urvilleana</i> (DC.) Cogn.	Melastomataceae	fruit	auto	2	47
<i>Asteraceae</i> sp. 3	Asteraceae	fruit	ane	7	42
Morphospecies sp. 5	indeterminate	seed	zoo	7	41
<i>Ilex theizans</i> Mart. ex Reissek	Aquifoliaceae	seed	zoo	3	39
<i>Hieronyma alchorneoides</i> Allemão	Euphorbiaceae	seed	zoo	5	32

Appendix 1. Continued.

Species	Family	Diaspores	Syndromes	Habits	Number of diaspores
<i>Myrsine</i> spp.	Primulaceae	seed	zoo	3	26
<i>Psychotria</i> cf. <i>carthagenensis</i> Jacq.	Rubiaceae	seed	zoo	3	26
Poaceae sp. 2	Poaceae	seed	ane	7	23
Solanaceae sp. 1	Solanaceae	seed	zoo	7	21
Morphospecies sp. 6	indeterminate	seed	ane	7	21
<i>Palicourea australis</i> C. M. Taylor	Rubiaceae	seed	zoo	1	20
<i>Ficus</i> sp. 2	Moraceae	seed	zoo	5	19
Morphospecies sp. 7	indeterminate	seed	ind	7	18
<i>Sida</i> sp.	Malvaceae	fruit	ane	1	16
<i>Melia azedarach</i> L.	Meliaceae	seed	zoo	3	13
<i>Pera glabrata</i> (Schott) Poepp. ex Baill.	Euphorbiaceae	seed	zoo	3	12
<i>Jacaranda puberula</i> Cham.	Bignoniaceae	fruit/seed	ane	3	12
<i>Cupania vernalis</i> Cambess.	Sapindaceae	seed	zoo	3	11
<i>Rhipsalis</i> spp.	Cactaceae	seed	zoo	6	11
<i>Tibouchina sellowiana</i> Cogn.	Melastomataceae	fruit	auto	3	10
<i>Urochloa</i> sp. 2	Poaceae	seed	ane	1	10
<i>Myrcia</i> sp.	Myrtaceae	seed	zoo	3	9
<i>Trema micrantha</i> (L.) Blume	Cannabaceae	seed	zoo	3	8
<i>Cordia</i> cf. <i>sellowiana</i> Cham.	Boraginaceae	seed	zoo	3	7
<i>Paullinia trigonia</i> Vell.	Sapindaceae	seed	zoo	4	7
Morphospecies sp. 8	indeterminate	seed	ind	7	7
<i>Forsteronia pubescens</i> A. DC.	Apocynaceae	fruit	ane	4	6
Morphospecies sp. 17	indeterminate	seed	ind	7	6
Asteraceae sp. 5	Asteraceae	fruit	ane	7	5
Morphospecies sp. 10	indeterminate	seed	ind	7	5
<i>Erythroxylum</i> cf. <i>argentinum</i> O.E. Schulz	Erythroxylacaceae	seed	zoo	2	4
<i>Ficus</i> cf. <i>adhatodifolia</i> Schott ex Spreng.	Moraceae	seed	zoo	5	4
Morphospecies sp. 11	indeterminate	seed	ane	7	4
Morphospecies sp. 18	indeterminate	seed	zoo	7	4
<i>Pouteria gardneriana</i> (A. DC.) Radlk.	Sapotaceae	seed	zoo	3	3
Morphospecies sp. 12	indeterminate	seed	ind	7	3
<i>Nectandra</i> cf. <i>megapotamica</i> (Spreng.) Mez	Lauraceae	seed	zoo	5	2
<i>Miconia</i> sp. 1	Melastomataceae	seed	zoo	7	2
Asteraceae sp. 6	Asteraceae	fruit	ane	7	2
Lauraceae sp. 1	Lauraceae	seed	zoo	5	2
<i>Cyperus</i> sp.	Cyperaceae	seed	auto	7	2
<i>Phyllanthus</i> sp.	Phyllanthaceae	seed	auto	7	2
<i>Psidium cattleianum</i> Sabine	Myrtaceae	seed	zoo	2	2
<i>Guatteria australis</i> A. St.-Hil.	Annonaceae	seed	zoo	3	2
<i>Scleria panicoides</i> Kunth	Cyperaceae	fruit	auto	1	2
Morphospecies sp. 13	indeterminate	seed	ind	7	2
Morphospecies sp. 14	indeterminate	seed	ind	7	2
Morphospecies sp. 15	indeterminate	seed	ind	7	2
Morphospecies sp. 19	indeterminate	seed	zoo	7	2
<i>Livistona chinensis</i> (Jacq.) R. Br. ex Mart.	Arecaceae	seed	zoo	3	1
<i>Psychotria</i> sp. 2	Rubiaceae	seed	zoo	1	1
<i>Symplocos</i> sp. 2	Symplocaceae	seed	zoo	3	1
Morphospecies sp. 20	indeterminate	seed	ind	7	1
Morphospecies sp. 26	indeterminate	seed	zoo	7	1
Morphospecies sp. 21	indeterminate	seed	ind	7	1
Morphospecies sp. 22	indeterminate	seed	zoo	7	1
Morphospecies sp. 23	indeterminate	seed	ind	7	1
Morphospecies sp. 24	indeterminate	seed	ind	7	1
Morphospecies sp. 25	indeterminate	seed	ind	7	1