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Biology-Botany

Functional ecology of species of fabaceae from riparian vegetation of the Tarumã-Açu River – Central Amazon

Ecologia funcional de espécies de fabaceae da vegetação ripária do Rio Tarumã-Açu – Amazônia Central

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ABSTRACT

Riparian vegetation provides crucial ecosystem services including climate regulation, hydrological balance maintenance, and soil conservation, while also offering shelter and food resources for wildlife. The biota in this environment displays functional adaptations that ensure reproductive success. This study aimed to analyze the functional ecology of plant species in the lower Tarumã-Açu River Basin. Fertile material from four Fabaceae species: *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth., and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend. was collected and processed at LABPRAD-UEA. For biometrical analysis, we used 30 fruits and seeds to determine water content and describe propagule morphology. Germination timing was assessed using four replicates of 25 seeds each. Fruit, seed, and seedling morphology were characterized following descriptors from Gunn (1981; 1984), Ribeiro (1999), Beentje (2010), and Ferraz et al. (2019). *H. courbaril* produces indehiscent fruits with seeds protected by a rigid tegument. *O. excelsa* and *T. hypoleuca* also bear indehiscent fruits, while *M. multijugum* has dehiscent fruits with permeable seed teguments. The species differed in fruit morphology, propagules dispersal syndromes, germination timing and patterns, and seedling architecture. These adaptive traits facilitate colonization of new areas and successful seedling establishment.

Keywords: Propagule and seedling morphology; Germination; Igapó

RESUMO

A vegetação ripária desempenha importantes serviços ecossistêmicos como a regulação do clima, o equilíbrio do regime hídrico, e a integridade do solo, além de fornecer abrigo e alimento para a fauna. A biota desse ambiente apresenta adaptações funcionais para garantir o sucesso reprodutivo. O objetivo da pesquisa foi analisar a ecologia funcional de espécies vegetais do baixo curso da Bacia Hidrográfica do Rio Tarumã-Açu. O material fértil de: *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth., *Tachigali hypoleuca* (Benth.) Zarucchi & Herend. foi coletado e direcionado ao LABPRAD – UEA. Para a biometria utilizou-se 30 frutos e sementes, foi realizado teor de água e descrição morfológica dos propágulos. Para analisar os aspectos temporais da germinação utilizou-se quatro repetições de 25 sementes. Para a morfologia dos frutos, sementes e plântulas foram utilizados os descritores Gunn (1981; 1984), Ribeiro (1999), Beentje (2010), Ferraz et al. (2019). Os frutos de *H. courbaril* são indeiscentes e as sementes apresentam tegumento rígido, protegendo o embrião, *O. excelsa* e *T. hypoleuca*, apresentam frutos indeiscentes e *M. multijugum* deiscente, e as sementes com tegumento permeável. As espécies apresentaram diferenças nos frutos, síndromes de dispersão de propágulos, nos tipos e aspectos temporais da germinação, e na arquitetura das plântulas. Essas características adaptativas auxiliam na colonização de novas áreas e no sucesso do estabelecimento das plântulas.

Palavras-chave: Morfologia de propágulos e plântulas; Germinação; Igapó

1 INTRODUCTION

The Amazon is a complex biome, renowned for having the largest expanse of tropical rainforest in the world. Besides its remarkable species richness, the biome plays a crucial role in global climate regulation, biodiversity conservation, and the provision of essential ecosystem services Fearnside, (2018); Scudeller and Vegas-Vilarrúbia, (2018).

On a macro scale, the Amazon Basins have high percentages of native forest cover. The scenario becomes less favorable when the scale is reduced, and the situation is more delicate when inserted into an urban matrix. This is the case of the Tarumã-Açu River Basin (TARB), which faces a series of environmental conflicts due to the process of urban expansion along with the development of agro-industrial and tourist activities Costa et al. (2021).

The Tarumã-Açu River, classified as a blackwater river, is one of the main tributaries of the Rio Negro (Silva et al., 2013). It is located in the northern and western region of the city of Manaus Melo et al. (2018), an area with fragments of Igapó forest that are

under the influence of the urbanization process of the city Vasconcelos et al. (2019). Along the riverbanks we find the igapó, forests periodically flooded by blackwater rivers, characterized by nutrient-poor soils and acidic waters Junk et al. (2015).

Vegetation plays an important role in the maintenance of water resources and in hydrogeochemical and hydrological cycles Polízio Júnior (2016). Igapó forest, in turn, performs complex ecological functions, stabilizes the soil to prevent erosion processes, and provides food and shelter for fauna. It has adaptations that give it specific forms, physiologies, and distinct functionalities Anschau et al. (2017); Melo and Romanel (2018).

Plants are able to establish themselves in environments with specific characteristics, such as periodic flooding, thanks to strategies developed over the course of evolutionary processes. These characteristics, known as functional traits, can include morphological, ecophysiological, and reproductive adaptations. Such traits, observable at the individual level, directly influence the establishment, reproduction, and survival of species (Jardim & Júnior, 2021).

For functional ecology, the characteristics presented by fruits, seeds, and seedlings provide information about the persistence of species in the seed and seedling banks, survival in competition, and the species' adaptation strategies. Additionally, morphology allows us to characterize the regenerative strategies of plants Pérez-Harguindeguy et al. (2013).

Fabaceae is the third largest family of Angiosperms, composed of 727 genera and 19,327 species spread worldwide LPWG (2017). Given the ecological and taxonomic importance of this family, a functional ecology study was conducted, analyzing the reproductive aspects and morphological characteristics of the propagules of four Fabaceae species: *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth., *Tachigali hypoleuca* (Benth.) Zarucchi & Herend.

2 MATERIALS AND METHODS

2.1 Geographical location of the matrix selection area

The Tarumã-Açu River is located in the northern and western regions of the city of Manaus Melo and Romanel (2018), an area with Igapó forest fragments that are under the influence of the city's urbanization process Vasconcelos et al. (2019). It is classified as a blackwater river, being one of the main tributaries of the Negro River Silva et al. (2013). The region where the Tarumã-Açu River is located presents a super-humid climate, according to the Martonne index Antonio (2017), with three dry months (July, August, and September), six months of higher humidity (December to May), and two transitional months (June and October), with an average temperature of 27 °C. The vegetation is characterized as Dense Ombrophilous Forest, with occurrences of Open Ombrophilous Forest, Igapó, Campinaranas, and urban expansion areas Costa et al. (2021).

2.2 Selection of matrix trees and collection of material

Four species of Fabaceae were selected in the lower course of the Tarumã-Açu River. Following the guidelines of the New Forest Code Law 12.651 of May 25, 2012, the collections were carried out in an Area of Permanent Preservation (APP) up to 500 meters from the riverside CBHTA (2018).

The matrices (Table 1) were selected based on the reproductive period and identified in the field by a parataxonomist. Fertile material (flowers and fruits) was collected directly from the tree for the preparation of herbarium specimens, which were deposited in the INPA herbarium - National Institute for Amazonian Research. The fruits were packed in plastic bags and transported to the Plant Propagation and Degraded Area Recovery Laboratory – LABPRAD, Escola Superior de Tecnologia - EST, Universidade do Estado do Amazonas, Manaus, AM.

Table 1 – Subfamily, species, common name and habitat of *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

Subfamily	Species	Common names	Habitat
Detarioideae	*Hymenaea courbaril* L.	Jatobá, Jutaí	Cerrado, Riparian Forest, Terra Firme Forest
Detarioideae	*Macrolobium multijugum* (DC.) Benth.	Arapari, Paricazeiro	Campinarana, Igapó Forest, Terra Firme Forest
Caesalpinioideae	*Ormosia excelsa* Benth.	Tento-amarelo	Igapó Forest, Várzea Forest
Caesalpinioideae	*Tachigali hypoleuca* (Benth.) Zarucchi & Herend.	Tachi	Campinarana, Igapó

Source: Authors' organization (2025)

2.3 Seed extraction procedures

The extraction of the seeds was carried out manually, according to the characteristics of each species, following Melo et al. (2014).

Dehiscent and dry fruits of *Macrolobium multijugum* were exposed to natural drying at the laboratory conditions (±18°C), on plastic trays, in a single layer. On the other side, indehiscent and dry fruits of *Hymenaea courbaril*, *Ormosia excelsa*, and *Tachigali hypoleuca* were opened with the aid of tools such as a hammer, knife, and/or scalpel.

For overcoming seed coat dormancy and accelerate the germination process of *Hymenaea courbaril*, manual mechanical scarification was performed using a Nº 40 sandpaper on the lateral portion of the seed until the embryo became visible.

2.4 Identification of functional attributes

The functional traits of fruits, seeds, and seedlings evaluated were based on the work of Pérez-Harguindeguy et al. (2013). The following attributes for the fruits were analyzed: fruit type, consistency, number of seeds per fruit, dehiscence; for the seeds:

seed coat, shape, length, fresh weight, and water content; seedling: type of germination and phyllotaxy. The propagules were classified according to the dispersal syndrome of each species: anemochory, hydrochory, autochory, barochory, and zoochory according to Van der Pijl (1982).

2.5 Biometry and morphology of fruits and seeds

Fruit and seed biometry was measured with a Mitutoyo digital caliper (accuracy: 0.001 mm) and an analytical balance (0.001 g). Biometric measurements were taken from 30 fruits and 30 seeds, measuring length, width, thickness, number of seeds per fruit, and fresh weight.

The morphological characterization of the fruits and seeds was performed using a binocular stereoscopic microscope and photographic records. The morphological aspects observed for the fruits were: type, dehiscence, indument, coloration, consistency, and seed position within the fruit; for the seeds: transverse and longitudinal sections, and consistency. The descriptions were based on specialized literature Gunn (1981), (1984); Ribeiro et al. (1999); Beentje, (2010); Ferraz et al. (2019).

2.6 Germination and seedling development

The determination of seed water content was based on Seed Analysis Rules, RAS Brasil (2009). The germination test was carried out with four replicates of 25 seeds for each species on a substrate of washed sand covered with a layer of vermiculite. Germination monitoring and irrigation were performed daily, recording the emergence of the epicotyl or hypocotyl.

The germination percentage of seed was calculated, and the Emergence Speed Index (ESI) was calculated according to Maguire (1972), and the Mean Germination Time was based on Labouriau and Valadares (1976). Seedling morphology was descripted based on the terminology by Ducke (1965, 1969); Oliveira and Trombert (2001); Beentje (2016); Ferraz et al. (2019).

3 RESULTS AND DISCUSSION

3.1 Biometry and Morphology of the Fruits

The biometric measurements for fruit length of *H. courbaril* (111.6 mm) are very close to those of *H. reticulata* (100 mm), differing in fruit weight and the number of seeds, which can reach up to seven (Table 2) Ferraz et al. (2019). *Hymenaea courbaril* has a fruit with a rigid epicarp and rough texture, a tapered apex, and a broader base (Table 3) (Figure 1A). *H. intermedia* Ducke and *H. parvifolia* Huber have fruits with chamber type, as the same type described for *H. courbaril*.

Macrolobium multijugum has a fruit with transversal lines on the exocarp and is visible under a magnifying glass; it presents a quadrangular shape with truncated apex and base (Figure 1C). *Macrolobium* species occurring in the Rio Negro also showed fruits with color changes during maturation, varying from green to brown, and the transversal lines observed on the epicarp (Table 2) are characteristics observed in American and African species Félix-da-Silva et al*. (*2013). The fruits have one seed (Table 3) or rarely two, as found also for *Macrolobium acaciifolium* (Benth.) Benth. Santos et al. (2020).

Ormosia excelsa differs in seed quantity per fruit, *Ormosia arborea* produces one to four seeds per fruit, while *O. paraensis* bears one to two seeds (Table 2), with seed coloration ranging from brown to black Silva et al. (2015); Gonçalves et al. (2008). The fruit features a thin, fibrous, and glabrous epicarp, with internal structures of spongy texture (Figure 1E). *Ormosia arborea* (Vell.) Harms and *Ormosia paraensis* Ducke have fruits similar to *O. excelsa*, differing primarily in seed number per fruit and external fruit coloration (Table 3).

Tachigali hypoleuca has a fusiform fruit, with a tapered apex, a widened median portion, and an acuminate base (Figure 1G). *Tachigali vulgaris* L. G. Silva & H. C. Lima, a widely distributed species Leão et al. (2022), showed similarities with *T. hypoleuca*. Both species have the same type of fruit (cryptosamara) and similar biometric measurements of fruit length with approximately 50,0 mm and the presence of only one seed per

fruit in *T. vulgaris* (Table 2). The detachment of the epicarp was also observed, but in different ways, as in *T. hypoleuca*, the detachment occurs in plates, whereas in *T. vulgaris*, according to Leão et al. (2022), it occurs irregularly, separating the valves. This detachment of the epicarp is a characteristic described for other species of the genus.

Table 2 – Fruit biometry of *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

Species		Fruit biometry				
		Length (mm)	**Width (mm)**	**Thickness (mm)**	**Fresh weight (g)**	**Number of seeds per fruit**
Hymenaea courbaril L.	M	111,6	57,4	27,7	74,1	3
	SD	13,6	5,5	6	21,6	1,3
Macrolobium multijugum (DC.) Benth.	M	63,3	46,7	8,7	7,6	1
	SD	4,7	3,7	1,0	1,0	2
Ormosia excelsa Benth.	M	49,1	28,5	12,2	4,4	1,3
	SD	9,8	1,5	0,8	1,9	0,6
Tachigali hypoleuca (Benth.) Zarucchi & Herend.	M	51,0	23,6	3,6	1,0	1
	SD	4,6	1,2	0,4	0,1	0

M: Mean and SD: standard deviation. Source: Authors' organization (2025)

Table 3 – Morphological characteristics of the fruits of *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

	Fruit morphology			
	***Hymenaea courbaril* L.**	***Macrolobium multijugum* (DC.) Benth.**	***Ormosia excelsa excelsa* Benth.**	***Tachigali hypoleuca* (Benth.) Zarucchi & Herend.**
Type of Fruit	Camara	Legume	Nucoide legume	Cryptosamara
Fruit Dehiscence	Indehiscent	Dehiscent	Indehiscent	Indehiscent
Exocarp Consistency	Rigid	Lignified	Lignified	Lignified
Fruit Colour	Brown	Brown	Orange	Dark brown

Source: Authors' organization (2025)

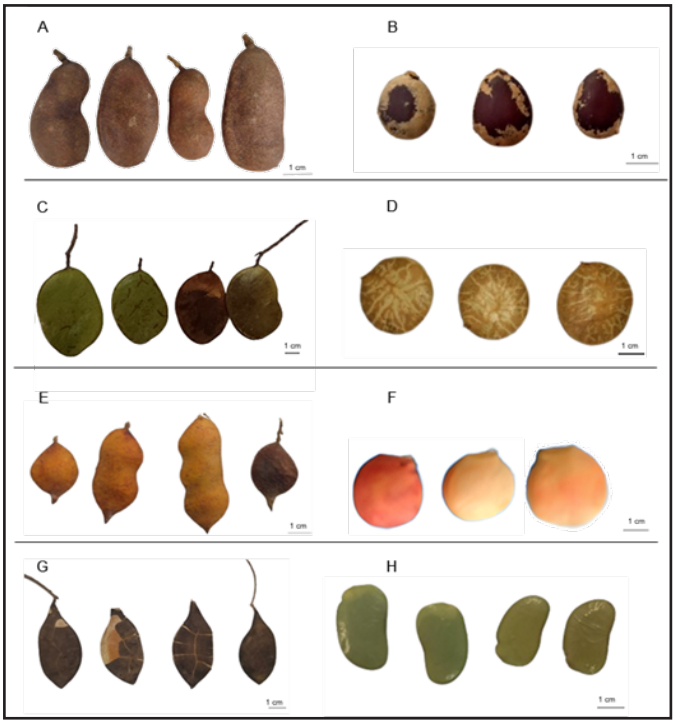
3.2 Biometry and Morphology of the Seeds

The seeds of *H. courbaril* are stenospemic, smooth, with a true aril, without markings on the seed coat (Figure 1B). Ferraz et al. (2019) described the seeds of *Hymenaea intermedia* Ducke and *Hymenaea parvifolia* Huber have distinct morphology compared to *H. courbaril* in terms of seed color and shape (Table 5), but with the same rigid seed coat consistency, which provides physical dormancy to the species. Additionally, they have similar biometric measurements (Table 4).

(Conclusão)

Seeds of *M. multijugum* are stenospemic, with an invisible hilum (Figure 1D). Changes in the seed color were observed, ranging from green to light beige as they became mature, similar to the description by Souza (2012). The biometric measurements of *M. multijugum* (Table 4) are similar to those found for *Macrolobium acaciifolium* (Benth.) Benth. Santos (2018) including morphological characteristics.

Figure 1 – Fruits and seeds of four species of Fabaceae from the Tarumã-Açu River Basin, Amazonas



Source: The authors' personal collection (2024). Caption: A-B) Fruits and seeds of *Hymenaea courbaril* L.; C-D) Fruits and seeds of *Macrolobium multijugum* (DC.) Benth.; E-F) Fruits and seeds of *Ormosia excelsa* Benth.; G-H) Fruits and seeds of *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

Ormosia excelsa has stenospemic seeds, with a visible, elevated hilum, and a smooth texture (Figure 1F). Distinct morphological seed characteristics of *Ormosia arborea* (Vell.) Harms and *Ormosia paraensis* Ducke have seeds with distinct morphological characteristics Silva et al. (2015); Gonçalves et al. (2008). *O. arborea* has bicolored seeds (orange and black), and *O. paraensis* (black and red) differs from *O. excelsa*, which has monochromatic yellow-color testa (Table 5). The biometric measurements are shown in Table 4.

The seeds of *Tachigali hypoleuca* are stenospemic, smooth, glossy, without an indumentum, without an impression on the testa (Figure 1H). The hilar groove has a white coloration that is difficult to visualize. Comparing *Tachigali vulgaris* L. G. Abreu et al. (2017), *T. hypoleuca* presented seed length (14.1 mm) longer than *T. vulgaris* seed (9.4 mm) (Table 4) and showed yellowish colour (Table 5).

Table 4 – Seed biometry of *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

		Seed biometry			
Species		**Length (mm)**	**Width (mm)**	**Thickness (mm)**	**Fresh weight (g)**
Hymenaea courbaril L.	M	23,6	16,7	11,4	3,1
	SD	2,1	1,8	1,3	0,7
Macrolobium multijugum (DC.) Benth.	M	31,7	28,3	6,5	4
	SD	4,8	4,8	0,8	0,8
Ormosia excelsa Benth.	M	20,1	17,8	9,3	2,1
	SD	1,9	1,3	0,6	0,3
Tachigali hypoleuca (Benth.) Zarucchi & Herend.	M	14,1	8,90	1,87	0,1
	SD	1,6	1,7	0,2	0,04

M: Mean and SD: standard deviation. Source: Authors' organization (2025)

Table 5 – Seed morphology of *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

	Seed morphology			
	***Hymenaea courbaril* L.**	***Macrolobium multijugum* (DC.) Benth.**	***Ormosia excelsa* Benth.**	***Tachigali hypoleuca* (Benth.) Zarucchi & Herend.**
Seed shape	Globular	Oval	Oval	Reniform
Seed coat colour	Reddish brown	Light beige	Yelowish/reddish	Green
Seed coat opacity	Opaque	Opaque	Opaque	Glossy
Seed coat texture	Rigid	Leathery	Leathery	Considerable rigidity

Source: Authors' organization (2025)

3.3 Germination and Seedling Development

In the present study, seedling emergence of *H. courbaril* occurred on average 8 days after sowing (Table 6), and there was no significant variation in biometric values and water content. Nonato et al. (2022) also recorded in *H. courbaril*, the emergence of the hypocotyl, cotyledons, and epicotyl between 15 to 25 days after sowing, then the data from this study, therefore, corroborated with the results in the literature.

Seedling of *H. courbaril* presents a reddish primary root, axial, odorless, a pinkish hypocotyl with fine, short, and hyaline hairs, an epicotyl greenish with lenticels (Figure 2A). Eophylls compound, opposite, reniform-shaped, obtuse apex, rounded base with an opaque green color, pinnate venation, nerves impressed on the adaxial surface, leathery consistency, the cross-section showed a biconcave shape, and greenish smooth internodes. The protophylls are bifoliate, with leaflet shaped lanceolate, cuneate apex, asymmetrical base, sessile and opposite leaflets, distichous alternate phyllotaxy, also with leathery consistency, primary venation characterized as pinnate, both surfaces with an opaque light green color, broad base petiole, glabrous, and rounded in cross-section. Comparing the description made for

Hymenaea intermedia by Melo et al. (2004), we can highlight distinct characteristics between species of the same genus that are essential for differentiating the two species at the seedling stage, such as the presence of indumentum on the cotyledons, epicotyl, and protophylls.

The germination characteristics and seedling development of *Macrolobium acaciifolium* (Benth.) Benth. were characterized by Maia et al. (2005), who reported it as having epigeal phanerocotylar germination, differing from the seedling of *M. multijugum* (hypogeal cryptocotylar) (Table 6). Both species occur in areas under influence of flood pulses, where, according to the literature, epigeal phanerocotylar germination is more frequent in nutrient-rich environments such as várzea (floodplain forests), while hypogeal germination is more common in nutrient-poor areas like igapó (blackwater-flooded forests) Maia et al. (2005).

Seedling of *M. multijugum* features an axial primary root with a caramel color, lacking indumentum. The secondary roots are branched, the collar is not evident, and the epicotyl is green, smooth, with sparse lenticels, hyaline, and short indumentum. The cataphylls are alternate with a rust-colored base (Figure 2B). The eophyll, as well as the protophylls, are compound, with alternate phyllotaxy, coriaceous consistency, leaflets with an elliptical shape, emarginate apex, asymmetric base, and brochidodromous primary venation. In cross-section, they are cylindrical, glabrous, with a green and opaque adaxial surface and a whitish, opaque abaxial surface. The petiole has a pulvinus, and the interpetiolar stipules are green, appearing winged in cross-section.

Ormosia arborea (Vell.) Harms, *Ormosia fastigiata* Tul. Gurski et al. (2012), and *O. excelsa* exhibit hypogeal germination (Table 6). However, *O. fastigiata* is phanerocotylar, while *O. excelsa* and *O. arborea* are cryptocotylar. This characteristic of protecting the cotyledons with the seed coat may be related to the adverse environmental conditions in which these species are found, such as periods of flooding Ressel et al. (2004).

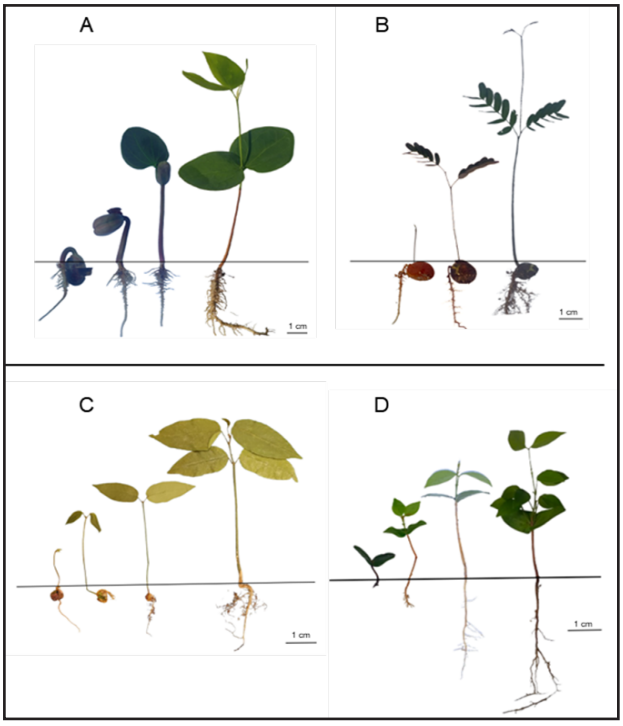
Seedling of *O. excelsa* (Figure 2C) has an axial primary root with a yellowish color, green epicotyl, smooth with lenticels and golden colored indumentum; simple opposite eophylls, with a leathery consistency and oblong shape, acuminate apex, both surfaces green and opaque, green petiole with golden indumentum, cross-section channeled, stipules and golden indumentum. The internodes are green, smooth, with lenticels and golden indumentum; protophylls presented both alternate and opposite phyllotaxy, simple leaves, leathery consistency, acuminate apex, obtuse base, concave cross-section, green and opaque on both surfaces; greenish petiole with golden indumentum, and round cross-section. *Ormosia arborea* (Vell.) Harms, *Ormosia fastigiata* TUL., and *O. excelsa* present simple and opposite eophylls, however, the following leaves changed phyllotaxy to alternate Gurski et al. (2012).

T. hypoleuca presented a low germination percentage of 25% (Table 6). The study of Leão et al. (2022) showed differences in the seed germination of *Tachigali vulgaris* L. G. Silva & H. C. Lima collected from different mother trees, observing a seed germination range varying from 50% to 95%. This variation can be due to genetic factors or the physiological maturity stage of the seeds at sowing, which can be attributed to the need for pre-germination treatments, that could be the same factor occurring for *T. hypoleuca.*

The seedling of *T. hypoleuca* (Figure 2D) has an axial taproot with a cylindrical shape, light brown color, with an evident and dilated collar in beige. The hypocotyl is elongated with a brown color, without indumentum. The cotyledons are foliaceous, reniform-shaped, with a rounded apex and cordate base, positioned oppositely in dark green. Herbaceous green epicotyl, smooth with golden indumentum. The eophylls and protophylls are compound bifoliate, with alternate phyllotaxy, papery consistency, oval-shaped blade, acute apex, and asymmetrical base, primary brochidodromous venation, cross-section characterized as cylindrical. The adaxial surface is opaque with golden indumentum concentrated on the central vein and leaflet margins, the abaxial surface is also opaque with golden indumentum. The

internodes are green with golden indumentum. The petiole has stipules at the base, cross-section characterized as round.

Figure 2 – Germination and seedling development of four Fabaceae species



Source: Authors' private collection (2024). Caption: A) *Hymenaea courbaril* L., B) *Macrolobium multijugum* (DC.) Benth., C) *Ormosia excelsa* Benth., and D) *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

Table 6 – Germination characteristics of *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

(To be continued...)

Germination Characteristics				
	***Hymenaea courbaril* L.**	***Macrolobium multijugum* (DC.) Benth.**	***Ormosia excelsa* Benth.**	***Tachigali hypoleuca* (Benth.) Zarucchi & Herend.**
Seed Water Content (%)	14,0	46,3	44,8	51,3
Type of Germination	Epigeal phanerocotylar	Hypogeal cryptocotylar	Hypogeal cryptocotylar	Epigeal phanerocotylar
Type of Cotyledons	Reserve	Reserve	Reserve	Foliaceous
IVE	1,2	0,3	0,8	0,3

Table 6 – Germination characteristics of *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend

(Conclusion)

Germination Characteristics					
		***Hymenaea courbaril* L.**	***Macrolobium multijugum* (DC.) Benth.**	***Ormosia excelsa* Benth.**	***Tachigali hypoleuca* (Benth.) Zarucchi & Herend.**
Average Germination Time (days)	M	6	11	3	3
	SD	3	1	0,2	2
Germination Percentage (%)	M	88	37	67	25
	SD	9	10	10	11
Normal Seedling (days)	M	8	8	13	3
	SD	3	2	1,7	1

M: Mean and SD: standard deviation. Source: Authors' Organization (2025)

3.4 Analysis of functional traits

Among the functional attributes of the four observed Fabaceae species, the variations in fruit types are noteworthy (Table 2), which are the main factors responsible for the distribution and maintenance of species diversity in tropical forests. The fruiting period coincides with the flooding of rivers, indicating a synchronization of these cycles Conserva (2007). The alignment of fruiting with river water levels suggests a strategy adopted by Igapó forest species, as increased air moistureduring this period facilitates seed imbibition, leading to more efficient seedling development due to greater resource availability. Silva et al. (2018)

In general, fruits of the Fabaceae family are modified legumes, but they exhibit remarkable diversity in morphological characters, such as the different consistencies of the pericarp, the dehiscence of the fruits, and the number of seeds per fruit. These characteristics are considered evolutionary evidence of specialized adaptation features resulting from interactions between organisms over time Díaz-Bardales, (2001).

Seeds with a hard seed coat, commonly found in Fabaceae species, are related to the protection of the embryo and nutrient reserves, ensuring seed viability for long periods. This characteristic is also associated with dormancy mechanisms, as observed in *H. courbaril* Abreu et al. (2012). Some species, however, do not exhibit this functional trait, such as *M. multijugum* and *O. excelsa*, which have more permeable seed coats that allow for easier rehydration of the seeds. Differences in seed coat permeability may be linked to the survival strategies of the species and characteristics of seed recalcitrance, as these seeds lack a physical barrier that would otherwise delay germination.

Seeds measuring 1,0 cm or smaller, exhibited epigeal germination, while larger seeds showed hypogeal germination. Seed size may be related to the dispersal process. Smaller seeds can be dispersed over greater distances away from the parent plant, allowing them to colonize areas with higher sunlight exposure, where epigeal germination is more advantageous. In contrast, larger seeds, with greater nutrient reserves, are dispersed over shorter distances, where competition for light is more intense, and thus they possess larger reserves to support initial growth Moreira e Moreira (1996).

The dispersal syndrome of *H. courbaril* was characterized by Moraes Neto (2023) as zoochoric; however, in this study fruit hydrochoric dispersal was also observed. For *M. multijugum* and *O. excelsa*, evidence of hydrochoric dispersal was noted, and for *T. hypoleuca*, hydrochoric dispersal of fruits was observed based on field observations.

There is a dependency between the plant and its dispersers, and this relationship is crucial for the perpetuation of the species, as the effectiveness of dispersal is linked to ecosystem conservation Stefanello et al. (2010). In studies of flooded areas, hydrochoric dispersal is prominent Peleja & Moura (2012). Propagule buoyancy is a trait adopted by many species in flood-prone environments, as it increases the distance of colonized areas and enhances the efficiency of ichthyochory (fish-mediated dispersal) Conserva (2007); Piedade et al. (2005). Dispersal by fish can extend the distance over which viable seeds are transported, as ingestion allows

seeds to be carried upstream to more remote areas with reduced competition, Zoochory contributes also to genetic diversity Noronha (2018); Nazareno et al. (2021).

Table 7 – Functional attributes observed in *Hymenaea courbaril* L., *Macrolobium multijugum* (DC.) Benth., *Ormosia excelsa* Benth. and *Tachigali hypoleuca* (Benth.) Zarucchi & Herend. The table presents the mean biometric values of fruits and seeds

		Species			
		***Hymenaea courbaril* L.**	***Macrolobium multijugum* (DC.) Benth.**	***Ormosia excelsa* Benth.**	***Tachigali hypoleuca* (Benth.) Zarucchi & Herend.**
Fruit	Type of Fruit	Camara	Legume	Nucoide legume	Cryptosamara
	Type of Deshiscence	Indehiscent	Dehiscent	Indehiscent	Indehiscent
	Number of Seeds	3	1	1,3	1
	Dispersal Syndrome	Zoochory/ Hydrochory	Hydrochory	Hydrochory	Hydrochory
Seed	Seed Coat	Rigid	Leathery	Leathery	Considerable rigidity
	Seed Shape	Globular	Oval	Oval	Reniform
	Length (mm)	23,6	31,7	20,1	14,1
	Fresh Weight (g)	3,1	4,0	2,1	0,1
	Water Content (%)	13,9	46,32	44,8	51,3
Seedling	Type of Germination	Epigeal phanerocotylar	Hypogeal cryptocotylar	Hypogeal cryptocotylar	Epigeal phanerocotylar
	Eophyll Phyllotaxy	Compound / alternate	Compound / alternate	Simple/ opposite	Bifoliate / alternate
	Protophyll Phyllotaxy	Bifoliate / alternate	Compound / alternate	Simple/ opposite	Bifoliate / alternate

Source: Authors' Organization (2025)

Phanerocotylar epigeal germination is more frequent in nutrient-rich environments such as várzea (whitewater floodplain forests), while hypogeal

germination is more common in nutrient-poor areas like igapó (blackwater-flooded forests) Maia et al. (2005). *H. courbaril* and *T. hypoleuca* exhibit phanerocotylar epigeal germination, with storage cotyledons and leaf-like cotyledons, respectively. The storage cotyledons in *H. courbaril* suggest adaptability to varying environmental conditions, given the species' wide distribution. *M. multijugum* and *O. excelsa* exhibit cryptocotylar hypogeal germination. In this case, reserves and the embryo remain protected for a longer period compared to phanerocotylar germination, as observed by Ressel et al. (2004), which may enhance seedling establishment success in environments influenced by flood pulses.

4 CONCLUSION

The indehiscence of legumes in the three analyzed species, as well as the hardness of seeds, can be interpreted as a factor for embryo protection and ensuring viability of these propagules over longer periods. In these species, such propagules comprise fruit and seed. In contrast, *Macrolobium multijugum*, a dehiscent legume, presents the seed as the propagule.

The hydrochoric dispersal mode exhibited by all species is well-suited to their environment. This trait enables long-distance dispersal and reduces competition with the parent plant, in addition to contribute to genetic diversity.

The germination time varied among the four Fabaceae species, the seedlings exhibited distinct types of germination: *H. courbaril* and *T. hypoleuca* are epigeal phanerocotylar, while *M. multijugum* and *O. excelsa* have hypogeal cryptocotylar germination. These differences of characteristics of seedlings have evolved for their survival in the environment.

The species exhibited differences in fruit types, dispersal syndromes, and classification of germination types, and germination timing. These characteristics allow plants to colonize new spaces and adapt during establishment in these new environments. The su ccess of the propagation methods of the species is related to their

efficiency in regeneration and ecological succession in highly dynamic environments, such as igapó areas.

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