

Historical review and academic interactions related to progresses of Brazilian Cecidology

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Cecidology is the study of galls, and comprise a multidisciplinary approach. The word cecidology is originated from the greek words *kēkis* (singular), *kēkidōs* (plural), diminutive *kēkidion*, in new latin, the words are *cecidium* (singular) and *cecidia* (plural). The first cecidologist to use the latin word *galla* (singular), *gallae* (plural) was the roman GAIUS PLINIUS SECUNDUS, Plinius the Elder (23–79 AD), who designated as *galla* the structure induced by a wasp (Cynipidae) in oak leaves (*Quercus* sp., Fagaceae), in his book *Naturalis Historia XXIV* (Meyer & Maresquele 1983, Fernandes & Martins 1985). Galls are structures formed by a host plant in response to the activity of different organisms, such as bacteria, fungi, nematodes, mites, and in most cases insects. These organisms cause deviations in the typical plant development patterns toward the formation of new plant structures. Galls may have bizarre shapes, different colors, and importance for medicine, food, ornaments, and commercial usages (Fagan 1918, Mani 1964, Berlin & Prance 1978, Fernandes & Martins 1985, Meyer 1987).

Galls have been known in China, India and Europe since ancient times, with the first mentions about galls going back to the Greek HIPPOCRATIS (460-375 BC), the Father of Medicine, whose legacy are the manuscripts known as *Corpus Hippocratum*, and THEOPHRATUS (371–287 BC), the Father of Botany, with the books *Historia Plantarum* and *De Causis Plantarum* (Fagan 1918, Fernandes & Martins 1985). These historical books cited above constitute the most important contribution to the science from antiquity until the renaissance period (14th-16th century).

After the Renaissance, the English scientist ROBERT HOOK (1635-1703) made gall observations on a microscope and described them in his book *Micrographia* (1665). He conjectured that the leaf tissues grew surrounding the insect larvae in apple-oak galls. However, the first scientific investigation of galls is credited to the Italian physician and biologist MARCELLO MALPIGHI (1628-1694), who published his observations *De Gallis*, in 1679, in the book *Anatome Plantarum II* (Mani 1992). According to MALPIGHI, "the gall formation arose from an emanation of the animal, which stimulates the behavior of the cells of the affected plant" (Krikorian 1984). Based on its accurate observations, MALPIGHI has proposed an explanation to the process of gall development, and he "made" science on this issue. In a scientific work, the most important part is the analysis and the interpretation of the results toward a valuable discussion; the discussion is the soul of the research.

However, it was only from the beginning of the 20th century that Cecidology established itself as an important area of scientific knowledge. ALESSANDRO TROTTER (1874-1967), an Italian

botanist and entomologist, is responsible for the great merit of establishing Cecidology as a field of biological research. He started publishing the specialized journal *Marcellia*, a name given in honor to MARCELLO MALPIGHI, in 1902. TROTTER described about 742 galls, many caused by new species of Cecidomyiidae and Cynipidae. During the same period, in 1900, the German botanist ERNEST KÜSTER (1874-1953) defended his thesis entitled *Beiträge zur Anatomie der Gallen* (Contributions to the Anatomy of Galls). KÜSTER is the author of several books on plant anatomy, including *Die Gallen der Pflanzen: ein Lehrbuch für Botaniker und Entomologen* (The Plant Galls: A Textbook for Botanists and Entomologists), published in 1911 (reprinted in 2010). He wrote another important book, *Anatomie der Gallen* (Anatomy of Galls) published in 1930. KÜSTER was the editor of the *Zeitschrift für Wissenschaftliche Mikroskopie* (Journal for Scientific Microscopy) for almost 50 years.

Advances in the study of galls are conspicuous from the middle of the 20th century, when the Indians have special merits. The main reference is the illustrious, zoologist-entomologist, MAHADEVA SUBRA (MANYA) MANI (1908-2003), author of many books, highlighting the Ecology of Plant Galls, a *Magnum Opus*, the basis of the studies of galls, first published in 1964. Due to its importance, this book was reprinted in 2013. Another relevant of MANI's books was The Plant Galls of India, whose first edition is from 1973 and the second from 2000. MANI obtained the Master degree awarded by the University of Madras (Madras) and the Doctor degree by the Agra University (Agra), now called Dr Bhimrao Ambedkar University. He worked at the St. John's College (Dr Bhimrao Ambedkar University), and later at the Presidency College in Madras, both in India. An important point to emphasize on the reprinting of these famous and basic books is that they are important not only for his historical value, but because they provide important basic information, and help us avoiding to "reinvent the wheel".

The 1970 to 1990s were also important for the expansion of several areas of Cecidology, whether under the entomological, ecological, anatomical, chemical, and other scientific areas. Only some researchers will be mentioned to exemplify the range of scientists, which is much larger. In the 1970s, the evolutionary ecology of galls flourished under the guidance of PETER WILFRED PRICE, English, who completed the master's degree in Canada and the doctorate in the USA, at The Cornell University, Ithaca (USA). In 1980, PRICE went to Northern Arizona University, Flagstaff (USA), where he stayed up to his retiring in 2002. His teaching concentrated on insect ecology, entomology, and biological evolution. PRICE has numerous important publications: PRICE (1988), FERNANDES and PRICE (1988), PRICE et al. (1986, 1987, 1998) etcetera. His book entitled *Insect Ecology* (1975, 1984, 1997), now in the third edition, is a *Magnum Opus*. It is the world's foremost reference to the never-ending and crucial interactions of the insects, the richest taxon of organisms on the Earth, with

plants. He also published other books: *Evolutionary Biology of Parasites* (1980), *Plant-Animal Interactions: Evolutionary Ecology in Tropical and Temperate Regions* (Price et al. 1991), *Biological Evolution* (1995), among others.

Following a temporal line, TARACAD NARAYANAN ANANTHAKRISHNAN (1925-2015) was another important Indian entomologist and chemical ecologist of galling insects, especially in the order Thysanoptera. He completed Master and Doctorate degrees, both in the University of Madras. He founded the Entomology Research Institute at Loyola College, campus Chennai, India. He published several books, including *Biology of Insect Galls* (1985), *Chemical Ecology in Thrips-Host Plant Interactions* (1993) in collaboration with R. GOPICHANDRA; *Biocommunication in Insects* (1998) with A. SEN, etcetera. He had a great influence of Professor Mani, during his the time at the Presidency College.

Another contemporary cecidologist is ANATANARAYANAN RAMAN, an Indian biology educator and researcher. His achievements include research in Cecidology and tertiary education. Raman got his Master of Science by the Presidency College, and his Doctorate of Philosophy by the Loyola University at the University of Madras (1981). He is also a Doctor in Science by the University of Madras (2004). RAMAN published several books, many as co-author. *Thrips and Gall Dynamics* (1989) and *Chemical Ecology of Phytophagous Insects* (1993) with ANANTHAKRISHNAN (mentioned above), and currently works at the School of Charles Sturt University, Orange, Australia.

Following a temporal line, it is worth mentioning the publications of RAYMOND J. GAGNÉ, American specialist in Cecidomyiidae (Diptera), a family of flies known as gall midges. He works at the Systematic Entomology Laboratory, Agricultural Research Service of the Smithsonian Institute, Washington, D.C., USA. His books *The Plant-Feeding Gall Midges of North America* (1989), and *The Gall Midges of the Neotropical Region* (1994) are compendia of the current knowledge on the biology, recognition, and literature of plant-associated cecidomyiids of North America and Neotropical region.

Under the Plant Anatomy (histology) focus, the book *Anatomie des galles* (*Anatomy of Galls*), published in 1983, authored by JEAN MEYER and HENRI JEAN MARESQUELLE (1898-1977), is also a *Magnum Opus*. It includes a detailed study of the anatomy and development of plant galls. The numerous examples show how variable gall shapes are, and how the plant tissues undergo changes during gall development. Although with extensive production, the examples, for the most part, do not represent models for the neotropical region. The authors worked at the *Laboratoire de Cecidologie of the Université de Strasbourg* (Laboratory of Cecidology of Strasbourg University), Strasbourg (France). Several important researchers were part of this laboratory group: ODETTE ROHFRITSCH, ROBERTE BRONNER, FRANÇOISE DREGER-JAUFFRET and EVELYNE WESTPHAL. MEYER is also the author of *Plant Galls and Gall Inducers*, published in 1987.

In the 1990s, JOSEPH D. SHORTHOUSE from Laurentian University (Sudbury, Canada) and ODETTE ROHFRITSCH (mentioned above) published the book *Biology of Insect-Induced Galls* (1992), also a particularly important reference. This book provides comprehensive coverage of gall biology and its complex etiology. Several researchers wrote specific topics in plant-insect relationships; some collaborators belonged to the *Laboratoire de Cecidologie of the Université de Strasbourg*. For most of his research career, SHORTHOUSE has concentrated on the ecology, distribution and development of plant galls induced by cynipid wasps of the genus *Diplolepis* found on wild and introduced roses, genus *Rosa*.

At the beginning of the 21st century, the literature on galls flourished again. The researches range from studies on classical biology, anatomy of plant galls to immunocytochemistry, systematics of galling organisms to molecular phylogeny, populations, ecological and evolutionary gall theories, and genetics to molecular biology. Some books are basic and put on greater emphasis on the biology, behavior, and evolution of the gall-inducing arthropod and of associated organisms. For examples: *Biology, Ecology, and Evolution of Gall-Inducing Arthropods* (Raman et al. 2005); *Biological Control of Tropical Weeds Using Arthropods* (Rangaswamy Muniappan et al. 2009); *Insects and Plant Defense Dynamics* (Ananthakrishnan 2001); *Arthropods of Canadian Grasslands: Ecology and Interactions in Grasslands Habits* (Shorthouse and Floate 2010). The book *Insect Ecology: Behavior, Populations and Communities* (Price et al. 2011) gives a logical and cohesive introduction to insect ecology concepts with a broad range of examples and practical applications. The *Biology of Gall-Inducing Arthropods* (Csóka et al. 2012) is the result of an International Symposium (1997, Hungary), and explores many facets of the ever intriguing and enigmatic relationships between plants and their gall-forming herbivores. The important *Catalog of the Cecidomyiidae (Diptera) of the World* by R.J. GAGNÉ and MATHIAS JASCHHOF (2017), fourth edition, registers about 6,203 known species of Cecidomyiidae, either living or fossil.

Knowing that Brazil possesses the richest flora of the world with about 40,000 species (Forzza et al. 2012) and the number of galling species is estimated about 132,000 species on the planet (Espírito-Santo & Fernandes 2007), attention should be paid to the galls that represent the interaction with these organisms. The Neotropical region, including Brazil, is known to have a great richness and diversity of species. The Neotropical region is defined as southern North America, Central America, Caribbean Islands and South America (Udvardy 1975). Each ecosystem has specific characteristics that makes it unique. Hence, it is necessary to know the environmental characteristics and species in the diverse ecosystems in order to understand and preserve natural biodiversity.

The first studies on Brazilian galls were made by the Portuguese Jesuit priest JOAQUIM DA SILVA TAVARES (1866-1931), an entomologist, who surveyed the galls of the Atlantic Forest, where

he was exiled from 1910 to 1913. In his studies, however, he mostly came to the level of plant families, due to the lack of specialists in the country at that time. TAVARES sent material to the American entomologist EPHRAIM PORTER FELT, and the French botanist CLODOMIR ANTONY VINCENT HOUARD (both mentioned below). Part of TAVARES collection is currently in Germany, at the *Staatliches Museum für Naturkunde Stuttgart* (State Museum of Natural History Stuttgart), according to GAGNÉ (1994). TAVARES was one of the founders of the Portuguese-Brazilian journal *Brotéria - Revista de Ciências Naturaes* (1902-2002), together with Cândido Azevedo Mendes (1874-1943) and Carlos Zimmermann (1871-1950), a qualified journal among Portuguese scientific publications during the past century. Most of TAVARES researches was published in *Brotéria* (TAVARES 1906, 1909, 1915, 1916a, b, 1917a, b, 1918, 1920b, 1921, 1922, 1925), and just one paper was published in *Marcellia* (1920a).

EWALD HEINRICH RÜBSAAMEN (1857-1919), German entomologist, also studied some species of Brazilian insect galls (RÜBSAAMEN 1907, 1908). As above-mentioned, FELT and HOUARD received samples of Brazilian insect galls. FELT (1868-1943), American entomologist, studied at Cornell University, Ithaca, USA, and worked mostly with Nematocera, particularly Cecidomyiidae. He wrote the book *Plant Galls and Gall Makers* (1940) and described about 1,000 species of gall midges. His collection is at the National Museum of Natural History, Washington D.C., USA. HOUARD (1873-1943), French botanist, worked at the *Université de Strasbourg* and is the author of several works with galls, notably the book *Les Zoocécidies des Plantes de l'Amérique du Sud et de l'Amérique Central*, 1933 (*Plant Zooecidia of South and Central America*). His extensive collection of galls is preserved in the *Muséum National d'Histoire Naturelle* (National Museum of Natural History), in Paris (France).

In the 30s, 20th century, in Rio de Janeiro, the botanist, pathologist, FERNANDO ROMANO MILANEZ (1905-1987) carried out the first anatomical study on galls. He described a gall on guava trees (*Psidium guajava* L., Myrtaceae), published in the first issue of *Rodriguésia, Revista do Jardim Botânico do Rio de Janeiro*, in 1935. Subsequently, two unpublished doctoral theses are mentioned in the literature: the first one authored by J.A. GUIMARÃES (1957) that described in few details some leaf galls on *Copaifera langsdorffii* Desf. (Leguminosae) and *Anemopaegna mirandum* (Bignoniaceae), now *Anemopaegna arvense* (Vell.) Stellfeld ex de Souza, in Rio de Janeiro; the second one authored by J.P. ALVARENGA (1959) that described a stem gall on *Vernonia polyanthes* (Spreng.) Less. (Asteraceae), from Minas Gerais. Later, in the 1980s PAULO OCCHIONI (1979, 1981) made a descriptive survey of 110 types of galls. The galls were collected in different vegetation types, distributed in 34 families of phanerogamous

plants and one in a pteridophyte. However, there is no identification of the inducers and the plants are in most cases identified only to the family level.

It is in the mid-1980s that Brazilian cecidology gains a new stimulus, highlighting the ecological works developed at the *Universidade Federal de Minas Gerais* (Federal University of Minas Gerais), Belo Horizonte, by the mentor GERALDO WILSON FERNANDES. He did his master's and doctorate (1987, 1992, respectively) at Northern Arizona University, Flagstaff, under the guidance of PETER W. PRICE, and later post-doctorate at Stanford University, Palo Alto (both in USA). Its numerous scientific publications (460 or more) are of indisputable importance. However, it is relevant to mention the publication on the journal *Ciência Hoje* (1985), in which the range of gall studies is shown in a didactic way for people and students interested in the theme. The book chapter *Insetos Galhadores* (Galling Insects) is also very didactic (FERNANDES and CARNEIRO 2009). FERNANDES published several books with emphasis on the entitled Neotropical Insect Galls (2014), edited in collaboration with JEAN CARLOS SANTOS. The chapters were written by several researchers and reported the reaction of plant cells to the galling insects, their natural enemies, diversity and ecological evolution on these special taxa on the Neotropics. A Handbook of Sampling Methods (2021), again in collaboration with SANTOS, aims to be a reference for zoologists, entomologists, ecologists, cecidologists, botanists, students, researchers, and for those interested in arthropod science and biodiversity. It is worth mentioning that the group of researchers led by FERNANDES is the largest in the country in the area of gall ecology and evolutionary biology. The approach taken in different Brazilian biomes has brought up the knowledge on part of our biodiversity (e.g. Fernandes et al. 1988; Lara & Fernandes 1996; Price et al. 1998; Maia & Fernandes 2004). An overview of the inventories of gall-inducing insects in Brazil was made by ARAÚJO et al. (2019).

It is also in the mid-1980's, that gall studies began under the anatomical approach in Brazil. The first doctoral thesis focusing on morphological, histological and ontogenetical aspects of galls was carried out by LÉA DE JESUS NEVES (1987), under the guidance of BERTA LANGE DE MORRETES, at the *Universidade de São Paulo* (São Paulo University), São Paulo. Two types of galls were studied in *Ficus tomentella* Miq. (Moraceae), one induced by Diptera and the other by Hymenoptera. However, MORRETES did not pursue this research line.

In that same period, mid-1980s, JANE ELIZABETH KRAUS and MARGARIDA VENTURELLI (1942-1989) resumed anatomical studies on galls. KRAUS obtained her master's and doctoral degrees in Botany at the *Universidade de São Paulo* (1981, 1986, respectively), and initially worked with plant tissue culture in this institution. As VENTURELLI was specialist in *Struthanthus vulgaris* L. (Loranthaceae), a hemi-parasitic plant that hosts the galls studied on anatomical basis for the first time (Arduin et al. 1989). From the 90s onwards, KRAUS defined anatomical studies on galls

as a research line, with focus on galls in the Neotropical region. She retired in 2002, but continued to contribute as she published some papers, and book chapters, with emphasis on the chapter entitled *Galhas: morfogênese, relações ecológicas e importância econômica* (Galls: Morphogenesis, Ecological Relationships and Economic Importance) in *Interações Ecológicas & Biodiversidade* (Ecological Interactions & Biodiversity) edited by TISSOT-SQUALLI (2009), a basic introduction for the study of morphogenesis in galls. Two other book chapters were published by KRAUS as a co-author with ISAIAS et al. (2014a, 2017). The most commented paper shows the distribution of metabolites on galled and non-galled leaf tissues of *Tibouchina pulchra* (Cham.) Cogn. (Melastomataceae) (Motta et al. 2005). However, the root galls of *Cattleya guttata* Lindt, Orchidaceae (Kraus & Makoto 1999; Kraus et al. 2004) are an interesting model because galls in aerial root are uncommon.

In 2000, also at the *Universidade Federal de Minas Gerais*, a group is formed for morphological, anatomical, histochemical, physiological and chemical studies on galls, having as mentor ROSY MARY DOS SANTOS ISAIAS, who became an exponent in the area. She did her master's degree at the *Museu Nacional / Universidade Federal do Rio de Janeiro* (National Museum of Federal University of Rio de Janeiro), under the guidance of LEA J. NEVES and her doctorate (1998), at the *Universidade de São Paulo*, advised by JANE E. KRAUS. ISAIAS has numerous published papers (more than 120), highlighting the Illustrated and Annotated Checklist of Brazilian Gall Morphotypes (Isaias et al. 2013), published in the journal *Neotropical Entomology* as her most cited paper. It is also worth mentioning her collaboration with international research groups by invitation (Martin J. Steinbauer, of the La Trobe University, Melbourne, Australia), that recognized her research (Isaias et al. 2018). She is also the co-author of several book chapters with emphasis on those dealing with gall morphotypes and the developmental anatomy of galls in the Neotropics (Isaias et al. 2014a, b) published in the book *Neotropical Insect Galls* (Fernandes & Santos 2014). ISAIAS has also contributed to the book coordinated by MELO JÚNIOR and BOEGER (2019), entitled *Patrimônio Natural, Cultura and Biodiversidade da Restinga do Parque Estadual Acaraí* (Natural Heritage, Culture and Biodiversity of Coastal Thicket of Acaraí State Park), located in Santa Catarina, Brazil (Isaias et al. 2017). ISAIAS is also the co-author of a guide to Brazilian insect galls - *Guia de Galhas de Insetos de Caetité, Bahia, Brasil* (Guide to Insect Galls from Caetité, State of Bahia, Brazil) published recently (Silva et al. 2020).

Concomitantly, at the beginning of the 21st century, the studies on galling insects, with emphasis on Cecidomyiidae (Diptera), were established by VALÉRIA CID MAIA. Her first contact with galls was during the under-graduation training under the guidance of RICARDO FERREIRA MONTEIRO, at the *Universidade Federal do Rio de Janeiro*, Rio de Janeiro. She obtained her master's

and doctorate degrees (1994, 1999, respectively) in Zoology, at the same university, under the guidance of MÁRCIA SOUTO COURI. During her doctoral studies, she maintained contact and training with RAYMOND J. GAGNÉ, mentioned above, specialist in Cecidomyiidae. Later, she completed a post-doctorate at the *Universidade Federal de Minas Gerais*. MAIA develops research in taxonomy and ecology of galling insects (Cecidomyiidae, Diptera), with about 150 publications. She works at the *Museu Nacional / Universidade Federal do Rio de Janeiro*. Among numerous works, it is worth highlighting those that report Restinga galls (Maia 2001a, b) and the survey of galling insects carried out in the *Parque Nacional de Itatiaia* (Itatiaia National Park, State of Rio de Janeiro), where she observed a great diversity of gall morphotypes (Maia & Mascarenhas 2017). Maia has also contributed with chapters in the books *Biodiversidad de Artrópodos Argentinos* (Maia 2014) and *Neotropical Insect Galls* (Fernandes & Santos 2014).

It is important to mention the paper “30 years of research on insect galls in Brazil; a scientometric review” (Araújo 2018), a revision about gall scientific production. This revision shows that the most common topic studied was ecology, followed by inventory and taxonomy, which together represent 82,41%, and anatomy, revision, agriculture and genetic represent the remaining 17,59%. Unfortunately, most anatomical (histological) works have not been accounted for, giving a false idea of the research in this area. ARAÚJO also forgot that the studies on galls began, and they will be continued with botanists! In order to maintain and preserve natural environments, basic studies on the biology of the species under the focus of different areas of the biological knowledge are extremely important and constitute the basis for scientific information.

This brief historical tour of Cecidology demonstrates that there is an intricate network of relationships, which enables the advance of the knowledge on galls. Entomological studies are developed mainly at the *Museu Nacional / Universidade Federal do Rio de Janeiro*. It is also worth emphasizing that, currently, the largest and most important center of gall studies in Brazil is at the *Universidade Federal de Minas Gerais*. Morphological, Anatomical, Histochemical and Ecological Studies are the main research lines. As a training center of excellence, the disciples have been creating new groups in other universities, expanding the knowledge network.

As biologists, our fascination with galls as models of study comes from the interactions of different biological areas of the knowledge. To finish, we would like to tell the students that in the scientific studies it is necessary to interact with diverse specialists. This is enriching both from the scientific and the human point of views.

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