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THE POLLINATION OF CULTIVATED PLANTS

A COMPENDIUM FOR PRACTITIONERS

POLLINATION SERVICES FOR SUSTAINABLE AGRICULTURE
EXTENSION OF KNOWLEDGE BASE

THE POLLINATION OF CULTIVATED PLANTS

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Volume 1

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9.3 SELECTED STUDIES

9.3.1 Brazil nut in the Amazon

M. Maués, M.C. Cavalcante, A.C. dos Santos and C. Krug

Brazil nut natural history and uses: The Brazil nut, Pará nut or Paranuss, as it is known in the United States and Europe, is a native tree of the Amazon forest. A.J.A. Bonpland first identified the forest tree *Bertholletia excelsa* (Lecythidaceae) in 1808 as a species within a monospecific genus *Bertholletia* from the Lecythidaceae family, which occurs in non-flooded – "terra firme" – forest in Brazil, Bolivia, Colombia, the Guianas, Peru and Venezuela [1]. The tree produces particularly hard globose fruit varying from 11 cm to 16 cm in diameter and weighing 500 **g** to 1 500 g. Each bears 10 to 25 seeds approximately 3.5 cm to 5.0 cm long by 2 cm wide, with a distinctly triangular cross-section. Brazil nuts are protected by the hard case, and are readily harvested when the fruit falls many metres to the ground [1, 2]. Under natural conditions the nut is mostly consumed by the agouti (*Dasyprocta*), a caviomorphic rodent that eats seeds but also plays a major role in seed dispersal. Due to its habit of burying seeds in the forest for later consumption, where they are often forgotten, *B. excelsa* is dispersed and can regenerate [3, 4]. Some studies also suggest an anthropogenic influence on Brazil nut phytogeography [5].

Brazil nut is essentially a seed rather than a nut, but nomenclatural tradition prevails. The seeds sustain one of the most important extractive industries in the Neotropics. It is unique because they are harvested in natural forests and have been internationally traded for over 120 years by local people, thereby generating income in Brazil, Bolivia and Peru [6].

The commercial use of *B. excelsa* mainly involves the seeds, which are rich in oil, unsaturated fatty acid, sulfuric amino acid, phosphorous, potassium, iron, sodium, vitamin A, thiamine, riboflavin, niacin and Selenium [7]. The timber is extremely durable and one of the finest found among the many Amazonian tree species [8], although logging and trade of *B. excelsa* in natural forests is prohibited under law in Brazil [9].

Breeding system and seasonality: From October to January, Brazil nut trees display terminal panicles 14 cm to 45 cm long with an average of 0.76 (N = 182) flowers opening per day. Anthesis begins at night or after midnight, and full flower opening occurs from 01:00 a.m. to 05:30 a.m. The androecium of Neotropical Lecythidaceae is a peculiar structure and evidently evolved from an open and radially symmetrical form, such as in *Allantoma*, *Gustavia* and *Grias*, to the closed and zygomorphic structure composed of curved and concrescent staminodes in *Couratari*, *Corythophora*, *Coroupita*, *Escheweilera* and *Bertholletia* [10]. This type of androecium specialization is closely related to the pollination agents, as shown in the affinity of *B. excelsa* with medium to large-bodied native bees and long-tongued bees (orchid bees, tribe Euglossini). The nectar is produced at the staminode base, restricting the guild of pollinators to those capable of lifting the modified petal and the concrescent staminodes, then inserting the glossa far inside the floral chamber to reach the nectar [1, 11–13].

Bertholletia excelsa is predominantly an allogamous (outcrossing) plant, but apparently some self-compatibility exists, as observed in the initial fruit formation of selfed pistils from hand-pollination tests (geitonogamy) at two study sites [14, 15]. However, more reliable results come from cross-pollination and open-pollination tests [14]. Fruit abortion may indicate post-zygotic self-incompatibility, which deserves more detailed study. Evaluation of pollen tube growth in hand-pollinated pistils 48 hours after anthesis resulted in observations of pollen germination from all treatments (cleistogamous or automatic, self, cross and natural pollination), thus excluding sporophitic self-incompatibility (SSI) or pollen rejection at the stigmatic surface. Pollen tube growth from the top of the stigma down to the ovary predominates in cross-pollination, in comparison with geitonogamy and open-pollination treatments, thus providing little evidence for autogamy. This result raises the possibility that the incompatibility system in *B. excelsa* is ovarian or post-zygotic.

Brazil nut cultivation and pollination: The Brazil nut is a key non-timber forest product (NTFP) component in Extractivist Reserves (RESEX) in the Brazilian Amazon [16]. It is also a component of Agroforestry Systems (SAFs) and large-scale monocultures, such as those found in Pará and Amazonas States [17, 18]. Unfortunately, the idea prevails that Brazil nut plantations are not viable [19]. According to Soldán (2003), *B. excelsa* forms part of a complex and interconnected ecosystem, which may explain why all efforts to cultivate the tree outside the Amazon basin (e.g. Indonesia, Malaysia, Sri Lanka and the West Indies) have failed. In spite of this argument, Brazil nut has been raised in agroforestry systems and pure monoculture in the Brazilian Amazon since the 1980s, where there is high pollinator diversity [11, 14, 20]. Although few hard data have been published concerning fruit yield in silvicultural plots, Brazil nut growers complain of low production.

What is possibly leading to low fruit set? Natural Brazil nut populations in primary forest are densely aggregated in groups of 50 to 149 trees [21, 22], and fruit set ranges from 0 to 800 fruit per tree each year, with a mean of 66.2 [23], demonstrating very high variability. In a large-scale Brazil nut monoculture in the central Amazon region [24], annual production in 2007 registered 36.45 fruit/ha, resulting in 5.5 tonnes of nuts/ha, but the following year produced a fruit yield of 3 000 fruit/ha or 45 tonnes of nuts/ha. This pattern, generally called "alternate bearing" (see Glossary) is observed in natural stands [23].

Brazil nut plantations may obtain fewer benefits from pollinators, as observed in other crops [25] because of lower species richness and pollinator abundance in cultivated areas. This factor is correlated with larger distances from natural vegetation. The result is usually a pollination deficit caused by habitat modification [26]. Aside from the absence of pollinators or lower amounts of pollen transported by them [27], the potential drivers of pollination deficits are lack of compatible pollen for self-incompatible and dioecious species, and reduced pollen production and/or poor pollen quality due to plant genotype or phenotype and their interaction with nutrient status, water deficit or other growing conditions (see also Chapter 3.1). In a study of 41 crops worldwide [28], the diversity and abundance of wild insect pollinators proved to be declining in most agricultural landscapes, but the effect on crop yield is still uncertain. Pollen flow disruption due to inappropriate pollen transfer and insufficient pollen deposition by pollinators may be the main cause of a pollination deficit. The presence of wild pollinators in agroecosystems may also provide a complement to managed pollinators [27].

The main pollinators of the Brazil nut are bees of the genera *Bombus, Centris, Xylocopa, Eulaema* and *Epicharis*, both in natural populations and cultivated plots [11–14] (Table 9.1, Figure 9.22). *Xylocopa frontalis*, *Eulaema mocsaryi*, *Epicharis flava*, *Bombus transversalis*, *Centris ferruginea* and *Centris denudans* collect nectar and pollen while visiting the flowers, while *Eufriesea flaviventris* collects only pollen [14].

Pollinator-friendly practices for Brazil nut: In order to enhance natural populations of Brazil nut pollinators, best management practice should focus on compliance with the Brazilian Forest Code [29], which states that Amazonian properties shall use only 20 percent of the total area for any economic activity and/or buildings, leaving up to 80 percent as Legal Reserve and Permanent Preservation Areas (APPs). By preserving such natural habitats, pollinators, as well as predators, parasites and competitors that affect plants and their natural enemies or mutualists will be protected, and ecological services of pollination will provide seeds, fruit, vegetation and plant populations for other living things, including humankind. Farmers may adopt the following list of pollinator-friendly practices to support *on-farm* pollinator conservation (see also section 3.2):

- Be aware of pollinators present on the property and their nests (in order to protect nesting sites or related resources, such as dry wood, mud, water, resin, sand).
- Avoid pesticide use, particularly insecticides, giving preference to biological control or integrated pest management (IPM) practices, if necessary.
- Avoid the use of fire to clear non-cropping areas.

- Retain complementary flowering plants that are important for pollinator food and nesting requirements.
- Provide nesting sites for bees (old tree trunks, wood blocks, bamboo internodes, fence posts, and large trees) within the property.
- Maintain the connectivity of remnant native vegetation areas, in order to facilitate pollinator movement (ecological corridors).
- Disseminate the importance of pollinator-friendly agricultural practices and share experiences with other people.

Table 9.1
FLOWER VISITORS OF *BERTHOLLETIA EXCELSA* IN ITACOATIARA, AMAZONAS STATE*, TOMÉ-ASSU AND BELÉM, PARÁ STATE, BRAZIL

FAMILY	FLOWER VISITOR SPECIES	TYPE
Apidae	*Xylocopa (Neoxylocopa) frontalis* Olivier, 1789	EP
Apidae	*Xylocopa (Neoxylocopa) aurulenta* Fabricius, 1804	EP
Apidae	*Epicharis (Hoplepicharis) affinis* Smith, 1874	EP
Apidae	*Epicharis* (*Epicharana*) *flava* Friese, 1900	EP
Apidae	*Epicharis* (*Epicharana*) *conica* Smith, 1874	OP
Apidae	*Epicharis (Epicharana) rustica* Olivier, 1789	EP
Apidae	*Epicharis* (*Epicharis*) *umbraculata* Fabricius, 1804	EP
Apidae	*Epicharis* (*Parepicharis*) *zonata* Smith, 1854	EP
Apidae	*Epicharis sp.*	OP
Apidae	*Centris* (*Ptilotopus*) *americana* Klug, 1810	OP
Apidae	*Centris* (*Heterocentris*) *carrikeri* Cockerell, 1919	OP
Apidae	*Centris* (*Xanthemisia*) *ferruginea* Lepeletier, 1841	EP
Apidae	*Centris* (*Ptilotopus*) *denudans* Lepeletier, 1841	EP
Apidae	*Centris (Trachina) similis* Fabricius, 1804	EP
Apidae	*Centris sp.*	OP
Apidae	*Eulaema* (*Eulaema*) *meriana* Olivier, 1789	EP
Apidae	*Eulaema* (*Apeulaema*) *mocsaryi* Friese, 1899	EP
Apidae	*Eulaema* (*Apeulaema*) *cingulata* Fabricius, 1804	OP
Apidae	*Eulaema (Apeulaema) nigrita* Lepeletier, 1841	EP
Apidae	*Bombus* (*Fervidobombus*) *transversalis* Olivier, 1789	EP
Apidae	*Bombus* (*Fervidobombus*) *brevivillus*	EP
Apidae	*Eufriesea purpurata* Mocsàry, 1896	EP
Apidae	*Eufriesea flaviventris* Friese, 1899	EP
Apidae.	*Eufriesea* sp.	EP
Apidae	*Apis mellifera* Lepeletier, 1836	V
Apidae	*Frieseomelitta longipes* Smith, 1854	R
Apidae	*Melipona* (*Michmelia*) *lateralis* Erichson, 1848	V
Apidae	*Melipona (Michmelia) lateralis* Erichson, 1848	V
Apidae	*Trigona pallens* Fabricius, 1798	R
Apidae	*Frieseomelitta longipes* Smith, 1854	R
Megachilidae	*Megachile* sp.	PO

Notes: *Visitor list from [14]. EP = effective pollinator, OP = occasional pollinator, V = visitor, R = pollen robber or thief.

Source: M. Maués, M.C. Cavalcante, A.C. dos Santos and C. Krug

Figure 9.21
VISITORS AND POLLINATORS OF BRAZIL NUT - *BERTHOLLETIA EXCELSA* AT TWO CULTIVATED SYSTEMS, MONOCULTURES IN ITACOATIARA, AMAZONAS STATE AND AGROFORESTRY SYSTEMS IN TOMÉ-ASSU, PARÁ STATE, BRAZIL

(a) *Xylocopa frontalis* (♀); (b) *Bombus tranversalis* (♀); (c) *Centris americana* (♀); (d) *Centris denudans* (♀); (e) *Centris ferruginea* (♀); (f) *Epicharis zonata* (♀); (g) *Epicharis flava* (♀); (h) *Eufriesea flaviventris* (♀); (i) *Eufriesea purpurata* (♀); (j) *Eulaema bombiformis* (♀); (k) *Eulaema mocsaryi* (♀); and (l) *Eulaema cingulata* (♂)

Source: M. Casimiro Cavalcante

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