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Scientific literature on *Inga* (Fabaceae) from Santa Catarina state, Southern Brazil (1983-2017)

Altamir Rocha Antunes*, Guilherme Alves Elias, Gisele Pezente & Robson dos Santos

Herbário Pe. Dr. Raulino Reitz (CRI). Programa de Pós-Graduação em Ciências Ambientais, Universidade do Extremo Sul Catarinense – UNESC, Criciúma, SC, Brasil; altamirmad@hotmail.com, guilherme@unesc.net, gipezente@hotmail.com, rsa@unesc.net

* Correspondence

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ABSTRACT. The genus *Inga* Mill. belongs to the mimosoid clade (Fabaceae, Caesalpinioideae) that includes 131 species in Brazil. It is the most important genus of Fabaceae. In this sense, this study aimed to perform a bibliometric analysis on *Inga* from Santa Catarina state. A survey of the published literature was conducted using the electronic databases of the Web of Science, Scopus and SciELO with the accepted names of *Inga* species and its synonyms. Papers were distributed in four subject categories: C1 (Ecological), C2 (morphology, anatomy, taxonomy, histology, physiology and genetics), C3 (production and use) and C4 (biochemical and nutritional properties). We registered 232 papers for 13 species of *Inga*. C1 was the most studied subject category, mainly in topics such as nutrient supply, shade and nitrogen fixing capacity. We also noticed that the subjects diversified over the years, with registered papers in all categories. *Inga edulis, I. vera* and *I. marginata* were the most registered species in our survey. Our results showed an increase in the number of articles on *Inga* over time, especially in the last 13 years. However, some important gaps need to be addressed, such as the relatively small number and/or lack of studies conducted for some species.

Key words: bibliometrics, *Inga edulis*, legumes, Ingeae.

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The Fabaceae Lindl. (legumes) family is the richest in Brazil with 751 genus and 19 000 species; it is one of the most representative in the world (Bruneau et al., 2013). Among them, *Inga* is the most expressive and larger genus of Ingeae (Possette & Rodrigues, 2010). It can be distinguished from other genera for their arboreal habit, paripinnate leaves with nectary located between each pair of leaflets, fleshy and indehiscent fruits with seeds surrounded by a sweet and fleshy sarcotesta (Vasconcelos, 2014). *Inga* is exclusively neotropical and Brazil is one of the main centers of genetic diversity (Pennington, 1997). It has economic potential for reforestation, phytotherapy, energy production and food (Fernandes, Dondoni Da Costa, Araújo, & Lopes, 2016). Besides that, legumes are essential for fertilization, fodder, wood, tannins, oils, resins in the manufacture of varnishes, paint and dyes and in horticultural trade (Gepts et al., 2005; LPWG, 2017).

As most information about *Inga* is being published and made available in electronic databases, studies have been focused on nitrogen fixation capacity (Yatazawa, Uchino, & Hambali, 1983), shading plantations (Bishop, 1983; Staver, 1989; Alegre & Rao, 1996; Kettler, 1996), medicinal potential (Tauchen et al.,

2016) and nutritional and biochemical properties (Lima, Santos, & Porta, 2018). Bibliometric studies are very important and are being increasingly used to measure and analyze the scientific development in a specific research field (Hood & Wilson, 2001; Elias, Corrêa, Citadini-Zanette, & Santos, 2015).

The state of Santa Catarina has been a pioneer in the study of its forests and flora, exemplified by the Illustrated Flora of Santa Catarina - one of the most comprehensive works on Brazilian plants - developed by Reitz (1965), and the Barbosa Rodrigues Herbarium (HBR). Currently, the Floristic and Forest Inventory of Santa Catarina (IFFSC) (Vibrans, Sevegnani, Gasper, & Lingner, 2012a; Vibrans, Sevegnani, Gasper, & Lingner, 2012b; Vibrans, Sevegnani, Gasper, Müller, & Reis et al. 2013a; Vibrans, Sevegnani, Gasper, & Lingner, 2013b; Vibrans, Sevegnani, Gasper, & Lingner, 2013c) is responsible of disseminating current comprehensive data on Santa Catarina forest flora. In this context, this paper aimed to carry out a bibliometric analysis of the genus *Inga* naturally occurring in Santa Catarina, southern Brazil. We expect that our results may provide support for future researches on *Inga* species in Brazil.

Literature reviewed: The survey of the published literature on *Inga* was conducted using the databases Web of Science, Scopus and SciELO. Accepted names and the synonyms of naturally occurring species in Santa Catarina (Tropicos, 2013; Flora do Brasil 2020 Under Contruction, 2019) were used as keywords (Table 1). The search was performed in March 2018 and all papers published until December 31st, 2017 were compiled.

As mentioned before, the study area is located in the state of Santa Catarina, southern Brazil because *Inga* has great representation in the tree component in this area (Burkart, 1979). However, few articles deal specifically with the genus in the state. The Köppen climate classification for Santa Catarina is humid subtropical with no defined dry season and hot summers (Cfa) or balmy summers (Cfb), corresponding to 40 and 60 % of the study

TABLE 1
Inga species distributed in Santa Catarina with its synonyms and vernacular names

TABLA 1
Especies de *Inga* distribuidas en Santa Catarina con sus sinónimos y nombres vernaculares

Accepted names	Synonyms	Vernacular names
Inga edulis Mart.	*Inga scabriuscula* Benth.	ingá-cipó
Inga edwallii (Harms) T.D.Penn.	none	ingá
Inga lentiscifolia Benth.	none	ingá
Inga marginata Willd.	none	ingá-feijão
Inga sellowiana Benth.	none	ingá-ferro
Inga sessilis (Vell.) Mart.	none	ingá-macaco
Inga striata Benth.	*Inga nuda* Salzm. *Inga salzmanniana* Benth.	ingá-quadrado
Inga subnuda Salzm. ex Benth.		ingá
Inga subnuda subsp. *luschnathiana* (Benth.) T.D.Penn.	*Inga luschnathiana* Salzm. ex Benth.	ingá
Inga vera Willd.	*Inga spuria* Humb. & Bonpl. ex Willd.	ingá-do-brejo
Inga vera subsp. *affinis* (DC.) T.D.Penn.	*Inga arinensis* Hoehne *Inga meissneriana* Miq. *Inga uraguensis* Hook. & Arn. *Inga uruguensis* Hook. & Arn. *Inga affinis* DC.	ingá
Inga virescens Benth.	none	ingá-torcido
Inga vulpina Mart. ex Benth.	*Inga guilleminiana* Benth.	ingá-estrela

TABLE 2
Study categories for *Inga* species distributed in Santa Catarina

TABLA 2
Categorías de estudio para las especies de *Inga* distribuidas en Santa Catarina

Category	Study categories	Description
C1	Ecological	Floristics, phytosociology, phenology, conservation, population dynamics and interactions.
C2	Biological properties	Morphology, anatomy, histology, taxonomy, plant physiology and genetics.
C3	Production and use	Production and transformation of forest products, use by communities or commercialization.
C4	Biochemical and nutritional properties	Plant services used as feedstock for the isolation of one or more biochemical substances.

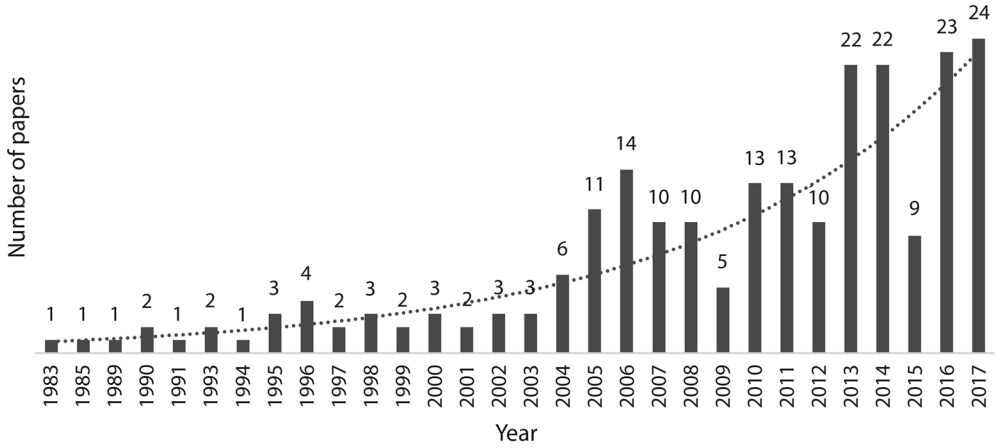

Fig. 1. Scientific production overview on *Inga* species distributed in Santa Catarina, southern Brazil.
Fig. 1. Producción científica sobre especies de *Inga* distribuidas en Santa Catarina, sur de Brasil.

area respectively (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013). Rainfall is well distributed throughout the state with an annual average of 1 250 - 2 000 mm /year with no areas of regular drought (Nimer, 1990). Each paper was identified by: (i) the year of publication, (ii) the scientific journal of publication, (iii) authors and (iv) study categories (Table 2) (Elias et al., 2015).

Trends in the literature: We found 232 papers for 13 species of *Inga* between 1983 and 2017. (Fig. 1). All papers were distributed in 133 scientific journals from different locations. All articles resulted in 934 collaborations among the 232 articles.

From 1983 to 1989 few papers were published and, for many years, no papers appeared on the subject. During this period, papers were mainly focused in the genus consortium with other species, highlighting the supply of nutrients and shading, which increases the yield of productions of coffee, cocoa and banana (Bishop, 1983; Staver, 1989). The following decade, publications maintained the same trend. Exceptionally, in 1996, the amount of articles published increased. At this time, papers called attention on the consortium between *Inga* and

monocultures, such as beans and rice (Alegre & Rao, 1996; Kettler, 1996).

From the year 2000 until 2010, the number of papers grew: in 2006, 14 papers were published, mainly on biochemical and nutritional properties of *Inga* (Arévalo-Pinedo, Dos Santos, Salles Arévalo, Zuniga, & Pinedo, 2006; Faria et al., 2006). These works dealt with *Inga's* increase in nutritional compounds as well as its conservation of germplasm. Despite the rise in publications, 2009 showed a decrease. The articles focused on *Inga*'s ecological relation with other organisms, such as the preference of birds for *Inga* species (Fink, Lindell, Morrison, Zahawi, & Holl, 2009).

During the years 2010-2017, we registered the highest scientific production on *Inga*. Most papers were focused on properties of secondary metabolism and applications in plant biological activities (De Sousa Dias, De Souza, & Rogez, 2010; Pinto, Souza, & Oliveira, 2010). The scientific production decreased exclusively in 2012 and 2015. However, they followed the same trend, where they focused on exploring the biochemical properties of *Inga* and their applications (dos Santos Barros, do Nascimento, & de Azevedo, 2012; Guillermo-Ferreira, Cardoso-Leite, & Gandolfo, 2012; De Freitas et al., 2015; Nygren & Leblanc, 2015).

Over the years, the growth in scientific production has been intensified in several areas of knowledge, such as ecology, biological activities, production and phytochemistry (De Sousa Dias et al., 2010; da Silva et al., 2014; Lamarca & Barbedo, 2015; Avila Jr., Pinheiro, & Sazima, 2015; Machado, de Oliveira, Zério, Parra, & Macedo, 2017). All papers were distributed in 133 scientific journals in several areas of knowledge. Agroforestry Systems was the main journal with 17 published papers, followed by Forest Ecology and Management (8), Revista Árvore (7), Rodriguésia (7) and Biotropica (6). These journals published articles on Forest Sciences, particularly the environment and nature conservation, forestry, use of forest products, taxonomy and forest management. Our results suggest a relatively dispersed paper distribution, where 19.6 % represents the five most influential journals. Other papers were distributed between one or two publications per journal.

The most productive author on *Inga* was Barbedo (on plant physiology) with 12 papers, followed by Leblanc (plant breeding) and Rogez (interactions of phenolic compounds) with nine papers each, Nygren (ecophysiology) with eight papers and Holl (restoration ecology) with six papers. On the other hand, the five most representative authors (those who have published more than six papers) mainly were focused on C1, the most representative in this study with 178 papers (Fig. 2). In this class, we found several research lines in ecological approaches, such as the floristic composition and phytosociological structure of a riparian forest in Southern Brazil, where *Inga marginata* was one of the most important species in the sample (Nakajima, Soares-Silva, Medri, Goldenberg, & Correa, 1996). Another study evaluated *Inga edulis* in processes of increasing soil fertility, highlighting its positive

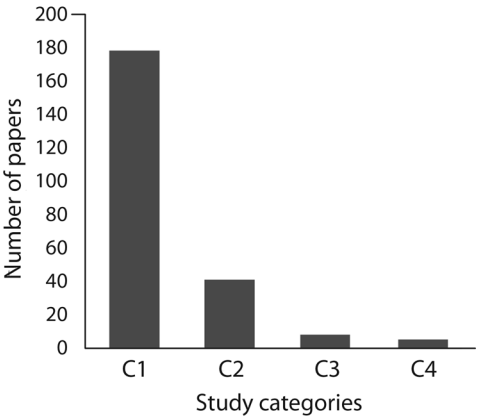

Fig. 2. Distribution of published papers per study categories on *Inga* species distributed in Santa Catarina, southern Brazil. C1 - Ecological; C2 - Morphology, anatomy, histology, taxonomy physiology and genetics; C3 - Production and use; C4 - Biochemical and nutritional properties.

Fig. 2. Distribución de artículos publicados por categoría de estudio sobre especies de *Inga* distribuidas en Santa Catarina, sur de Brasil. C1 - Ecológico; C2 - Morfología, anatomía, histología, taxonomía, fisiología y genética; C3 - Producción y uso; C4 - Propiedades bioquímicas y nutricionales.

performance (Kanmegne, Bayomock, Duguma, & Ladipo, 2000). Also, some studies called out *Inga*'s ability to resist disturbances such as herbivory (Thomaz Heerdt & Ferreira de Melo Junior, 2016) and herbicides (Cabral et al., 2017), besides facilitating regeneration of forests due to mycorrhizal associations (Iglesias, Salas, Leblanc, & Nygren, 2011; Nygren, Leblanc, Lu, & Luciano, 2013).

Conversely, C4 was the second place most researched field with 41 species, such as *Inga edulis*, *Inga vera* and *Inga marginata* (Fig. 2). The studies pointed out that Fabaceae is well known for the compounds of the secondary metabolism and their use in biological assays (Molares & Ladio, 2012). The majority of studies were published from 2010 onwards and they highlighted the active principles of *Inga* species (Lima et al., 2018). Research with methanolic extracts of the barks, leaves, and flowers of *Inga marginata* evidenced reduction of the severity of anthracnose in bean plantations to values below 35 % observed in the control group (Andrade Pinto, Souza, & Oliveira, 2010). Chemical studies showed phenolic compounds on the leaves of genus *Inga* used in traditional medicine as laxatives. On the other hand, another study shows that the leaves of *Inga edulis, I. marginata* and *I. laurina* presented high antioxidant capacity, probably related to the presence of phenolic substances (Lima et al., 2018).

These types of studies are important precursors for investigations on biological activities (Antunes, 2018). For instance, indigenous communities use *Inga* species for inflammation and rheumatism as reported in an ethnobotanical study (Lima et al., 2018). Besides that, it is a much appreciated genus in Northern Brazil as food, whereby it is important to know their nutritional values. Those studies have shown that some of its secondary compounds have a high content of phenolic compounds, elevating its pharmacological potential, especially its antioxidant capacity (Pompeu, Rogez, Monteiro, Tinti, & Carvalho, 2012). *Inga edulis*, particularly, exhibited a high content of phenolic compounds and high antioxidant capacity, capable of having antiulcerogenic activity (Pompeu et al., 2012). *I. vera*, on the other hand, provides a defense strategy – with peptidase inhibitors - that interferes in the physiology of insects. This mechanism has been considered as a biotechnological alternative for the control of pests (Bezerra, Oliveira, & Macedo, 2017).

We also registered eight papers on the C2 category (Fig. 2). In general, it is an underrepresented class; however, it is very relevant for the research line, particularly taxonomic studies (Rapini, 2004). Other papers investigated germination capacities, its break of dormancy and seed viability (Parisi, Biagi, Medina, & Barbedo, 2016; Delgado, Da Silva, & da Silva, 2017). On the other hand, C3 was the least representative class of our sample, with only five published papers (Fig. 2). All of them focused on timber and food uses (Clement, Cristo-Araújo, Eeckenbrugge, Pereira, & Picanço-Rodrigues, 2010; Lopes, Crepaldi, & Lobão, 2017; de Freitas et al., 2018).

The species *Inga edulis, I. vera* and *I. marginata* were the most cited species in our study, mainly in C1 class (Table 3). *Inga edulis* is a tree naturally distributed in tropical America, largely known by its wood quality and used, in Brazil, for food and shading of coffee plantations (Burkart, 1979). The strong ecological interactions, highlighted in our results, were related to animals, especially birds (Lindell, Reid, & Cole, 2013). Besides that, some studies emphasize the dispersers preference for *I. edulis* than other tree species in the same environment (Lindell et al., 2013). In addition, it shows antioxidant activities with moderate biological activities (Souza et al., 2007; De Freitas et al., 2018).

Studies on *I. vera* followed the same pattern of *I. edulis*: it stands out as a preferential diet for birds (Ragusa-Netto, 2004), and other ecological interactions. Patterns between morphological parameters of birds and flowers of *Inga* suggests a close mutualistic and complex relationship of pollination and environment (Githiru, Lens, Bennur, & Ogol, 2002; Cruz-Neto, Machado, Duarte Jr, & Lopes,

TABLE 3
Number of papers registered per species and study categories

TABLA 3
Número de artículos registrados por especie y categorías de estúdio

Species	C1	C2	C3	C4
Inga edulis Mart.	86	2	3	31
Inga edwallii (Harms) T.D.Penn.	0	0	0	0
Inga lentiscifolia Benth.	1	0	0	0
Inga marginata Willd.	22	0	0	4
Inga sellowiana Benth.	0	0	0	0
Inga sessilis (Vell.) Mart.	3	0	0	0
Inga striata Benth.	5	0	0	0
Inga subnuda Salzm. ex Benth.	8	0	1	1
Inga subnuda subsp. *luschnathiana* (Benth.) T.D.Penn.	2	0	0	0
Inga vera Willd.	45	4	1	5
Inga vera subsp. *affinis* (DC.) T.D.Penn.	5	2	0	0
Inga virescens Benth.	1	0	0	0
Inga vulpina Mart. ex Benth.	0	0	0	0
Total	**178**	**8**	**5**	**41**

2011). *I. marginata* also stood out in ecological approaches, exhibiting potential as a facilitator of natural regeneration in the Atlantic Forest, with the highest number of species growing under its individuals (Spadeto, Wilson Fernandes, Negreiros, & Kunz, 2017) as well as *I. edulis* and *I. vera*. Besides that, *I. marginata* has potential for phytoremediation, being used for ecological restoration, especially in environments contaminated by herbicides (Cabral et al., 2017).

Finally, few investigations have been conducted on *I. lentiscifolia, I. sessilis*, *I. striata*, *I. subnuda*, *I. subnuda* subsp. *luschnathiana, I. vera* subsp. *affinis, I. virescens*, while no published paper were found for *I. edwallii, I. sellowiana* and *I. vulpina*. These species are more restrict, occurring in a few places in Santa Catarina. In this context, the bibliometric analysis showed an increase in the number of papers on *Inga* over time, especially in the last 13 years. However, some important gaps need to be addressed, such as the relatively small number and/or lack of studies conducted for some species. In addition, we expect that more researches will be performed with *Inga*, emphasizing the less studied categories and species to reveal the real potential of this genus in Santa Catarina.

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RESUMEN

Literatura científica sobre *Inga* (Fabaceae) en el estado de Santa Catarina al sur de Brasil (1983-2017). El género *Inga* Mill. pertenece al clado mimosoide (Fabaceae, Caesalpinioideae) con 131 especies en Brasil. Es el género más importante de las Fabáceas. En este sentido, el objetivo de este estudio fue realizar un análisis bibliométrico de *Inga* en el Estado de Santa Catarina. Se condujo un estudio de la literatura publicada utilizando las bases de

datos electrónicas de la Web of Science, Scopus y SciELO con los nombres aceptados de las especies *Inga* y sus sinónimos. Los trabajos se distribuyeron en cuatro categorías temáticas: C1 (ecológico), C2 (morfología, anatomía, taxonomía, histología, fisiología y genética), C3 (producción y uso) y C4 (propiedades bioquímicas y nutricionales). Se registraron 232 trabajos para 13 especies de *Inga*, donde se exhibió un notable incremento de publicaciones. C1 fue la categoría temática más estudiada, principalmente en temas tales como: suministro de nutrientes, sombra y capacidad de fijación de nitrógeno. *Inga edulis*, *I. vera* e *I. marginata* fueron las especies más registradas en nuestro estudio. Nuestros resultados mostraron un aumento en el número de artículos sobre *Inga* con el tiempo, especialmente en los últimos 13 años. Sin embargo, es necesario abordar algunos vacíos importantes como el número relativamente pequeño y/o la falta de estudios realizados para algunas especies.

Palabras clave: bibliometría, *Inga edulis*, legumbres, Ingeae.

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