REPRODUCTIVE ECOLOGY OF THE EXOTIC TREE *Muntingia calabura* L. (MUNTINGIACEAE) IN SOUTHEASTERN BRAZIL[1]

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ABSTRACT – The exotic tree *Muntingia calabura* L. (Muntingiaceae), a species native to Central America, is used as fish feed and fiber and cellulose production in Brazil. This study was carried out in urban areas and verified the reproductive biology of this plant species. Flower and fruit morphology, compatibility system, reproductive phenology, pollination and frugivore animals, and germination of disseminated seeds were recorded by standard field and laboratory procedures. This tree is self-compatible and autonomously self-pollinated, with its flowers being mainly visited by bees and its fruits consumed by birds and bats. Germination of its dispersed seeds is fast and occurs at a high rate. The results of this work suggest that *M. calabura* is very adaptable to cultivated areas,thus being an excellent choice for urban reforestation. However, its reproductive characteristics place this plant as an invasive species with significant potential in southeastern Brazil.

Keywords: Plant reproduction, heterogeneous reforestation and urban ecosystems.

ECOLOGIA REPRODUTIVA DA ÁRVORE EXÓTICA Muntingia calabura L. (MUNTINGIACEAE) NO SUDESTE DO BRASIL

*RESUMO – A árvore exótica **Muntingia calabura L.** (Muntingiaceae) é nativa da América Central e, no Brasil, ela é utilizada para alimentação de peixes e para produção de fibras e celulose. Este estudo, realizado em áreas urbanas, verificou a biologia reprodutiva dessa espécie vegetal. A morfologia de flores e frutos, o sistema de compatibilidade, a fenologia reprodutiva, os animais polinizadores e frugívoros e a germinação das sementes foram estudados através de procedimentos-padrão de campo e laboratório. A árvore é autocompatível e apresenta autopolinização espontânea, com suas flores visitadas por abelhas e frutos consumidos por aves e morcegos. A germinação das sementes é rápida e com elevada taxa. A conclusão é que **M. calabura** é uma espécie vegetal altamente adaptada à reprodução sob condições de cultivo, sendo uma excelente opção para inclusão em projetos de reflorestamento urbano. Apesar disso, as características reprodutivas colocam essa espécie como importante e potencial planta invasiva no Sudeste brasileiro.*

Palavras-chave: Reprodução vegetal, reflorestamento heterogêneo e ecossistema urbano.

1. INTRODUCTION

Muntingia calabura L. (Muntingiaceae) is a tree native to tropical America (BAYER et al., 1998), known as Jamaica Cherry in the U.S.A. and calabura in Brazil, where it occurs as an exotic species (SOUZA and LOZENZI, 2005). The species reaches up to 13m high (LORENZI et al., 2003) and is commonly cultivated in urban areas (SILVA FILHO and BORTOLETO, 2005). Fibers and cellulose are industrially obtained from *M. calabura* and its soft and sweet mature fruits are used for fish feeding (LORENZI et al., 2003). Although the species is not considered medicinal in Brazil (LORENZI and MATOS, 2002), in Central America its flowers are traditionally used as antispasmodic and antiseptic, and some compounds isolated from its roots may be

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used to control malignant cell growth (KANEDA et al., 1991).

Despite its economic and medicinal potential, ecological aspects of *M. calabura* have received little scientific attention in Brazil. This may be corroborated by the fact that only studies dealing with seed physiology and seedling production have been published so far (LOPES et al., 2002; CASTRO and ALVARENGA, 1996; LAURA et al., 1994; LEITE and TAKAKI, 1991).

Reproductive ecology is of particular importance to evaluate the adaptive potential of a plant species growing in urban environments or an exotic species in the process of naturalization in Brazil (FIGUEIREDO et al., 1995; FIGUEIREDO, 1997). Some studies have investigated reproductive aspects of *M. calabura* in Central America, such as Bawa and Webb (1983) and Fleming et al. (1985), in which autonomous self-pollination and fruiting were observed in all the months of the year.

The objective of this study was to present data on the reproductive ecology of *M. calabura* growing in urban areas in southeastern Brazil, especially concerning its flower and fruit morphology, compatibility system, reproductive phenology, pollination system, frugivory by native vertebrates, and germination of dispersed seeds.

2. MATERIAL AND METHODS

Most of the fieldwork was carried out in 2004-2005 with three adult *M. calabura* individuals growing in an urban green area (Bosque Cambui), near a stream, in São Carlos, São Paulo, Brazil (22º02'S, 47º52'W, 856m alt.). Additional observations on pollination and phenology were made in 2007 including two individuals growing on the campus of Universidade Federal de São Carlos - UFSCar (21º59'S, 47º52'W, 839m alt.).

São Carlos climate is sharply seasonal, with a rainy season from October to March and a dry season from April to September (TOLENTINO, 1967). According to Köppen's classification, the climate of São Carlos is a transition between $Cwa_i - Aw_i$. The annual average rainfall is 1440mm, concentrated in the hottest months, with the average maximum annual temperature being 26.82ºC and the average minimum annual temperature, 15.63ºC (data provided by Embrapa Pecuária Sudeste).

Bosque Cambui is in the northwestern region of São Carlos, in an area with one of the highest rates of green coverage in the municipality, varying from 8 to 9 m^2/inhabitant (HENKE-OLIVEIRA, 1996). The neighboring area has an occupational rate of 60%. Bosque Cambui, an area of 35.570m^2, was previously pasture land, reforested by its neighborhood denizens in 1998 with native and exotic trees. About 5,000 trees were planted, 325 species of 62 families. Out of these plant species, 80% were native and 20% were exotic (MATTIAZZI et al., 2000). The UFSCar campus, in turn, is located in one of the cerrado areas of the state of São Paulo that has suffered the most damage in the last decades. According to Kronka et al. (1998), this region has lost over 115,000 hectares of several cerrado physiognomies, corresponding to 93% of its original coverage. In UFSCar there is a 130ha vegetation reserve classified as stricto sensu cerrado. Besides this intact cerrado reserve, there is a former grassy field that was reforested from 2003 to 2005. Individuals of *M. calabura* focused in this work were found nearby these areas.

The morphology of *M. calabura* flowers and fruit was described by using collected material from the Bosque Cambui individuals. The scent of the flowers and fruit was detected by keeping them in a tightly closed bottle, which was smelled after one hour (DAFNI, 1992).

In order to verify the occurrence of autonomous self-pollination, 15 randomly chosen immature flowers from Bosque Cambui individuals and 38 randomly chosen flower buds from UFSCar campus individuals were isolated in waterproof paper bags (DAFNI, 1992). In addition, a control sample consisting of 15 and 38 randomly chosen flowers from Bosque Cambui and UFSCar campus, respectively, provided data on open pollination. Fruiting was checked 30 days after flowering and this was used as an indicator of successful pollination.

Reproductive phenology was verified by observing the three Bosque Cambui individuals and the two UFSCar campus individuals from January to December 2007. The beginning of flowering was defined as beginning when at least one individual bearing flower buds could be observed and ending when no individuals of the species would bear flowers in anthesis. Fruiting was defined as starting when at least one of the individuals would bear unripe fruit and ending when individuals of the species would bear no ripe fruit.

Flowers of the plant were observed for 52 hours (from 08h00 to 18h00) in order to record insect visits to Bosque Cambui individuals. Additional 24 hour (from 06h00 to 18h00) observations were conducted on UFSCar individuals. Frugivore birds were observed on Bosque Cambui individuals, with binoculars, for 24 hours (from 07h30 to 17h30), and additional observations were made from 19h00 to 23h00 in order to register the presence of frugivore bats feeding on mature fruit of the same individuals.

Germination tests followed the methodology described by Figueiredo and Perin (1995). Seeds were collected from bird and bat feces, found in the entire reforestation area as well as directly under the branches of the trees. Three 400-seed replicates were prepared for every treatment. Seeds were deliberately extracted from different fruit (control). These seeds, undigested by vertebrates, were sown on filter paper and placed in 15cm germination boxes (gerboxes), which were left to stand near a window receiving natural illumination at the laboratory. One ml of water was put in the boxes every two days to maintain constant humidity. Seeds randomly chosen from bird and bat feces underwent the same treatment. The number of germinated seeds in each replicate was verified every other day, over 43 days. Statistical analysis of the data was performed using one-way analysis of variance (ZAR, 1996).

3. RESULTS AND DISCUSSION

Muntingia calabura flowers are composed of five green sepals, 0.6 cm long, and five white petals 0.5 cm long and 0.7 cm wide, on average. There are dozens of stamens with yellow anthers forming their androecium. The average ovary diameter is 0.8 cm, with the stigma positioned 0.2 cm above the receptacle. The flowers emit a weak sweet scent. Its fruits are constituted by 5-6 locules with hundreds of very small seeds immersed in a gelatinous mass. When mature, fruit are reddish to brown, soft, sweet, and without a perceptible odor.

Muntingia calabura flowered and produced fruit throughout the entire year at the study sites. Figure 1 shows the reproductive episodes of the studied individuals. In Central America, the plant species also produces large quantities of fruit every month of the year (WEBB, 1984; FLEMING et al., 1985).

Muntingia calabura is self-compatible and produces fruit and seeds through spontaneous self-pollination (Table 1). Bawa and Webb (1983) also found that the plant shows self-compatibility in Costa Rica. Self-compatibility allows *M. calabura* to develop a great amount of seeds along the year, even in degraded areas where pollination agents are scarce. The large seed set found for this tree is a good indicator that agamospermy should not be excluded (KEARNS and INOUYE, 1993), but future studies must be carried out to confirm this hypothesis.

Flower visitors are shown in Table 2. Few bee species, but with a large number of visits, contribute to cross pollination of *M. calabura* individuals in Bosque Cambui. The stingless bee *Trigona spinipes* were the most frequent flower visitor, followed by the exotic bee *Apis mellifera*. Flowers of UFSCar individuals were visited by a greater number of species of small bees and syrphid flies (Table 2). The sweet odor and whitish color of *M. calabura* flowers are very attractive to hymenoptera and diptera (PROCTOR et al., 1996), which may contribute to cross-pollination of this self-compatible plant species. Cross-pollination of *M. calabura* in Central America is also carried out by native bees (BAWA and WEBB, 1983).

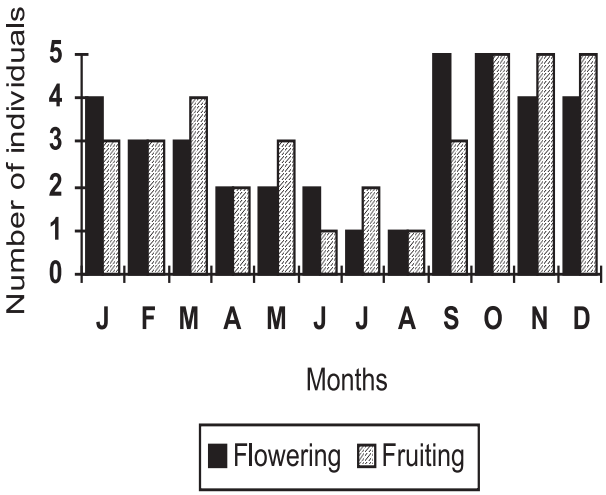

Figure 1 – Reproductive phenology of *Muntingia calabura* in São Carlos, SP, Brazil. J = January, F = February... N = November, and D = December.

Figura 1 *– Fenologia reprodutiva de Muntingia calabura em São Carlos, SP, Brasil. J = janeiro, F = fevereiro... N = novembro e D = dezembro.*

Table 1 – Production of *Muntingia calabura* fruit through autonomous self-pollination (bagged flower buds) and natural pollination (control) in São Carlos – SP, Brazil

Quadro 1 *– Produção de frutos por Muntingia calabura através de autopolinização autônoma (botões florais ensacados) e por polinização natural (controle) em São Carlos, SP, Brasil*

Autonomous self-pollination (n flower buds bagged/n fruits formed)	Natural pollination (n flower unbagged/n fruits formed)
Bosque Cambuí	Bosque Cambuí
15 / 15 (100%)	15 / 15 (100%)
UFSCar campus	UFSCar campus
38 / 35 (92.10%)	38 / 32 (84.21%)

Table 2 – Insects visiting *Muntingia calabura* flowers in São Carlos, SP, Brazil. Study site: 1 – Bosque Cambui, 2 – UFSCar campus

Quadro 2 *– Visita de insetos nas flores de Muntingia calabura em São Carlos, SP, Brasil. Local de estudo: 1 – Bosque Cambuí, 2 – campus da UFSCar*

Genus	Order, Family, Subfamily	N visits	Study site
Trigona spinipes	Hymenoptera, Apidae, Meliponinae	149	1
Apis mellifera	Hymenoptera, Apidae, Apinae	96	1
Pseudauglochloropsis sp.	Hymenoptera, Halictidae	90	1
Trigona spinipes	Hymenoptera, Apidae, Meliponinae	16	2
Augochloropsis sp.	Hymenoptera, Halictidae	11	2
Apis mellifera	Hymenoptera, Apidae, Apinae	10	2
Oxaea flavescens	Hymenoptera, Andrenidae	02	2
Ocyptamus sp.	Diptera, Syrphidae, Sirphini	08	2
Ornidia obesa	Diptera, Syrphidae, Volucellini	03	2
Palpada sp.	Diptera, Syrphidae, Eristalini	01	2

Muntingia calabura fruit were consumed by 14 bird species (Table 3), as well as fruit bats. The most frequent bird species were the Sayaca Tanager (*Thraupis sayaca*, Thraupidae) and the Plain Parakeet (*Brotogeris tirica*, Psittacidae). The Sayaca Tanager consumed the greatest number of fruit per visit, swallowing the seeds immersed in the gelatinous mass. Bird visits occurred mainly during the early morning hours and in the afternoon. Birds (mainly parakeets) and bats are also the most important seed dispersers of *M. calabura* in Central America (FLEMING et al., 1985). Primates were also reported to ingest seeds of this plant species in Costa Rica (CHAPMAN, 1989).

During the entire observation period, ants (mainly Attini) were observed to remove seeds from fallen fruit and bird/bat feces. These ants were not collected and identified, but their presence indicated that these invertebrates may act as secondary seed dispersers. Peternelli et al. (2004) have shown that Attini and Pheidolini are important ant groups involved in secondary seed dispersion.

Table 3 – Bird species consuming fruit of *Muntingia calabura* in São Carlos, SP, Brazil

Quadro 3 *– Espécies de aves consumindo frutos de Muntingia calabura em São Carlos, SP, Brasil*

Genus	Family	N visits
Muscipipra vetula	Tinamidae	02
Brotogeris tirica	Psittacidade	07
Drymophila ferruginea	Formicariidae	03
Fluvicola nengeta	Tyrannidae	02
Pitangus sulphuratus	Tyrannidae	01
Danacobius atricapillus	Mimidae	03
Euphonia sp.	Thraupidae	01
Lanio versicolor	Thraupidae	01
Neothraupius fasciata	Thraupidae	01
Tangara cayana	Thraupidae	04
Thraupis sayaca	Thraupidae	23
Turdus amaurochalinus	Muscicapidae	01
Turdus leucomelas	Muscicapidae	03
Poospiza cinerea	Fringilidae	01

Germination rates of *M. calabura* seeds are shown in Table 4. There was no significant difference among the germination rates of seeds ingested by birds, those ingested by bats and control seeds (which were not ingested by these vertebrates) (one-way ANOVA, F=0.54, p=0.61). The three treatments showed seeds beginning their germination after seven days of sowing, while the bat-defecated seeds germinated faster than the others (Figure 2).

The high germination rate of seeds ingested by birds and by bats, recorded for the first time by this study, indicates that both vertebrate groups can efficiently disperse *M. calabura* seeds in urban reforestation areas and contribute to increase the population of this plant species. In laboratory conditions, Leite and Takaki (1991) observed a high germination rate of *M. calabura* seeds at 35ºC and under direct illumination. In addition, Lopes et al. (2002) verified that the germination of *M. calabura* seeds would not occur unless the gelatinous mass around them was eliminated, which could be accomplished by their passage through the bowels of animals.

The tree species in question provides a year-round source of nectar and fruit, an important source of food to several animal species. Moreover, these frugivores, attracted to the urban reforestation area by *M. calabura* fruit, may also transport seeds of other plant species on which they feed disseminating them in this area, thus increasing its biological diversity. Fleming and Heithaus (1981) found mixed-species seed-shadows created by bat dispersal, including *M. calabura* seeds, occurring in disturbed forest sites of Costa Rica. In addition, Fleming et al. (1985) showed that *M. calabura* can quickly invade disturbed sites in Costa Rica, with a high density of seedlings, with its adult trees being replaced by later successional species in less than 30 years.

Table 4 – Germination rates of *Muntingia calabura* seeds ingested and not ingested (control) by vertebrates in São Carlos, SP, Brazil

Quadro 4 *– Taxas de germinação de sementes de Muntingia calabura ingeridas e não- ingeridas (controle) por vertebrados em São Carlos, SP, Brasil*

Treatment	Germination (n seeds sowed/n seeds germinated)
Control seeds	1200 / 979 (81.6%)
Seeds ingested by birds	1200 / 907 (75.6%)
Seeds ingested by bats	1200 / 995 (82.9%)

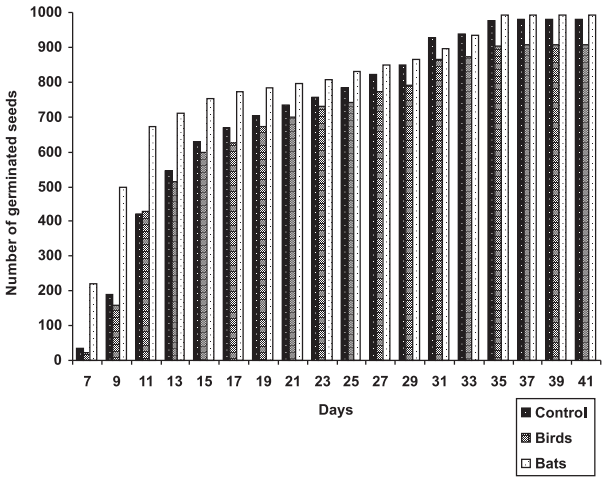

Figure 2 – Germination velocity of *Muntingia calabura* seeds not ingested by vertebrates (control), ingested by birds, and ingested by bats in São Carlos, SP, Brazil.

Figura 2 *– Velocidade de germinação de sementes de Muntingia calabura que não foram ingeridas por vertebrados (controle), ingeridas por aves e ingeridas por morcegos em São Carlos, SP, Brasil.*

4. CONCLUSIONS

Muntingia calabura is a fast-growing tree that thrives in poor soils. These characteristics, associated with spontaneous self-pollination and self-compatibility system, large amount of fruit and seeds produced round the year, attractiveness to a great number of frugivore species, and high seed germination rate, makes this plant species an excellent choice for urban reforestation.Nevertheless, it should be noted that *M. calabura* can become a problematic invasive plant species in Southeastern Brazil. Thus, reproductive ecology studies such as this are of particular importance to evaluate the adaptive potential of this species and other plant species growing in urban environments and in process of naturalization in Brazil.

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