

Regeneration under the Canopies of Native Species in a Restoration Area

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Abstract

This study aimed at evaluating the potential of *Inga vera* (Ingá) and *Enterolobium contortisiliquum* (Timbaúva) as facilitating species and their species-specific interaction on the restoration of a degraded and protected area in Rio Grande do Sul, Brazil. We surveyed the natural regeneration occurred under the canopies of 50 *I. vera* and *E. contortisiliquum* individuals, considering tree and shrub species with heights ≥ 30 cm and collar diameter ≥ 0.3 cm and < 10 cm. We found 756 individuals under *I. vera* and 166 individuals under *E. contortisiliquum*. The study revealed that, despite corresponding to 19% of the total species found, the exotic species comprises 43.6% under *I. vera* and 11% under *E. contortisiliquum*. The *I. vera* presented a more significant number of species and individuals under its canopies when compared to *E. contortisiliquum* and the reference area.

Keywords: conservation, protected areas, ecology.

1. INTRODUCTION AND OBJECTIVES

Facilitating species for the recovery of degraded areas are those which, in the initial phase of succession, change the conditions of the community, facilitating the establishment of other species (Ricklefs, 2003). They are capable of forming aggregates of other species around them (Baylão et al., 2012), especially through the dispersion of seeds by animals (Carpanezzi, 2005). Thus, the use of species with attractive fruitification to the fauna is a strategy with high potential for inducing the recovery of degraded environments.

The interaction occurring between the individuals of a community (Hurlbert, 1971) favors the recovery of the degraded system. Therefore, the arrival of species of all forms of life and the establishment of interaction networks between the organisms strengthen the natural regeneration (Marcuzzo & Viera, 2015). However, the facilitation hypothesis considers that in specific ecological contexts the native species can facilitate the entry of exotic species into natural communities (Gómez-Aparicio et al., 2004) and these species-specific relationships can present essential impacts on the spatial structure of the invasion process (Cushman et al., 2011)

According to Melo & Durigan (2007), the study of natural regeneration that occurs under the canopies of

reforestation is an important parameter of the evolution of restoring communities. This process can represent an evaluation and monitoring indicator of the restoration of degraded ecosystems (Rodrigues & Gandolfi, 1998). The knowledge of the structural organization of the population of shrubs and tree species through phytosociological studies constitutes the base for the definition of species management and conservation strategies or any other form of intervention in the forest (Souza et al., 2012). The analysis of the structural organization allows us to indicate the most significant species (based on the abundance, spatial distribution, biomass, size or cover) which can interfere on the other associated species and aid in the forest restoration in degraded areas (Salomão et al., 2013).

In this sense, Gandolfi et al. (2007) consider that the canopy of the forest act as filters with different levels of permeability that create microclimatic conditions, influencing the species that will establish. These filters act as facilitator mechanisms due to the decrease in radiation, temperature, and water stress, allowing seed germination and seedling development.

Among the many species of the *Inga* genus, *Inga vera* Willd. has an extensive and dense canopy, quick growth (Carpanezzi, 2005), biological nitrogen fixation (Faria &

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Franco, 2002), and is capable of improving the environmental conditions around it. This species, representative of the Fabaceae family, presents a pod type, pilose fruit of yellow coloring, measuring from 4 cm to 12 cm of length, and presents white, sweet and edible pulp, attractive to the frugivorous fauna (Carvalho, 2008), which are, in this case, small mammals. The plant is classified as a pioneer species, of a rounded canopy, long branches, and with wide geographical distribution, found mainly in the Atlantic Forest biome (Carvalho, 2008). The *Enterolobium contortisiliquum* (Vell.) Morong, also belonging to the Fabaceae family, is a deciduous tree with large canopy in the form of an umbrella (Carvalho, 2003). It presents an indehiscent bacoid legume type fruit, and its dispersion is autochorous by gravity and zoochorous by land mammals after falling to the ground. According to Gonçalves (2002), the species has a vast root system that allows the efficient exploration of soil resources and, in association, the capacity of fixating nitrogen to the soil (Baggio et al., 2008).

Because of these characteristics, this work aimed at evaluating the potential of *Inga vera* and *Enterolobium contortisiliquum* as facilitating species for the establishment of natural regeneration under canopies and the resulting species-specific interactions in a degraded area located in the Quarta Colônia State Park, Rio Grande do Sul, Brazil.

2. MATERIALS AND METHODS

2.1. Description of the study area

The study area is located in an environmental recovery plot (2.0 ha) of the Quarta Colônia State Park, an Integral Protection Conservation Unit (Law no. 9,985/2000) with 1,847.9 ha, located between the municipalities of Agudo and Ibarama, RS, Brazil (29°37'40" S and 53°22'00" W), in the River Jacuí basin.

According to the Brazilian Soil Classification System (Embrapa, 2006), the predominant soil at the conservation is classified as Litolite Neosol. According to the Köppen classification, the climate is humid subtropical of the Cfa variety, defined by presenting average temperature in the coldest months of between -3 °C and 18 °C (from June to August) and in the warmest month superior to 22 °C (in January) (Nimer, 1990). The location is situated close to a vegetation fragment belonging to the Atlantic Forest biome, in a phytogeographic Deciduous Seasonal Forest (Brena & Longhi, 2002).

According to the Ministry of Environment (Brasil, 2000a), the region of the Quarta Colônia is considered a priority area for conservationist public policies, such as its

insertion into the Atlantic Forest Biosphere Reserve. The park is a conservation unit belonging to Quarta Colônia Ecological Corridor, Decree SEMA 143/2014, which has the objective of promoting the connectivity between the Conservation Unit and the other priority conservation targets of the biodiversity identified in the region (Rio Grande do Sul, 2014).

The Conservation Unit was created due to the construction of Dona Francisca Hydroelectric Power Plant (HPP) on the River Jacuí in 2005. According to Marcuzzo et al. (2014), there was a set of residences for workers of the power plant in the recovery area, the target of this study. With the conclusion of the HPP, these residences were demolished, and the area submitted to restoration.

The restoration process began in 2003 with the plantation of 25 seedlings of native species, in spacings of 4.0 m × 4.0 m. The plantation was conducted after opening the planting pits, with no other cultural treatment, according to the requisites established by the environmental organ for the restoration of the area. During the plantation, the soil presented fragmented rocks and the rubble from the demolitions (Marcuzzo et al., 2014). Ten years after planting, when the field was measured, there was natural regeneration in various densities under the canopy of the planted trees, as well as grasses and invasive tree species.

For comparing the successional stage of the restoration community and the functional attributes of the species present in the restored area, a forest area in intermediate to advanced restoration stage was sampled, located 556 m from the study area. The forest has remained without anthropic intervention for more than 20 years. It was previously occupied by small rural properties in which the migratory agriculture system was developed, currently reflecting on a mosaic of different successional stages (Marcuzzo et al., 2014).

2.2. Data collection

The field data collection occurred 10 years after planting the native species in the recovery area. For studying the natural regeneration, the vegetation under the canopy of the 50 individuals of *Inga vera* (Ingá) and *Enterolobium contortisiliquum* (Timbaúva) included in the sample were analyzed.

For each Ingá and Timbaúva individual, we measured the diameter at breast height (DBH) (cm), the canopy projection (m), and the total plant height (m). A measuring tape graduated in millimeters was used to obtain the first two parameters. The total height was measured using a rod graduated in centimeters. To define the canopy projection,

we determined the distance between the trunk and the greatest canopy projection in the four cardinal points.

To sample the forest area in an intermediate-advanced stage, a study published by Marcuzzo et al. (2014) was used, in which the authors installed a circular plot of 10 m² (radius of 1.78 m) (Finger, 1992) situated at the center of 18 previously marked 10 m × 20 m plots. The polygonal plots used as a reference for the implementation of these samples were distributed every 10 m, within six lanes 20 m from each other, totaling 0.36 ha in each area (Marcuzzo et al., 2014).

For the natural regeneration, we measured all individuals of the tree and bush species presenting height ≥ 30 cm and collar diameter (CD, measured 5 cm above the ground level) equal or superior to 0.3 cm and inferior to 10 cm. During the measurement of the CD and total height, we used a digital pachymeter and a rod graduated in centimeters, respectively.

The natural regeneration data was compiled to later conduct the phytosociological estimation analyses of absolute (A) and relative (R) density (AD, RD), frequency (AF, RF), and to calculate the percentage of importance value (IV) for each species (Souza et al., 2012). The floristic diversity and equitability were calculated using the Shannon diversity index (H') and the Pielou coefficient (J'), respectively (Souza et al., 2012).

When it was possible, the individuals were identified in the field. For the unidentified species, the botanical material was collected and sent for determination at the Herbarium of the Department of Forestry Sciences of the Federal University of Santa Maria (UFSM).

The species found were organized on a list with their scientific name, family, ecological group and dispersion. The updating and confirmation of the species nomenclature and author names were conducted using *The international plant names index* (IPNI, 2013). The remaining information followed the procedure described by Backes & Nardino (1998), Lorenzi et al. (2003), Sobral & Jarenkow (2006), Carvalho (2006, 2008), Grings & Brack (2009), and Instituto Hórus (2013). The ecological groups were framed based on the classification of Budowski (1965), who recognized four categories (pioneer, initial secondary, late secondary, and climax).

3. RESULTS AND DISCUSSION

With the data obtained from the restoration area after 10 years of the plantation, it is possible to indicate an average DBH of 7.67 cm for the Ingá and of 6.316 cm

for the Timbaúva individuals. The average height was of 5.23 m and 8.8 m, and the average canopy projection area represented 43.81 m² and 34.30 m², respectively for Ingá and Timbaúva individuals. The canopy projection area sampled for Ingá was of 2,190.45 m², representing 10.95% of coverage for the restoration area, while for the Timbaúva was of 1,716.53 m² or 8.58%. Although small, this percentage demonstrates the importance of the Ingá species in the recovery process of a degraded area, given that the higher the canopy coverage, the lower the presence of grasses that usually limit the establishment of regenerating individuals (Marcuzzo et al., 2014). The plant coverage controls the quantity, quality and distribution of light that filters onto the forest ground, interfering with the growth and survival of seedlings and determining the plant composition (Melo, 2010).

The parameters related to the structure and diversity of the natural regeneration under the Ingá canopy present values very similar to those of the preserved area (reference), apart from the percentage of pioneer and non-pioneer species (Table 1). However, significantly inferior density and richness values under the Timbaúva canopy were verified (Table 1). A predominance of zoochorous species occurred in relation to anemochorous species, in both the recovery and reference areas. This same behavior was verified in two other recovery areas of the same Conservation Unit (Marcuzzo et al., 2014), indicating that this is the dispersion pattern of the species that occur in the State Park.

In the natural regeneration under the canopy of the 50 Ingá individuals, we found 756 individuals belonging to 47 species and 25 families, including Fabaceae (five species; 183 individuals), Myrtaceae (four species; 157 individuals), and Solanaceae (four species; five individuals) as the most representative in relation to species richness. Regarding Timbaúva, we found 166 individuals distributed into 21 species, highlighting the Fabaceae family.

Concerning the ecological groups, the results were similar for the natural regeneration under the Ingá and Timbaúva canopies, consisting of 55% and 52% for the pioneer species and 45% and 48% for the initial secondary and late secondary species, respectively (Tables 1 and 2). Regarding the dispersion under the Ingá canopies, 28 species are zoochorous (59.6%), 11 anemochorous (23.4%), four autochorous (8.5%), two barochorous (4.3%), and two were unidentified (4.3%), while under the Timbaúva canopies, 15 species were zoochorous (71.4%), three were anemochorous (14.2%), two autochorous (9.5%), and one barochorous (4.7%) (Table 2).

Table 1. Structure and diversity of the natural regeneration under the canopies of *Inga vera* and *Enterolobium contortisiliquum* and in the preserved area at Quarta Colônia State Park, RS, Brazil.

Variables	<i>Inga vera</i>	<i>Enterolobium contortisiliquum</i>	Reference area (Marcuzzo et al., 2014)
Average height (m)	2.0	2.38	2.8
Density (individuals ha ⁻¹)	15,120	3,320	15,909
Richness	47	21	42
Diversity (H')	2.7	2.4	2.6
Equability (J')	0.7	0.1	0.7
Zoochorous species (%)	60	71	79
Anemochorous species (%)	23	14	20
Successional group (% P:NP)	55:45	52:48	12:88
Exotic species (%)	19	19	0

P: Pioneers; N: Non-pioneers.

Table 2. Structural parameters, ecological group, and dispersion syndrome of the natural regeneration under the canopies of *Inga vera* and *E. contortisiliquum* individuals at Quarta Colônia State Park, RS, Brazil.

Scientific name	RD		RF		IV		IV (%)		EG	Disp.
	Ingá	Timbaúva	Ingá	Timbaúva	Ingá	Timbaúva	Ingá	Timbaúva		
<i>Ligustrum lucidum</i> W. T. Aiton*	21.69	4.81	8.51	5.21	30.2	11.29	15.1	3.76	P	Zoo
<i>Inga vera</i> Willd.	17.86	6.02	9.57	6.08	27.43	16.35	13.72	5.45	P	Zoo
<i>Syzygium cumini</i> (L.) Skeels*	12.83	4.81	6.38	5.21	19.21	12.28	9.61	4.09	P	Zoo
<i>Baccharis semiserrata</i> DC.	7.67		10.28		17.96		8.98		P	Anemo
<i>Psidium guajava</i> L.*	6.35		8.51		14.86		7.43		P	Zoo
<i>Allophylus edulis</i> (A. St.-Hil. et al.) Hieron. ex Niederl.	5.29	3.01	7.45	4.34	12.74	7.96	6.37	2.65	SI	Zoo
<i>Calliandra brevipes</i> Benth.	5.16	27.71	3.19	14.78	8.35	43.75	4.18	14.58	P	Auto
<i>Cupania vernalis</i> Cambess.	3.17	1.8	5.32	1.73	8.49	5.36	4.25	1.78	SI	Zoo
<i>Sorocea bonplandii</i> (Baill.) W. C. Burger et al.		3.01		4.34		10.04		3.34	SI	Zoo
<i>Nectandra megapotamica</i> (Spreng.) Mez	1.72		2.13		3.85		1.93		SI	Zoo
<i>Schinus terebinthifolia</i> Raddi	1.72	16.26	4.26	14.78	5.97	33.02	2.99	11	P	Zoo
<i>Myrsine</i> sp.	1.46		2.84		4.29		2.15		SI/ ST	Zoo
<i>Eriobothrya japonica</i> (Thunb.) Lindl.*	1.06		1.77		2.83		1.42		P	Zoo
<i>Syagrus romanzoffiana</i> (Cham.) Glassman	1.06	2.4	1.77	3.47	2.83	10.13	1.42	3.37	SI	Zoo
<i>Myrcianthes pugens</i> (O.Berg) D.Legrand		0.6		0.86		1.84		0.61	ST	Zoo
<i>Psidium cattleianum</i> Sabine	1.06	6	2.13	5.21	3.19	17.17	1.6	5.72	P	Zoo
Non-identified 1	1.06		0.71		1.77		0.89		—	—
<i>Luehea divaricata</i> Mart. & Zucc.	0.93	12.04	2.13	17.39	3.05	37.33	1.53	12.44	SI	Anemo
<i>Casearia sylvestris</i> Sw.	0.79		2.13		2.92		1.46		P	Zoo
<i>Cinnamomum verum</i> J. Presl *	0.79		1.42		2.21		1.11		P	Zoo

Table 2. Continued...

Scientific name	RD		RF		IV		IV (%)		EG	Disp.
	Ingá	Timbaúva	Ingá	Timbaúva	Ingá	Timbaúva	Ingá	Timbaúva		
<i>Enterolobium contortisiliquum</i> (Vell.) Morong	0.66	1.8	1.06	2.6	1.73	13.39	0.87	4.46	P	Baro
<i>Handroanthus heptaphyllus</i> (Vell.) Mattos	0.66	1.2	1.77	1.73	2.43	4.59	1.22	1.53	SI	Anemo
<i>Parapiptadenia rigida</i> (Benth.) Brenan	0.66	3.01	1.42	4.34	2.08	20.56	1.04	6.85	P	Auto
<i>Eugenia involucrata</i> DC.	0.53		1.42		1.95		0.98		SI	Zoo
<i>Boehmeria caudata</i> Sw.	0.53		0.71		1.24		0.62		P	Anemo
<i>Cordia americana</i> (L.) Gottshling & J.S. Mill.	0.4	0.6	1.06	0.86	1.46	2.06	0.73	0.68	SI	Anemo
<i>Hovenia dulcis</i> Thunb*	0.4	1.2	1.06	1.73	1.46	20.7	0.73	6.9	P	Zoo
<i>Gymnanthes Klotzchiana</i> Müll.Arg	0.4		1.06		1.46		0.73		SI	Baro
<i>Peltophorum dubium</i> (Spreng.) Taub.	0.4		0.71		1.11		0.56		SI	Auto
<i>Trichilia elegans</i> A. Juss.	0.4		1.06		1.46		0.73		ST	Zoo
<i>Citharexylum montevidense</i> (Spreng.) Moldenke	0.26	0.6	0.71	0.86	0.97	13.48	0.49	4.49	SI	Zoo
<i>Cordia trichotoma</i> (Vell.) Arráb. ex Steud.	0.26		0.71		0.97		0.49		SI	Anemo
<i>Jacaranda mimosifolia</i> D. Don*	0.26		0.71		0.97		0.49		P	Anemo
<i>Justicia brasiliana</i> Roth.	0.26		0.35		0.62		0.31		P	Auto
<i>Solanum mauritianum</i> Scop.	0.26		0.71		0.97		0.49		P	Zoo
<i>Trema micrantha</i> (L.) Blume	0.26		0.35		0.62		0.31		P	Zoo
<i>Cedrela fissilis</i> Vell.	0.13		0.35		0.49		0.25		SI	Anemo
<i>Cestrum strigilatum</i> Ruiz & Pav.	0.13		0.35		0.49		0.25		P	Zoo
<i>Escallonia bifida</i> Link & Otto	0.13		0.35		0.49		0.25		P	Anemo
<i>Escallonia megapotamica</i> Spreng.	0.13		0.35		0.49		0.25		P	Anemo
<i>Machaerium paraguayense</i> Hassl.	0.13		0.35		0.49		0.25		SI	Anemo
<i>Matayba elaeagnoides</i> Radlk.	0.13	0.6	0.35	0.86	0.49	2.34	0.25	0.78	SI	Zoo
<i>Morus alba</i> L.*	0.13		0.35		0.49		0.25		P	Zoo
<i>Morus nigra</i> L.*	0.13		0.35		0.49		0.25		P	Zoo
<i>Citrus limon</i> (L.) Burm.*		0.6		0.86		8.34		2.78	P	Zoo
<i>Ocotea puberula</i> (Rich.) Nees	0.13	1.8	0.35	2.6	0.49	7.92	0.25	2.64	SI	Zoo
<i>Solanum</i> sp.	0.13		0.35		0.49		0.25		P	Zoo
<i>Solanum variabile</i> Mart.	0.13		0.35		0.49		0.25		P	Zoo
<i>Trichilia claussenii</i> C. DC.	0.13		0.35		0.49		0.25		ST	Zoo
Non-identified 2	0.13		0.35		0.49		0.25		—	—
Total	100		100	100	300	300	100	100		

RD: relative density; RF: relative frequency; IV: importance value; EG: ecological group; Disp: dispersion; Zoo: zoochorous; Anemo: anemochorous; Baro: barochorous; Auto: autochorous; * exotic species.

In this study, the Shannon diversity index (H') was of 2.68 for the regeneration under the Ingá canopy, and of 2.40 under the Timbaúva canopy, indicating intermediate values, according to Cavalcanti & Larrazábal (2004), who considered as high diversity the values superior to 3.0, as intermediate between 3.0 and 2.0, as low between 2.0 and 1.0, and as very low values inferior to 1.0. The Pielou equitability index (J') was of 0.7 for the regeneration under the Ingá canopies and of 0.1 under the Timbaúva canopies. The 0.7 value for the Ingá species indicates a relative uniformity of species since the closer the values of J' are to 1, the greater the uniformity in the area ($J' = 1$ indicated the maximum uniformity). The low value ($J' = 0.1$) for the regeneration under the Timbaúva canopies indicate minimum uniformity in the area. On the other hand, Callegaro et al. (2013) found in Santa Maria, municipality close to the study area, superior values for the natural regeneration under the canopy of *Peltophorum dubium* (cassia fistula), *Handroanthus heptaphyllus* (pink trumpet tree) and equal values for *Hovenia dulcis* (Japanese raisin tree), presenting $J' = 0.82, 0.83$ and 0.70 , respectively.

Melo & Durigan (2007) found an inferior value ($H' = 2.28$) to those obtained in this study in the state of São Paulo when comparing to other studies conducted in restoration plantations in regions with similar climatic variables. According to Marcuzzo et al. (2014), the differences verified between studies of this nature can be attributed to factors such as the distance of the propagule source, the number of species used and their functionality, arrangement, soil quality, climatic variation, phytogeography and degradation history.

Regarding the regeneration under the Ingá canopy, *Ligustrum lucidum* (privet) (21.7%), *Inga vera* (Ingá) (17.9%), *Syzygium cumini* (Java plum) (12.8%), *Baccharis semiserrata* (*vassourá*) (7.7%), *Psidium guajava* (guava) (6.5%) and *Allophylus edulis* (*chal-chal*) (5.3%) represent, in total, 71.7% of the density of the natural regeneration (542 individuals), which explains the low equability registered for the sample.

When comparing the density of natural regeneration individuals under the canopy of Ingá or Timbaúva, the high potential of Ingá species as facilitator in the establishment of natural regeneration becomes evident, especially when considering that the value obtained is very close to the value found for the reference area evaluated by Marcuzzo et al. (2014). The density of the Ingá canopy is higher than that of the Timbaúva due to the size of the leaves, their disposition, and the branch structure, which directly affects the light intensity that reaches the ground. In this case, the shade reduces the temperature allowing an increase of soil moisture and efficiency in the production processes of organic matter and nutrient cycling (Gonçalves, 2002), a condition which favors the establishment of seedlings.

Therefore, the canopy structure also serves as shelter, landing, and nidification for the dispersing avifauna, since the canopy has no frugivorous relation to birds and only psittacines consume them while breaking the pods. The fauna that consumes the fruits is comprised of primates and small mammals (Possette & Rodrigues, 2010). Likewise, the Timbaúva fruits are consumed by the mastofauna since they are dry. Thus, we affirm that the natural regeneration that occurs under the Ingá and Timbaúva canopies are a result of the dispersion by the avifauna which uses the canopies as shelter, given that the most established species are zoochorous and pioneers.

However, regarding the floristic composition of the individuals comprising the natural regeneration under the Ingá and Timbaúva canopies and in the reference area, there were no similarities, especially concerning the presence of invasive exotic species verified in this study and the establishment of a natural regeneration comprised only of native from the reference area, according to Marcuzzo et al. (2014).

This shows the positive interactions between the native (Ingá and Timbaúva) and exotic plants, such as privet, Java plum, Japanese raisin tree and guava, which found favorable conditions for germination and establishment under the canopies of the referred species. The exotic plants were benefitted by the soothing of temperature, followed by the increase in water availability (Flores & Jurado, 2003).

The exotic species represent 19.1% of the specific richness of the sample, but 43.6% of the number of individuals. However, the privet, Java plum and guava, all presenting zoochorous dispersion, were highlighted for the high density (totalizing 40.9%). This installation pattern denotes its invasive potential, already described by Ziller (2001), which is a great risk for the success of the implemented restoration actions. These invasive species have competitive advantages due to the absence of natural predators.

These results confirm the existence of species-specific interactions generated by the interspecific variation of the physiological, morphological and ecological characteristics for both native and exotic species.

The Integral Protection Conservation Units (CUs) must be representative of the native species and ecosystems. Therefore, the existence of exotic species is not desired or permitted (Brasil, 2000b). When exotic species are introduced and established, adapting to the ecosystem, hindering the permanence and establishment of native species of the natural succession, the primary management strategies are eradication and control, considering that a control program must contemplate measures to contain the species dispersion, reduce its abundance and density and mitigate its impacts (Ziller, 2005). Thus, we must promote the recovery of degraded

areas within conservation units and avoid the occurrence of undesired species.

4. CONCLUSIONS

The natural regeneration found under the canopies of *Inga vera* (Ingá) is similar to the reference area comprised of native species and superior to those found under the canopies of *Enterolobium contortisiliquum* (Timbaúva). This demonstrates the potential of the species to recover degraded areas. The occurrence of invading exotic species in the recovery area was significant probably due to the presence of a seedbank.

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