August 30, 2019

PharmacologyOnLine

Archives • 2019 • vol.2 • 355-373

FABACEAE FAMILY FROM DRY FOREST IN COLOMBIA: POTENTIAL BIOTECHNOLOGICAL USE AS A SOURCE OF BIOCIDES AND ANTIOXIDANT COMPOUNDS.

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Abstract

The feasibility of bioprospecting is related to the great diversity that exists in regions such as those found in the tropics; only in Colombia has more than 50,000 species been recorded, in the place of which approximately 30,000 are plants, being exclusive for Colombia 1,500. Many studies in the world can find approximately 80,000 species of plants for the knowledge of the local communities, it is known that it can have a medical utility or another wide variety of uses, and that only 5,000 of them have been investigated, so it is necessary to carry out studies that contribute to the intellectual knowledge of the biochemical and biotechnological properties of the national biological resources; in this way generating contribution to the solution of problems in the biosystems. Plants of the family Fabaceae offer a valuable source of molecules that could be used in agricultural, agroindustry, pharmacology, medicine and other sectors. This review offers valuable information about studies regarding biotechnological applications derived from theirs compounds.

Keywords: *Antioxidants, Biocides, Bioprospecting, Dry Forest, Fabaceae*

Introduction

The floral composition of Colombian dry forest reflects that described by Gentry (1995) (1), that the Fabaceae, Bignoniaceae, and Rubiaceae families are the most diverse representatives therein. In the case of the Fabaceae family, 61 species from 37 different genera have been reported in protected areas of the Caribbean region, belonging to Atlántico and Bolívar departments (2). Many representative BST species have been assigned a certain threat status. This is the case of Hymenaea courbaril (Courbaril), a plant from the Fabaceae family that has near threatened status, owing to its importance for the logging industry. Within this family, there are also many species known for their cultural importance. This knowledge may be employed in diverse biotechnological areas, and similarly to contribute to existing local biodiversity genetic resource conservation efforts. This family presents specific characteristics, which permit its optimal growth in these regions, due to its high resistance to water stress (3), which is one of the most representative characteristics of this type of forest (4, 5, 6, 2). Plants that grow in these environments respond to drought differently, and all are regulated on the cellular and molecular level. Many genes are either expressed or repressed, in accordance with environmental variables such as this. Products obtained by the induction performed, as a result of water stress, emphasize different types of proteins, sugars, and even secondary metabolites (7). These may present differentially in species, as they depend upon evolutionary history, but even organisms of the same species may present variations, as secondary metabolism is linked to environmental alterations (8).

The active compounds that may be obtained from these plants present a wide range of potential uses, applicable to areas including pharmacology, the food industry, health sector, and agriculture, among others. The potential uses of the extracts and isolated compounds obtained from different species of the Fabaceae family, and even from different organisms or structures within the same species have been widely documented, as this is among the most diverse families in the tropical region. For this reason, the potential use of Fabaceae family species must be highlighted.

Methods

The Fabaceae family flora reported in the Atlántico and Bolívar departments is listed alphabetically, in accordance with their scientific names, information regarding common names, and cultural use. The report for this area of Colombia was extracted from said list of vascular plants, as constructed by Rodríguez and collaborators, and published in 2012 (2). This information was classified into five categories: scientific name verified at ITIS.gov, growth type, common name of plants in the Atlántico and Bolívar departments, cultural use, and biotechnological applications. Information regarding the latter category was sought by means of taxonomic criteria, grouping the information represented in the previous review of the family or genera. Key words used in the electronic bibliographic search for this review included: the scientific name and its synonym(s), medical uses, chemical studies, pharmacological activity, and natural products. For those species lacking said information, the search was broadened to include the genera, and species were grouped in accordance with this information. An absence of electronic bibliographic data was indicated with 'Not reported'.

Results and Discussion

Exactly 62 species have been reported, including five species from the Senna genus, four from Acacia, three from Erythrina, Lonchocarpus, Machaerium, and Mimosa, and Pithecellobium. These represent the most diverse genera of vascular flora present in the Atlántico and Bolívar departments. The species with the most information for biotechnological uses is Pithecellobium dulce, as shown in Table 1. It is commonly known as Chilacoa or Payandé, and is considered to be a source of antioxidants and proteins with protease.

Despite continuous efforts, the growing trend of pathogenic microorganism resistance to common antibiotics has become one of the most important concerns of modern biotechnology. Similarly, the search for compounds which may be used for disease control, principally those related to tumor formation, require significant investment, not only economically, but also in research and development. For this reason, the search for new management and control alternatives has renewed the importance of plants as alternatives to existing treatment strategies.

This review aims to highlight the relevance of the Fabaceae family, which contains countless compounds with different properties, and which may be used in diverse forms. Certain compounds have already been isolated and used as commercial antibiotics (26), however it is clear that the characteristics of many of the chemical components of these plants have yet to be explored, as is the case of tannins (13), flavonoids, alkaloids, terpenes, steroids (77), saponins, and glycosides (97) (Figure 1).

Cytotoxic and antiplasmoidial properties have been attributed to many of these compounds, as is the case of flavonoids isolated from the stem of *E. fusca* (39), or chalcones obtained from the roots of Lonchocarpus sericeus (48), to which antibacterial properties against S. aureus, (49) have also been attributed. Other isolated flavonoids from the same species have been attributed a biocidal effect against Fusarium oxysporum, Rhizopus oryzae, and Artemia salina (50). This permits exploration into the potential uses of these components as pest controllers of economic importance. This has been the case of F. oxysporum and other phytopathogens, which have proteins that may be valuable. These come from V. caracalla flowers, are used as insecticides (104), and act as α-amylase inhibitors (105). *P. dulce* possesses proteins that have been reported to have potential as protease inhibitors (70), as have plants in the Bauhinia genus. The use of existing information, regarding the properties and potential uses of plants in this family, goes hand in hand with biotechnological advances, which are focused on the development of strategies for the selection, search, elucidation, separation, and even synthesis of compounds, which may be harnessed in different areas. Among these strategies are proteinic and genomic techniques.

Conclusions

Chemical property information regarding the Fabaceae family, despite being quite broad, paves the way for the development of new, useful strategies in areas such as medicine, pharmacology, the cosmetics industry, and even different areas of the agricultural industry, such as pest control. Many known species in the Fabaceae family are considered pests, owing to their allelopathic characteristics, for which reason the use of these plants as a source of compounds of biotechnological interest may contribute to their control. Similarly, knowledge of their properties, and the way in which their genetic characteristics are linked may be useful in conservation and biodiversity efforts, as well as the consolidation of bioeconomic models beneficial for the development of those countries in which biodiversity has become a valuable opportunity, through sustainable development processes.

Acknowledgments

We thank to Universidad de Manizales and Centro Nacional de Bioinformática y Biología Computacional de Colombia – BIOS for the support received.

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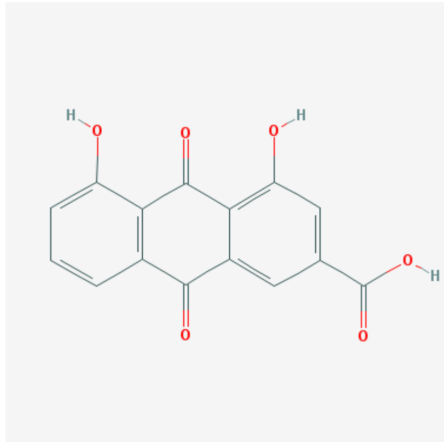

Figure 1. Rhein, 4,5-Dihydroxyanthraquinone-2 carboxylic acid, a compound isolated from *Cassia reticulata*, used generally as an antibiotic together with oxacillin or ampicillin, thanks to their important synergy (Image from PubChem).

Table 1. Summary of the biotechnological potential reported for plants in the Fabaceae family present in the dry forest of the Atlántico and Bolívar departments.

Scientific name	Type	Common name	Uses	Biotechnological applications
***Abrus precatorius* L.**	Liana	Ojito de santa Lucía	Magic, religious applications	Various plant structures present antioxidant activity (9, 10). Antimicrobial properties against *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Candida albicans* have been highlighted (11, 12).
***Acacia collinsii* Saff.**	Tree	Cachito, hombre solo,	No reports	The presence of tannins has been reported (Readel, Seigler, Hwang, Keesy, & Seilheimer, 2001).
***Acacia dealbata* Link.**	Liana	Zarza blanca	The gum in the trunk is consumed by cotton-top tamarins (*S. oedipus*)	The foliar biomass of this plant is considered an alternative for the development of microbial control substances (Silva, Fernandes, Bacelar, & Sampaio, 2016).
***Acacia farnesiana* (L.) Willd**	Tree	Aromo	Logging	These have shown potential for the control of gram-positive and gram-negative anaerobic bacteria. Stem and root extracts present antioxidant potential (Mueller, Janngeon, Puttipan, Unger, Viernstein, & Okonogi, 2015).

***Acacia macracantha* Willd**	**Tree**	**Aromo**	**Logging**	**Not reported.**
***Aeschynomene fascicularis* Cham. and Schltdl**	Herb			Potentially useful compounds have been isolated for their cytotoxic effect on carcinogenic cells (Caamal-Fuentes , Peraza-Sánchez , Torres-Tapia, & Moo-Puc, 2015).
***Albizia niopoides* (Benth.) Burkart**	Tree	Guacamayo	Logging	Alkaloids present in species of the same genus have shown inhibitory effects on *Fusarium verticillioides* (Thippeswamy, Mohana, Abhishek, & Manjunath, 2014). Extracts with hexane demonstrated inhibitory effects on different bacteria, especially on *Bacillus cereus* (Ali, Azhar, Ahmad, Ahmad, & Usmanghani, 2001).
***Albizia saman* (Jacq.) Merr.**	Tree	Campano	Logging, the gum exuded is consumed by cotton-top tamarins	
***Bauhinia glabra* Jacq**	Liana	Bejuco cadena	Medicinal, for the flu	These present protein components in seeds that may inhibit protease (19). Hydroalcoholic extract from stems presents antioxidant properties (Campos, et al., 2014).
***Bauhinia pauletia* Pers.**	Shrub	Pataevaca		These present protein compounds in seeds with potential for protease inhibition (Janzen, Ryan, Liener , & Pearce, 1986). Reports indicate that plant leaf extracts from this genus present antimicrobial activity against *Bacillus subtilis, Staphylococcus aureus, Salmonella typhi, Escherichia coli, Pseudomonas aeruginosa,* and *Candida albicans* (21, 22).
***Caesalpinia coriaria* (Jacq.) Willd**	Tree	Dividivi	Logging, the fruit is used for dye	Reports indicate the presence of compounds in leaves with antibacterial properties (23, 24).
***Caesalpinia ebano* H.Karst**	Tree	Ebano		There are no reports for the species. However, this genus has been well-documented, owing to its antimicrobial and cytotoxic potential (23, 24, 25).
***Cassia grandis* L.f**	Tree	Cañandonga	Edible and medicinal applications	Antibiotic molecules have been isolated from plants of the same genus (26). Aqueous leaf extract compounds exhibit inhibitory effects toward dermatophyte fungi (27).
***Centrolobium paraense* Tul**	Tree	Colorado, amarillo	Logging	Bioactivity has not been reported. The presence of isoflavonoids has been characterized (28).

***Chloroleucon mangense* (Jacq.) Britton and Rose**	**Tree**	**Viva seca**	**Logging**	**Widely documented in terms of phytochemical components and their antimicrobial properties (29).**
***Cojoba rufescens* (Benth.) Britton and Rose**	Shrub			Not reported.
***Coursetia ferruginea* (Kunth) Lavin**	Tree	Cucuiro		Reports indicate low ethanolic and ether extract activity against *C. albicans* (Tapia Contero & Tapia Contero, 2012).
***Dalbergia brownie* (Jacq.) Urb.**	Liana	Bejuco pende		Reports indicate cytotoxic (31, 32), antioxidant (34), and antifungal (35) properties, among others (36).
***Enterolobium cyclocarpum* (Jacq.) Griseb**	Tree	Orejero	Logging	Not reported.
***Erythrina berteroana* Urb.**	Shrub	Cantagallo		Antifungal properties are present in stem extracts against *Cladosporium cucumerinum* (Maillard, Gupta, & Hostettmann, 1987). Antimicrobial properties present in methanol and acetonic extracts against *E. coli* and *C. albicans* (Cates, et al., 2013).
***Erythrina fusca* Lour**	Tree	Cantagallo		Cytotoxic and antiplasmoidial properties have been attributed to flavonoids isolated from stems (Phongsak , Rukachaisirikul, & Suksamrarn, 2009). Hydroalcoholic stem extracts possess antioxidant properties (Debnath, Kannadasan, Acharjee, Bhattacharjee, Kumar, & Kumar , 2010).
***Erythrina velutina* Willd**	Tree	Arepo		Reports indicate the presence of anxiolytic properties in aqueous extracts, in animal models (41, 42). Ethanolic extracts from shells show antibacterial activity against *S. aureus* and *Streptococcus pyogenes* (Virtuoso, et al., 2005).
***Geoffroea spinosa* Jacq.**	Tree	Puy, silbadero		Antibacterial activity has been reported in aqueous, alcoholic, and hexanic extracts against gram-positive bacteria (dos Santos, Silva , Solidonio , sena , & Albuquerque , 2011).

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***Gliricidia sepium* (Jacq.) Walp**	**Tree**	**Matarratón**	**Living fences, logging**	**Antibacterial activity of ethanol extracts, against *S. aureus*, hemolytic *Straptococci* B, *P. aeruginosa*, and *E. coli* have been reported (Gacusan,, 2007). Flavonoids identified in methanolic extracts from this species have shown antifungal activity against *Colletotrichum acutatum* (Urdaneta, Sanabria , Rodríguez, Ettiene, & Pérez de Camarco, 2014), and aqueous leaf extracts have shown inhibitory effects toward dermatophyte fungi (Caceres, Lopez, Giron, & Logemann, 1991).**
***Hymenaea courbaril* L.**	Tree	Algarrobo		Hydroalcoholic extracts have demonstrated growth inhibition effects on *M. luteus* and various strains of *S. aureus* and *Streptococcus* sp (Fernandes, Pimenta, & Santos, 2005).
***Inga hayesii* Benth**	Tree	Guamito	Cotton-top tamarin food	Not reported.
***Lonchocarpus pictus* Pittier**	Shrub	Majagua de gallina	Logging	Cytotoxic activity reported for chalcones isolated with hexanic root extract (48), to which antimicrobial activity against *S. aureus* and high levels of antioxidant activity is also attributed (Vasconcelos, et al., 2014). Presence of bioactive flavonoids reported to work against *fusarium oxysporum*, *Rhizopus oryzae*, and *Artemia salina* (Magalhães, Tozzi, Magalhães, Sannomiya, Soriano, & Perez, 2007).
***Lonchocarpus violaceus* (Jacq.) DC.**	Shrub	Arepo, arepito	Logging	
***Lonchocarpus* sp.**	Tree	Bollo limpio	Logging	
***Machaerium biovulatum* Micheli**	Tree	Siete cueros		Ethanol extracts isolated from species of this genus show antimicrobial activity against *Propionibacterium acnes*, *Staphylococcus epidermidis,* and *S. aureus* (Díaz, 2011), as well as significant antioxidant activity (52, 53).
***Machaerium capote* Dugand**	Tree	Siete cuertos	Logging	
***Machaerium microphyllum* (E.Mey.) Standl**	Liana	Bejuco frente toro		

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***Mimosa camporum* Benth**	**Herb**	**Atlántico**		**Reports for the genus indicate the presence of bioactivity (54) in methanol extracts, from areal parts, against *C. albicans*, *Shigella boydii*, *P. aureginosa*, *B. subtilis*, and *B. megaterium*, and from roots against *B. cereus*, *B. subtilis*, *B. megaterium*, and *Sarcina lutea*, among others. Significant cytotoxic and antioxidant potential is also reported (55, 56, 57).**
***Mimosa pellita* Willd.**	Shrub	Zarza macho, zarza prieta		
***Mimosa pudica* L**	Herb	Cierrateputa		
***Mucuna mutisiana* (Kunth) DC**	Liana	Ojo de buey	Magic, religious applications	Reports for the genus indicate antimicrobial activity against *S. aureus*, *E. coli* (Kumar, 2009; Patel, Suthar, Shah, Hirpara, Joshi, & Katheria, 2010), *B. subtilis*, *P. aureginosa*, and *P. mirabilis* (60, 61) in *M. urens* seeds, and proteins with antibiotic potential have further been reported (Oliveira, et al., 2007).
***Myrospermum frutescens* Jacq**	Tree	Mano de pilón	Logging	These have been broadly characterized by their potential to control *Trypanosoma cruzi* (Torres Mendoza, Ureña González, Ortega-Barría, Capson, & Cubilla Rios, 2003).
***Myroxylon balsamum* (L.) Harms**	Tree	Bálsamo		Essential oils have been evaluated against *S. aureus* and *P. aureginosa*, showing a mild effect (Kavanaugh & Ribbeck, 2012). Hexanic extracts of their husks have shown larvicidal effects against *Aedes aegypti* (Simas, Lima, Conceicao, Kuster, Oliveira Filho, & Lage, 2004).
***Piptadenia viridiflora* (Kunth) Benth.**	Tree	Baranoa, chicharron	Logging	The effects of flower and stem extracts were evaluated against *S. epidermidis*, showing a mild antimicrobial effect (da Silva Trentin, et al., 2011).
***Piptadenia* sp.**	Liana	Zarza blanca		Plants of the same genus have been evaluated for their antimicrobial potential, attributed to tannins, saponins, and phenolic compounds present in extracts (Bezerra, Rodrigues, da Costa, Pereira, de Sousa, & Rodrigues, 2011).

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Piscidia carthagenensis **Jacq.**	**Tree**	**Arepita**		**Reports for the genus indicate the inhibitory effect of aqueous leaf extracts against various dermatophytes, including *epidermophyton floccosum, Microsporum canis, M. gypseum, Trichophyton mentagrophytes, T. mentagrophytes,* and *T. rubrum* (Caceres, Lopez, Giron, & Logemann, 1991).**
Pithecellobium dulce **(Roxb.) Benth.**	Shrub	Chilacoa		Ethanol extracts from husks have shown significant antimicrobial effects against *Enterobacter aerogenus, K. pneumonia, and C. albicans* (Singh, Khatoon, Singh, Kumar, Rawat, & Mehrotra, 2010). This plant is considered to be a potential source for natural antioxidants. It has been observed that aqueous and methanol seed extracts possess significant antioxidant capacity, as compared to standard compounds (Nagmoti, Khatri, Juvekar, & Juvekar, 2012). Proteins with potential as protease inhibitors have further been detected (Delgado-Vargas, López-Valdés, Valdés-Rodríguez, Blanco-Labra, Chagolla-López, & López-Valenzuela, 2004).
Pithecellobium lanceolatum **(Willd.) Benth**	Tree	Pintamono, tiribuchi	Logging, cotton-top tamarin food	Reports highlight antimicrobial (69, 71), cytotoxic (72), and antioxidant (69) properties, revealed in other species of the same genus.
Pithecellobium hymenaeafolium **(Willd.) Benth.**	Shrub	Buche blanco	Logging, used to make cords for tools	
Platymiscium pinnatum **(Jacq.) Dugand**	Tree	Trebol	Logging	Genus reports indicate the presence of flavonoids and isoflavonoids with antifungal (73) and cytotoxic properties (74), as well as apoptotic action on human tumor cell lines (GCG, et al., 2006).

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***Prosopis juliflora* (Sw.) DC.**	**Tree**	**Trupillo**	**Logging**	**Pollen extracts possess antioxidant activity, and are an important source of flavonoids (76). Additionally, tannin, phenolic, flavonoid, alkaloid, terpene, and steroid presence are reported (77) in the majority of *P. juliflora* components (77, 78). In the fruit, only patulitrin is reported (79). It presents antimicrobial activity against *Salmonella typimurium*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Escherichia coli*, *Psudomonas* sp., *Staphylococcus epidermis*, *Micrococcus luteus*, *Staphylococcus aureus*, *Streptococcus* sp., and *Bacillus subtilis* (Sathiya & Muthuchelian, 2008). Alkaloid leaf, pod, and flower extracts inhibit the growth of an *E. coli* strain, which is resistant to penicillin. Similarly, it has an effect on Acinetobacters and Alcaligens (Shachi Singh & Verma, 2011). Leaf extracts produce significant inhibition zones against pathogens of commercial interest (Lakshmi, Naidu, Murthy, Bobbarala, & Pandit, 2013).**
***Pseudopiptadenia* sp.**	Tree	Baranoa		Leaf extracts present antioxidant and antiviral activity against herpes simplex type 1, which is resistant to acyclovir. Flavonoids, catechins, and gallic acid have been identified in P. contorta. Phenolic derivatives (82) of low molecular weight, and proanthocyanidins showed the greatest antioxidant activity (Moreira, Leitão, Gonçalves, Wigg, & Leitão, 2005). Minimal antimicrobial activity against gram-positive bacteria, and strong antifungal activity against Pyricularia grisea has been reported in various stem husk extracts of P. africanum (84).

***Pterocarpus rohrii* Vahl**	**Tree**	**Guamo arroyero**		**Reports have been made on other species in the genus, such as Pterocarpus acapulcensis, in ethnobotany, to treat throat pain and periodontal disease. For this, the stem husk is used (85, 86). Stems are reported to have histological colorant potential. There is also a presence of alkaloids, steroid rings, cardiac glucosides, and sugar reducers (87). Aqueous stem extracts present antimicrobial activity against *S. aureus*, *P. aeruginosa*, and *Klebsiella* and synergic activity with antibiotics (88). Antihyperlipidemic, antidiabetic, and antioxidant activity is reported (89), chalcones (90).**
***Pterocarpus acapulcensis* Rose**	Tree	Sangregao	Medicinal, husks used to treat stomach problems	
***Senegalia polyphylla* (DC.) Britton and Rose**	Tree	Braza, chico	Medicinal, to heal skin injuries	Not reported.
***Senegalia riparia* (Kunth) Britton and Rose**	Shrub	Guacamayo		Not reported.
***Senna atomaria* (L.) H.S. Irwin and Barneby**	Tree	Chivato	Logging	Its use in ethnobotany to treat dermatological and skeleto-muscular system diseases is reported. Stems are used, as are fruit extracts (Frei, Baltisberger, Sticher, & Heinrich, 1998).
***Senna bacillaris* (L.f.) H.S. Irwin and Barneby**	Tree	Cigarrón		Activity against dermatophyte fungi is reported, making use of its exudate in ethnobotany (92).
***Senna fruticosa* (Mill.) H.S. Irwin and Barneby**	Tree	Cigarrón	Wood for charcoal	Antifungal activity has been reported in raw husk extracts against *Trichophyton*, *Microsporum*, and *Epidemophyton* (93, 94).
***Senna occidentalis* (L.) Link**	Tree	Chibato		Leaf extracts present antimicrobial activity against *E. coli, P. aeruginosa, P. mirabilis*, and *Candida albicans* (Arya, Yadav, Kumar, & Yadav, 2012), while seed extracts have demonstrated cytotoxic effects on human cells (96). The presence of alkaloids, tannins, saponin, glycosides, and flavonoids has also been reported (97).

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Senna reticulata **(Willd.) H.S. Irwin and Barneby**	**Tree**	**Bajagua**	**Medicinal: leaves used as purgatives**	**Methanol extracts from leaves present antimicrobial activity against *Mycobacterium phlei*, *Bacillus subtilis*, and MS *Staphylococcus aureus* (Lopez, Hudson, & Towers, 2001).**
Swartzia simplex **(Sw.) Spreng**	Tree	Arará	Logging	Saponins are reported to have been isolated from methanol leaf extracts with molluscicide properties (99). Extracts with dichloromethane show antifungal activity against *C. albicans* (Favre-Godal, et al., 2015).
Vachellia macracantha **(Humb. and Bonpl. ex Willd.) Seigler and Ebinger**	Shrub	Aromo		Ethanol extract shows an inhibitory effect on the growth of *S. aureus* (Bussmann, Glenn, & Sharon, 2010). The secondary metabolites present have been qualitatively characterized (Ojeda, N. Obispo, Gil, & Matute, 2015).
Vachellia tortuosa **(L.) Seigler and Ebinger**	Shrub	Aromo		The structural characterization of exudate has been performed (Martínez , Beltrán, Rincón, León de Pinto, & Igartuburu, 2015).
Vigna caracalla **(L.) Verdc.**	Liana	Bejuco Zaragoza		Insecticidal properties have been reported in the proteic extracts of flowers (104), which act has α-amylase inhibitors (105). Flavonoids present in this genus are used as chemotaxonomical characters, and may be useful in other aspects (Zallocchi, Pomilio , & Palacios, 1993).
Zygia inaequalis **(Willd.) Pittier**	Tree	Guamo arroyero	Logging, ornamental	Not reported.

ISSN: 1827-8620