

ALLELOPATHY IN NATIVE SPECIES OF BRAZILIAN SAVANNAH

ALELOPATIA EM ESPÉCIES NATIVAS DO CERRADO

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ABSTRACT - In this review, allelopathic studies of 70 species native from Cerrado, distributed in 34 families and studied from 1992 until late 2008, were compiled in a list. The Cerrado Biome comprises several distinct landscape areas constituted by different phytophysiognomies, and is the most biodiverse savanna in the world. From the 12.000 species native to Cerrado, only a small amount of species have been studied. Few allelochemicals in leaves, flowers, shoots, and subterranean parts of plant species were identified in the restricted data. Isolated compounds from a few plants were shown in detail. The synthesis of those compounds was not identified for use in comprehensive control of plants and other organisms. Future studies should be directed to unknown and better known plants; identification of new compounds and their metabolism; synthesis and mode of action of those new compounds; agriculture effects and Cerrado plants establishment.

Keywords: Allelochemical. Brazilian Savanna. Future perspectives. Phytophysiognomy. New compounds.

RESUMO - Nesta revisão, estudos alelopáticos de 70 espécies nativas do Cerrado, distribuídas em 34 famílias e estudadas de 1992 até 2008 foram compiladas em uma lista. O Bioma Cerrado compreende várias paisagens distintas constituídas por diferentes fitofisionomias e é uma das biodiversidades mais ricas no mundo. Das 12.000 espécies lenhosas nativas do Cerrado, somente em uma pequena parte foram estudadas. Poucos aleloquímicos em folhas, flores, parte aérea e partes subterrâneas de espécies de plantas foram identificadas em dados restritos. Compostos isolados de poucas plantas foram mostrados em detalhes. A síntese desses compostos não foi utilizada para uso em controle de plantas daninhas e outros organismos. Futuros trabalhos poderiam ser direcionados para plantas estudadas e ainda não estudadas; a identificação de novos compostos e seu metabolismo; síntese e modo de ação daqueles compostos; efeitos na agricultura e no estabelecimento de plantas no Cerrado.

Palavras chaves: Aleloquímico. Savana brasileira. Perspectivas futuras. Fitofisionomia. Novos compostos.

INTRODUCTION

The Brazilian Cerrado is the second largest Biome in extension in the country, 2.036.448 km² (Anonymous, 2008), and the richest savanna in the world. It borders with the Atlantic Rainforest, Caatinga, Amazon Rainforest, and Pantanal Wetlands, which promotes important dynamics between them. The number of studies related to the establishment and development of species native to Cerrado is still small when compared to an array of more than 11 thousand species described (Mendonça et al., 2008). Currently the available studies about seed germination

comprehend no more than 700 species (Sousa-Silva & Camargo, 2008).

A myriad of metabolites are produced by plant species in their growth and development. However, their physiological functions are still unknown (Zimdahal, 1993). These substances are normally secreted by the roots or released from dead tissues. They are products of secondary metabolism, such as terpenoids, phenolic compounds, and alkaloids (Silva et al., 2006). When produced by the plant or plant-associated microorganisms, these substances may interfere in the growth and development of another organism. This interference

ce, when a chemical compound acts over another organism, is called allelopathy (Rice, 1984). Allelopathy has an important role in natural as well as in cultivated ecosystems. It interferes in species dominance, regulation of succession (Hilhorst & Karssen, 2000) and crop productivity as a natural alternative for weed control (Macías, 2007).

A more detailed knowledge will undoubtedly stimulate a better understanding of the environmental control of germination and emergence, of the species evolutive strategies, and some allelochemicals may ultimately lead to the development of alternative methods for weed control and management as well as models for new herbicides (Hilhorst & Karssen, 2000). Besides this has led to a situation of increasing complexity where phytochemical studies interact with many other disciplines, including plant physiology, pharmacy and drug design, medicine, palaeontology, ecology, and biochemistry. The results obtained from these studies can be applied in many fields such as pharmaceuticals, agrochemicals, evolutionary studies, paleobotany, ecosystem management and conservation and basic science (Macías, 2007).

Allelopathic species have been selected by evolutive pressure competing with species from neighborhood. These species have biochemical processes which spend energy to produce allelochemicals. The energy spent certainly is not a waste of energy because no species develops wasting its resources (Zimdahal, 1993), specially species native to Cerrado, where nutrients are, normally, scarce, and the rain occurs at widely spaced intervals.

Mineral deficiencies (e.g. boron, calcium, magnesium, nitrogen, phosphorus, potassium, and sulphur) and hydric stresses are some of the factors which may affect allelochemical production (Rice, 1984). To these factors, peculiar of Cerrado, one could include aluminum toxicity effects, which leads plants, as a defense mechanism, to exude higher amount of low molecular weight organic acids (Schöttelndreier et al., 2001), and other compounds which could present allelopathic effects. For this reason, some species native to Cerrado, which are not endemic, but presented allelopathic effects when tested in other biomes (e.g., Maraschin-Silva & Aquila, 2006a, b; Souza et al., 2005a, b), could produce higher amount of allelochemicals if grown at Cerrado region.

Allelopathic studies with species native to Brazil were brought together before by Ferreira et al. (1992). At that time, the amount of works was negligible, and there was no allelochemical characterization, and also a tendency in researching legume species whose are the most common plants in Cerrado. However, many studies were performed since that last review. The present document grouped allelopathic studies with species native to Cerrado Biome from 1992 until late 2008.

MATERIAL AND METHODS

THE CERRADO (BRAZILIAN SAVANNAH) REGION

The Brazilian Cerrado (Brazilian savanna) has no more than 60.5% of its original vegetation (Figure 1; Sano et al., 2008). This Biome comprises several distinct landscape areas constituted by different phytophysionomies associated to physical and physiographical factors (Cochrane et al., 1985). It has one of the biodiversity hotspots of the world (Machado et al., 2008; Mendonça et al., 2008) although this Biome is severely threatened (Myers et al., 2000) and some studies still little explored like shrub-tree growth (Paulilo & Felipe, 1998). This is a rather dangerous situation once that the Cerrado biodiversity is directly connected to its water resources which are very important to the other Brazilian watersheds (Lima & Silva, 2008).

Agriculture has expanded rapidly in the Cerrado Biome since 1960's mainly because its natural resources were highly advantageous (Klink & Alho, 1995; Reatto & Martins, 2005). In spite of the actual huge occupation, Cerrado Biome is likely to get worse, with agriculture activities may reach 75% of the whole region (Machado et al., 2008).

The Cerrado Biome comprises many distinctive phytophysionomies which at the present time are frequently gathered in three major groups as savanna, field, and forest vegetation structures (Ribeiro & Walter, 2008). The main common phytophysionomies in the savanna vegetation are Cerrado *stricto sensu* (closed), Parque de Cerrado (open Cerrado park), Palmeiral (palm tree group) and Vereda (palms and grass form plants related to water springs). Field vegetation structure has its more common phytophysionomies as Campo sujo (dirty field = scattered shrubs in a dense grassland), Campo limpo (clean field = grassland) and Campo Rupestre (rocky field = Trees associated to grassy plants on rocky areas above 1500 m sea level). Finally, Forest vegetation structure comprises of Mata de Galeria (gallery forest = associated to narrow rivers covering them completely), Mata Ciliar (riparian forest), Mata Seca (dry forest = not associated with water) and Cerradão (the augmentative of Cerrado). It is rather important to point out that the term Cerrado has the two following meanings, (a) Brazilian savanna vegetation in its generic sense, and (b) one particular form of this vegetation, i.e., the Cerrado *strito sensu* as mentioned before (Ratter et al., 1988; Ribeiro & Walter, 2008).

DATA COLLECTION

Species catalogued from scientific literature were classified as native to Cerrado following a compilation (Mendonça et al., 2008). According to these authors, there are 11.430 species in 195 families belonging to Cerrado's phanerogamic flora. Within these species were found allelopathic studies on 70 species in 34 families. The highest amount of allelopathic studies was found in the following

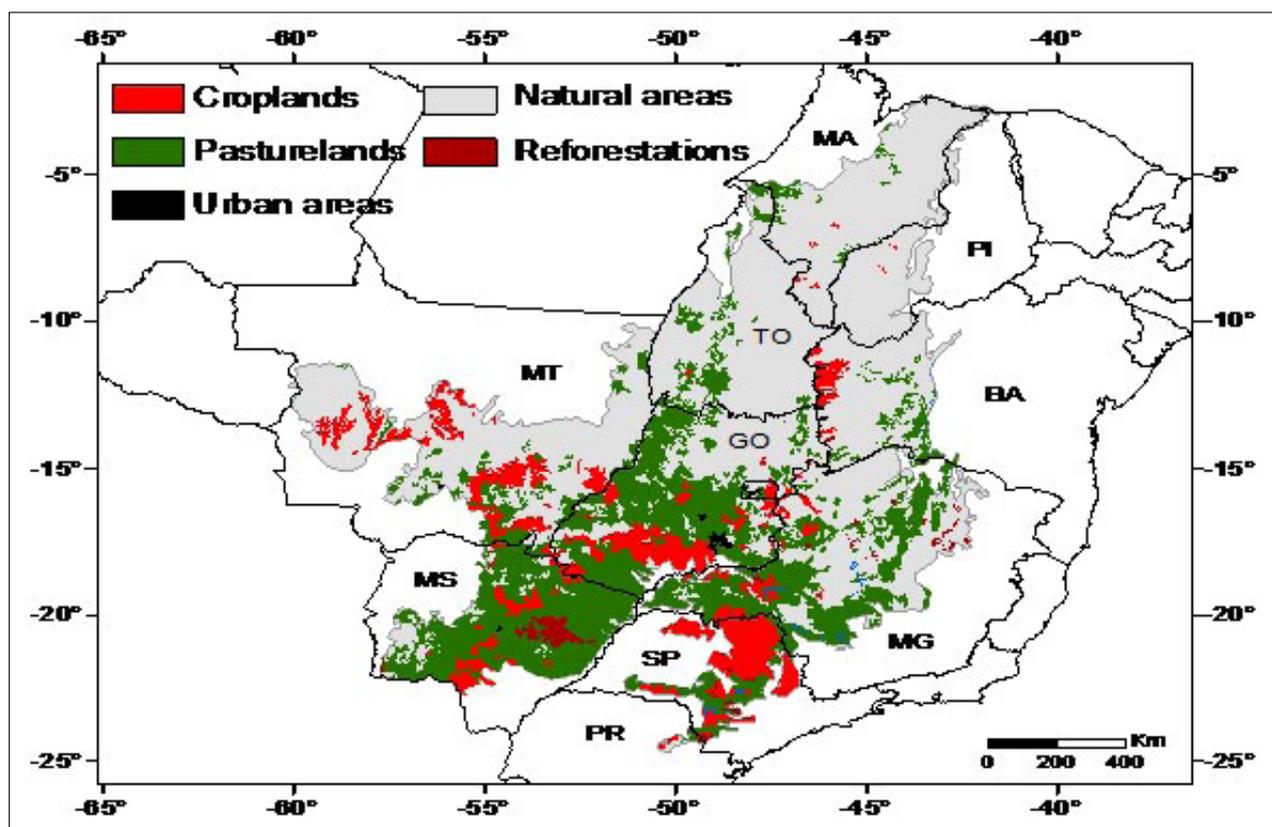


Figure 1. Location of the Cerrado biome in Brazil, and spatial distribution of land use classes in Cerrado Biome in 2002 (Sano et al., 2008). States: BA = Bahia; GO = Goiás; MA = Maranhão; MT = Mato Grosso; MS = Mato Grosso do Sul; MG = Minas Gerais; PR = Paraná; PI = Piauí; SP = São Paulo; and TO = Tocantins.

families: Leguminosae, Asteraceae, Orchidaceae, Poaceae, Melastomataceae, Eriocaulaceae, Rubiaceae, Euphorbiaceae, Myrtaceae, and Lamiaceae. Families such as Leguminosae, Asteraceae,

Poaceae, Rubiaceae and Euphorbiaceae were the most studied and presented the highest number of species with positive (Table 1), and negative (Table 2) results regarding to allelochemical effects.

Table 1. Species native to Cerrado biome classified within families with allelochemical activity.

FAMILY (Subclass, Order) / SPECIE	Growth Habitat	Phytophysiognomy ¹	Studied Organ	Reference
ANACARDIACEAE (ROSIDAE, Sapindales)				
<i>Anacardium humile</i> Mart.	Shrub	a ^{##} , b, d and e ^{##}	Leaves and stem	Periotto (2003)
<i>Myracrodruon urundeuva</i> Allem.	Tree	a [#] , b, f and g	Leaves, flowers, and fruits	Oliveira et al. (2002b)
APOCYNACEAE (ASTERIDAE, Gentianales)				
<i>Himatanthus phagedaenicus</i> (Mart.) Woodson	Tree	a [#] , e [#] and j	Leaves	Veloso (1996)
AQUIFOLIACEAE (ROSIDAE, Celastrales)				
<i>Ilex paraguariensis</i> A. St.-Hil.	Tree or small tree	b, f, and g ^{**}	Leaves, and fruits	Açúila (2000), Miró et al. (1998)
<i>Aristolochia esperanzae</i> Kuntze	Shrubby vine	a ^{##} , d, f and k	Leaves, stem, and roots	Gatti (2003; 2004)
ASTERACEAE (COMPOSITAE) (ASTERIDAE, Asterales)				
<i>Achyrocline satureioides</i> DC.	Perennial herb	a [#] , c, d, e [#] , j ^s , m and n	Leaves, and inflorescence	Souza et al. (2005a)

FAMILY (Subclass, Order) / SPECIE	Growth Habitat	Phytophysiognomy¹	Studied Organ	Reference
<i>Baccharis dracunculifolia</i> DC.	Erect shrub	a [#] , e [#] , j, n and o	Leaves	Gatti (2003); Verdi et al. (2005)
<i>Baccharis trimera</i> (Less.) DC.	Erect subshrub	b ^{##} , e [#] , g, j ^s , n and o	Leaves	Claudino & Carvalho (2004); Cruz et al. (2000); Torres et al. (2000); Verdi et al. (2005)
<i>Eupatorium maximiliani</i> Schrad. ex DC.	subshrub	a ^{##} , b, c, e [#] and o	Leaves	Corrêa et al. (2000)
<i>Mikania glomerata</i> Spreng.	Vine	j	Leaves, and inflorescence	Souza et al. (2005a)
<i>Vernonanthura phosphorica</i> (Vell.) H. Rob.	Shrub or subshrub	a ^{##} , d, f, g, j, n and o	Shoot, roots, and seeds	Souza Filho et al. (1996)
BIGNONIACEAE (ASTERIDAE, Scrophulariales)				
<i>Anemopaegma arvense</i> (Vell.) Stellfeld ex de Souza	Subshrub	a, d and e ^{##}	Leaves	Gatti (2003)
<i>Memora peregrina</i> (Miers) Sandwith	Subshrub	a ^{##} , b	Leaves, bark, and wood	Gatti (2003); Grassi et al. (2005)
CARYOCARACEAE (DILLENIIDAE, Theales)				
<i>Caryocar brasiliense</i> St. Hil.	Tree	a ^{##} , b, d, h and i	Seeds, and fruit parts (pulp, thorn and endocarp)	Melo & Gonçalves (2001); Rodrigues et al. (2006a, b)
CECROPIACEAE (HAMAMELIDAE, Urticales)				
<i>Cecropia pachystachya</i> Trécul	Tree	a [#] , f, g, j, n and p	Mature leaves	Maraschin- Silva & Aqüila (2006b)
CELASTRACEAE (ROSIDAE, Celastrales)				
<i>Maytenus ilicifolia</i> Mart. ex Reissek	Tree or shrub	a [#] , f and g [*]	Dry leaves	Souza et al. (2005b)
EUPHORBIACEAE (ROSIDAE, Euphorbiales)				
<i>Sapium glandulatum</i> (Vell.) Pax	Subshrub, shrub or tree	a ^{##} , c, d, e [#] , f, g, j, and n	Mature leaves	Maraschin- Silva & Aqüila (2006b)
FLACOURTIACEAE (DILLENIIDAE, Violales)				
<i>Casearia sylvestris</i> Sw.	Shrub or small tree	a ^{##} , b, d, h, j ^s and p	Leaves	Gatti (2003); Souza et al. (2005a)
GLEICHENIACEAE				
<i>Gleichenia pectinata</i> (Willd.) Pr.	Subshrub	a [#] , j and o	Green leaves	Peres et al. (1998); Soares & Vieira (2000)
<i>Dicranopteris flexuosa</i> (Schrad.) Underw.	Terrestrial herb	a [#] , j, m and p	Leaves	Soares & Vieira (2000)
<i>Sticherus bifidus</i> (Willd.) Ching	Subshrub	a [#] and o	Leaves	Soares & Vieira (2000)

FAMILY (Subclass, Order) / SPECIE	Growth Habitat	Phytophysiognomy¹	Studied Organ	Reference
<i>Sticherus penniger</i> (Mart.) Copel.	Subshrub terrestrial	e [#] , j and v ^s	Leaves	Soares & Vieira (2000)
HIPPOCRATEACEAE (ROSIDAE, Celastrales)				
<i>Peritassa campestris</i> (Cambess.) A. C. Sm.	Shrub	a ^{##} , c and f	Leaves, and roots	Gatti (2003); Lião et al. (2002)
LAURACEAE (MAGNOLIIDAE, Laurales)				
<i>Ocotea odorifera</i> (Vell.) Rohwer	Tree	j	Leaves	Gatti (2003); Souza et al. (2005a)
LEGUMINOSAE (ROSIDAE, Fabales)				
<i>Amburana cearensis</i> (Fr. Allem.) A. C. Sm.	Tree	g* and o	Seeds	Mano (2006)
<i>Anadenanthera peregrina</i> (L.) Speg.	Tree	a [#] , f, g, j and p	Leaves	Abreu, 1997); Silva et al. (2006)
<i>Andira humilis</i> Mart. ex Benth.	Shrub	a ^{##} , c, d and i	Leaves, and stem	Periotto (2003; 2004)
<i>Caesalpinia pluviosa</i> DC.	Tree or small tree	b and g	Leaves	Soares et al. (2002)
<i>Clitoria fairchildiana</i> R. A. Howard	Tree	a [#] and o	Leaves	Soares & Vieira (2000)
<i>Copaifera langsdorffii</i> Desf.	Tree	a [#] , b, f and j	Soil around the trunk	Dorneles et al. (2003)
<i>Dipteryx alata</i> Vog.	Tree	a ^{##} , b, g ^{**} , j and o	Leaves, and fruits	Silva et al (1996)
<i>Erythrina speciosa</i> Andrews	Tree	g and o	Leaves	(Faria et al. (2007); Soares et al. (2002)
<i>Hymenaea stigonocarpa</i> Mart. ex Hayne	Tree	a ^{##} and b	Bark, leaves, and fruits	Oliveira et al. (2002a)
<i>Mimosa bimucronata</i> (DC.) Kuntze var. Bimucronata	Tree or small tree	a [#] and j	Leaves	Astarita et al., 1996
<i>Mimosa caesalpiniaefolia</i> Benth.	Tree	a [#]	Green and dry leaves	Piña-Rodrigues & Lopes (2001)
<i>Piptadenia gonoacantha</i> (Mart.) J. F. Macbr.	Tree	g* and j	Leaves	Soares et al. (2002)
<i>Stryphnodendron adstringens</i> (Mart.) Coville	Tree	a ^{##} and b	Leaves	Barreiro et al., 2005); Silva et al. (2006)
MELASTOMATAACEAE (ROSIDAE, Myrtales)				
<i>Miconia albicans</i> (Sw.) Triana	Small tree	a ^{##} , b, d, i, j, n and p	Leaves	Gorla & Perez (1997)
MORACEAE (HAMAMELIDAE, Urticales)				
<i>Sorocea bonplandii</i> (Baill.) W.C.Burger, Lanj. & Boer	Small tree	f and j	Mature leaves	Maraschin-Silva & Aquila (2006b)
MYRISTICACEAE (MAGNOLIIDAE, Magnoliales)				
<i>Virola surinamensis</i> Warb.	Tree	a [#] and j	Leaves	Borges et al., 2007
MYRSINACEAE (DILLENIIDAE, Primulales)				

FAMILY (Subclass, Order) / SPECIE	Growth Habitat	Phytophysiognomy¹	Studied Organ	Reference
<i>Myrsine guianensis</i> (Aubl.) Kuntze	Tree	a [#] , e [#] , f, g, h, j, n and p	Mature leaves	Maraschin-Silva & Aqüila, (2005; 2006a); Silva et al. (2006)
MYRTACEAE (ROSIDAE, Myrtales)				
<i>Myrcia guianensis</i> (Aubl.) DC.	Shrub	a ^{##} , d, e [#] , f, g, j and n	Fresh leaves, essential oil	Souza Filho et al. (2006)
OCHNACEAE (DILLENIIDAE, Theales)				
<i>Ouratea spectabilis</i> Engl.	Tree	a ^{##} , b, h and i	Leaves	Silva et al. (2006)
PTERIDACEAE				
<i>Adiantopsis radiata</i> (L.) Fée	Terrestrial herb or rupicola	f, j and q	Green leaves	Peres et al. (2004)
<i>Adiantum serratodentatum</i> Willd.	Terrestrial herb	j, a [#] and n	Green leaves	Peres et al. (2004)
<i>Adiantum tetraphyllum</i> Humb. & Bonpl. ex Willd.	Terrestrial herb	j	Green leaves	Peres et al. (2004)
<i>Pityrogramma calomelanos</i> (L.) Link	Terrestrial herb	a [#] , b, j, n, m, u and v	Green leaves	Peres et al. (2004)
RUBIACEAE (ASTERIDAE, Rubiales)				
<i>Palicourea rigida</i> H. B. & K.	Small tree or Shrub	a ^{##} , c, d, e ^{##} , h, i, j, n and p	Leaves	Gatti (2003)
<i>Psychotria leiocarpa</i> Cham. & Schlttdl.	Shrub or subshrub	f, j and m	Dry leaves	Maraschin-Silva & Aqüila (2006b)
SAPINDACEAE (ROSIDAE, Sapindales)				
<i>Dodonaea viscosa</i> Jacq.	Small tree	e [#]	Leaves	(Maraschin-Silva & Aqüila, (2005)
SAPOTACEAE (DILLENIIDAE, Ebenales)				
<i>Pouteria ramiflora</i> Radlk.	Tree	a ^{##} , b, j, i, n and p	Leaves	Silva et al. (2006)
SOLANACEAE (ASTERIDAE, Solanales)				
<i>Solanum crinitum</i> Lam..	Shrub	a ^{##} , e [#] and j ^s	Green leaves, thorns	(Alves et al. (2003); Cornelius et al. (2004); Silva et al. (2003)
<i>Solanum lycocarpum</i> A. St.-Hil.	Small tree or Shrub	a ^{##} , d, n and o	Leaves and fruits	Aires et al., 2005); Borghetti & Pessoa (1997); Jerônimo (2006); Mola et al. (1997); Oliveira et al. (2004a, b)
TILIACEAE (DILLENIIDAE, Malvales)				

FAMILY (Subclass, Order) / SPECIE	Growth Habitat	Phytophysiognomy ¹	Studied Organ	Reference
<i>Luehea divaricata</i> Mart.	Tree	a [#] , b, f, g and j	Leaves, inflorescence	(Maraschin-Silva & Aquila, (2006a); Souza et al. (2005a))
WINTERACEAE (MAGNOLIIDAE, Magnoliales)				
<i>Drimys brasiliensis</i> Miers	Tree	e [#] , j and n	Leaves	Gatti (2003)
<i>Drimys winteri</i> Forst.	Tree	f and g	Leaves	Gorla & Perez (1997)
VERBENACEAE (ASTERIDAE, Lamiales)				
<i>Lantana camara</i> L.	Subshrub	j	Leaves	Cruz et al. (2000); Gorla & Perez (1997)
<i>Lippia alba</i> N. E. Br. ex Britton & P. Wilson	Shrub	a	Leaves, inflorescence	Cruz et al. (2000); Souza et al. (2005a)
<i>Lippia sidoides</i> Cham.	Subshrub	a ^{##} , f, k ^s	Mature leaves – essential oil	Alves et al., 2004
VOCHYSIACEAE (ROSIDAE, Polygalales)				
<i>Qualea grandiflora</i> Mart.	Tree	a ^{##} , b, d, f, h, i, j ^s and p	Leaves	Silva et al. (2006)

¹ Phytophysiognomy: a = Cerrado; b = Cerradão (the augmentative of cerrado); c = Clean field; d = Dirty field; e = Rocky field; f = Riparian forest; g = Dry forest; h = Murundu field; i = Carrasco; j = Gallery forest; k = River bank; m = Swamp; n = Vereda (palms and grass form plants related to water springs); o = Anthropic área; p = Amazonic savanna; q = Babassu; u = Natural revegetated area; v = Stream. | ^s = border. | * deciduous; **semi-deciduous. | #lato sensu; ## stricto sensu (closed).

Table 2. Species native to Cerrado classified within families without allelochemical activity.

FAMILY (Subclass, Order) / SPECIES	Growth Habit ¹	Phytophysiognomy ¹
APOCYNACEAE (ASTERIDAE, Gentianales)		
<i>Aspidosperma tomentosum</i> Mart.	Tree	a ^{##} , b and g
ARALIACEAE (ROSIDAE, Apiales)		
<i>Didymopanax vinosum</i> Marchal	Tree	e
CLUSIACEAE / GUTTIFERAE (DILLENIIDAE, Theales)		
<i>Kielmeyera variabilis</i> Mart. & Zucc.	Tree	a [#] , b and j
LEGUMINOSAE (ROSIDAE, Fabales)		
<i>Anadenanthera falcata</i> Speg.	Tree	a [#] , b, g* and j
<i>Machaerium villosum</i> Vog.	Tree	a [#] , b and j
<i>Acosmium subelegans</i> (Mohlenbr.) Yakovlev	Tree	a [#] and j
MALPIGHIACEAE (ROSIDAE, Polygalales)		
<i>Byrsonima coccolobifolia</i> H.B. & K.	Tree	a ^{##} , b, d, h, j ^s and p
<i>Byrsonima verbascifolia</i> Rich. ex Juss.	Tree	a ^{##} , d, e [#] , h, j and p
STYRACACEAE (DILLENIIDAE, Ebenales)		
<i>Styrax ferrugineus</i> Nees & Mart.	Tree or small tree	a ^{##} , b, h, j ^s and n
VOCHYSIACEAE (ROSIDAE, Polygalales)		
<i>Vochysia tucanorum</i> Mart.	Tree	a [#] , f, j and n

¹ data extracted from Silva et al. (2006); The studied organ for this table were leaves;

² Phytophysiognomy: a = Cerrado; b = Cerradão (the augmentative of cerrado); c = Clean field; d = Dirty field; e = Rocky field; f = Riparian forest; g = Dry forest; h = Murundu field; i = Carrasco; j = Gallery forest; k = River bank; m = Swamp; n = Vereda (palms and grass form plants related to water springs); o = Anthropic área; p = Amazonic savanna; q = Babassu; u = Natural revegetated area; v = Stream. | ^s = border. | * deciduous; **semi-deciduous. | #lato sensu; ## stricto sensu (closed)

RESULTS AND DISCUSSION

Allelochemicals

Brazilian researchers found several allelochemicals using plants native to Cerrado, however these substances were not, as a whole, synthesized and tested for weed control. According to this, we pointed out data related to the new substances detected.

Some alkaloids, extracted successively with hexane and ethanol, were found in leaves and flowers of *Erythrina speciosa* (Figure 2). In vitro bioassays with leaf extracts of *E. speciosa* showed promising activity against *Trypanosoma cruzi*. The substances were not tested biologically (Faria et al., 2007).

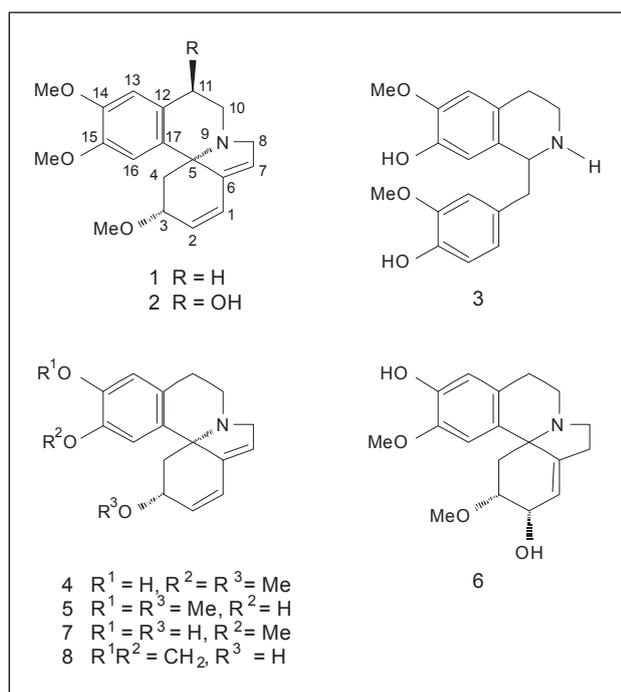


Figure 2. Alkaloids in leaves and flowers of *Erythrina speciosa* Andrews – 1: erysothrine; 2: erythartine; 3: erythraline; 4: erysodine; 5: erysovine; 6: erysotine; 7: erysonine; 8: erythrocarine (Faria et al., 2007).

Ouratea spectabilis, *Pouteria ramiflora*, *Qualea grandiflora* and *Stryphnodendron adstringens* collected in the Cerrado Reserve in Mogi Guaçu, State of São Paulo, Brazil, showed inhibitory effects. As *S. adstringens* presented the greatest inhibitory effect, leaf extracts of this species were fractionated by liquid-liquid partition with use of different polarity solvents (hexane, chloroform, ethyl acetate, and n-butanol). Fractions were submitted to lettuce (*Lactuca sativa* L), maize (*Zea mays* L.), bean (*Phaseolus vulgaris* L), and beggar-ticks (*Bidens pilosa* L.) germination bioassays. Terpenoids, not detailed in the study, were found in chloroform and ethyl acetate fractions. (Silva et al., 2006).

In *Eupatorium maximiliani* Schrad. Ex DC. chloroform:methanol 2:1 extracts were applied to rice (*Oryza sativa* L. Cv. Caiapo, maize (*Zea mays*

L. Cv. AG302A), beans (*P. vulgaris* Cv. Cariquinha) and-lettuce (*Lactuca sativa* Cv. Grand rapids) and two weed species [pigweed (*Amaranthus* spp) and hairy beggarticks (*Bidens pilosa* L.)]. The extract significantly reduced seed germination of lettuce, pigweed and hairy beggarticks, radicle elongation and shoot growth in lettuce, beans and rice and had no effect on maize. It was found, after a thin-layer chromatography analysis, through infra-red spectroscopy and Nuclear Magnetic Resonance (NMR ¹H, and ¹³C), the following compounds: 5,6,7,3',4',5'-hexamethoxyflavone, and 5,6,7,3',4',5'-hexamethoxyflavanone. (Corrêa et al., 2000).

Ferreira et al. (1992) showed allelopathic activity of *Baccharis trimera* (Less.) DC. was measured in terms of inhibition of germination and radical growth of two varieties of *Lactuca sativa*. Later, from a compilation of the genus *Baccharis* (Verdi et al., 2005) it has been shown, in methanolic leaf extracts of *Baccharis trimera*, a Cerrado species (Tannus & Assis, 2004), three clerodane diterpenoids (Figure 3), and ten flavonoids identified. Among these flavonoids four were identified: 5,4'-dihydroxy-7-methoxyflavone (genkwanine) [1], 5,4'-dihydroxy-6,7-dimethoxyflavone (cirsimaritin) [2], 5,7,4'-trihydroxy-6-methoxyflavone (hispiduline) [3], and 5,7,4'-trihydroxyflavone (apigenine) [4]. In *Baccharis trimera* ethyl acetate leaf extracts, other three flavonoids were isolated: 3,5,7,3',4'-pentahydroxyflavone (quercetin) [5], 5,7,3',4'-tetrahydroxyflavone (luteolin) [6], and 5,7,3',4'-tetrahydroxy-6-methoxyflavone (nepetin) [7]. Here these compounds were not tested in plants, but, clerodane and flavonoids are known allelochemicals (Bisio et al., 2011; Rice, 1987).

The same compilation above showed also, in *Baccharis dracunculifolia* leaf extracts, two flavo-

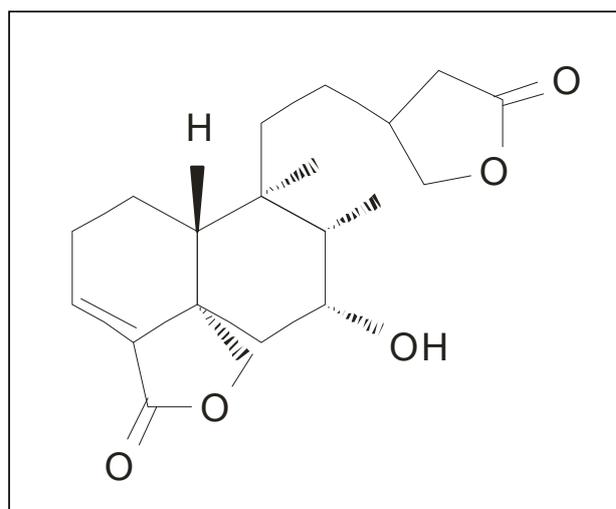


Figure 3. Clerodane diterpene in [*Baccharis trimera* (Less.) A. DC.] (Torres et al., 2000).

nes [8-OH flavone; 3,5,7-OH-6,4'-OMe flavone (betuletol)], a flavanone, and a triterpene isolated

from, another weedy species from Cerrado Biome.

From roots of *Peritassa campestris* (Cambess.) A. C. Sm., collected in São Carlos, State of São Paulo – Brazil (Figure 1), methanolic extracts were isolated two triterpenoids, campestrine-I and -II (Figure 4). (Lião et al., 2002). Many different natural quinones from plants inhibit PSII (Duke & Dahan, 2006).

Chromatographic studies from thorns, shoots and fruits of *Solanum crinitum* isolated the fol-

lowing flavonoids: tiriloside [3-O-(6"-trans-cinamoil-glycopyranosyl)], astragaline (3-O-β-D-glycopyranosyl), and kaenpherol (Figure 5). Alkaloids were extracted with a sephadex column and, from green fruit extracts, solasonine was isolated. Isolated substances were, then, analyzed by infra-red spectroscopy, NMR ¹H, and ¹³C (Cornelius et al., 2004).

Several compounds (alantoine, 6β-hidroxy polyamide, hiperine, 3'-O-methyl-hiperine, 4-hidroxy-N-

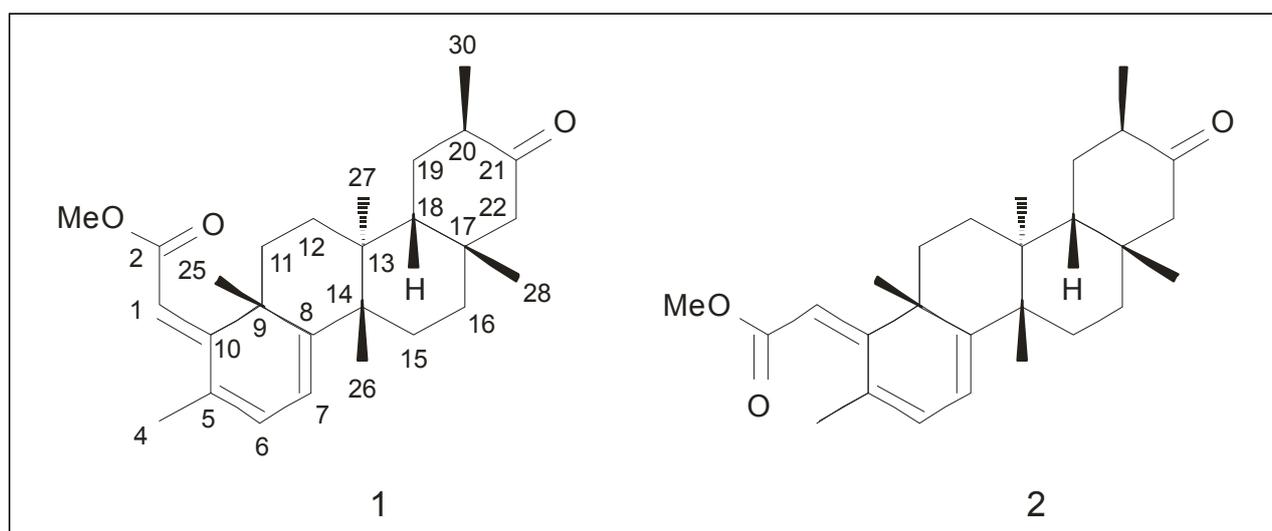


Figure 4. Isolated terpenoids in *Peritassa campestris* (Cambess.) A. C. Sm methanolic extracts: 1) campestrine-I and 2) campestrine-II (Lião et al., 2002).

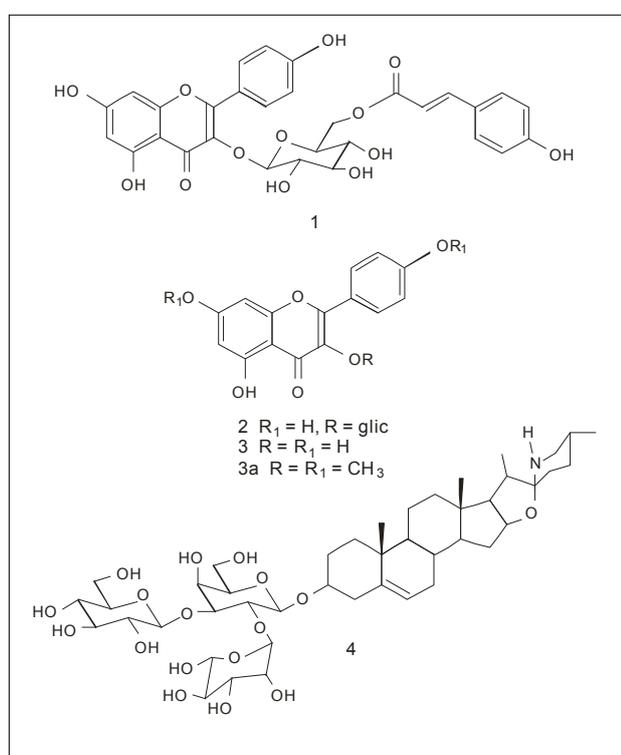


Figure 5. Structure of isolated components of *Solanum crinitum* Lam.: 1) tiriloside; 2) astragaline; 3) kaenpherol; 3a) metilation with diazomethane, and 4) solasonine (Cornelius et al., 2004).

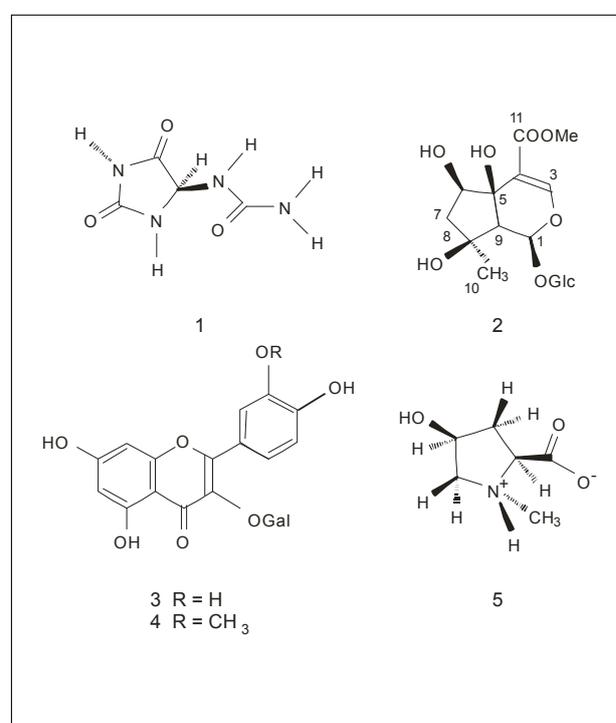


Figure 6. Isolated compounds of *Memora peregrina* (Miers) Sandwith: 1) alantoine; 2) 6β-hidroxy polyamide; 3) hiperine; 4) 3'-O-methyl-hiperine; 5) 4-hidroxy-N-methylproline (Grassi et al., 2005).

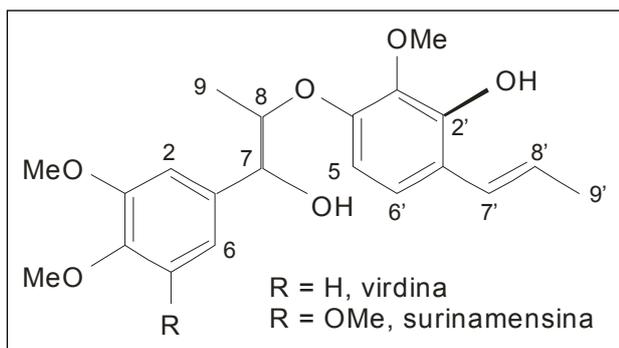


Figure 7. Isolated chemical substances structures from leaves of *Virola surinamensis* Warb. (Borges et al., 2007).

-methylproline, α -amirine, β -amirine e lupeol, Figure 6) from the leaves, and subterranean parts of *Mimosa peregrina*, such as bark and wood were identified. The allelochemical effects of these substances induced lettuce seed germination, and produced a moderated activity in *Anagasta kuehniella* (Lepidoptera) larvae development. (Grassi et al., 2005).

Chemical substances obtained from *Virola surinamensis* extracts were isolated and identified. The process involved use of organic solvents and NMR (^1H , ^{13}C and ^{13}C -DEPT), COSY and HETCOR spectrum in order to identify two neolignane compounds: surinamensina and avirolina (Figure 7). In spite of this plant have been collected from the Rainforest, *V. surinamensis* is a tree also found in Cerrado biome (Mendonça et al., 2008). Three weed species were used to test *V. surinamensis* allelochemicals: *Mimosa pudica* L., *Senna obtusifolia* (L.) H. S. Irwin & Barneby, and *Senna occidentalis* (L.) Link. This study represented a further step in relation to the allelopathic studies with Cerrado plants. Surinamensina and virolina were isolated, and tested. Surinamensina presented higher potential in the inhibition of seed germination, and radicle and hypocotyl development than virolina. (Borges et al., 2007)

FUTURE RESEARCH PERSPECTIVES

Most of the results obtained in allelopathic studies cannot be explained in terms of a single disciplinary approach. The present review gathered information about allelopathy studies performed with 71 species native to Cerrado. Leaves were more studied than any other plant parts. More attention is necessary to study root leachates. According to the related allelopathic studies it was possible to detect some compounds like alkaloids, terpenoids, phenolic compounds and others. Most of these results were reached on seed germination studies in laboratory, though isolated from the environmental conditions. This situation was part of the process related to the establishment of Cerrado plants. Studies were rather superficial, small in number, and scattered in the literature. Besides this critical situation, there were no attempts for establishing connections among the results reached. In 1992,

Ferreira et al. had pointed in their review many results and inconsistencies on allelopathy research. This situation has not changed until nowadays. We hope that the present survey can contribute to more detailed and applied studies with Cerrado species. The main targets to be reached are the following: a) to promote more sophisticated studies with unknown and better known plants; b) to identify other compounds and their own metabolism; c) to synthesize those new compounds; d) to study the mode of action of the synthesized compounds; e) to test those compounds in agriculture conditions; f) to investigate the compound effects in the establishment strategies of Cerrado plants and for agricultural proposals too.

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