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Revisión | Review

The *Tillandsia* genus: history, uses, chemistry, and biological activity

[El género *Tillandsia*: historia, usos, química y actividad biológica]

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Abstract: *Tillandsia* L. genus comprises 649 species, with different uses at different times. *T. usneoides* L. uses are reported since the late-archaic and pre-Columbian cultures. In XIX-XX centuries, *T. usneoides* was used in some manufactured products, as polish and packing fruit. *Tillandsia* has a favorable reputation as medicine: for leucorrhea, rheumatism, ulcers, hemorrhoid treatment, as an anti-diabetic remedy, emetic, analgesic, purgative, contraceptive, antispasmodic and diuretic. *Tillandsia* chemical composition includes cycloartane triterpenes and hydroxy-flavonoids, which are present in at least 24 species. Several extracts and compounds from *Tillandsia* spp. have been reported with pharmacological actions, as anti-neoplasia, hypolipidemic, antifungal, anti-HSV-1, hypoglycemic and microbicide. This review communicates the economic importance, ethnobotany, chemistry composition and biological activities of the *Tillandsia* genus, and analyze its biological and economic perspective. *Tillandsia* genus has cultural, economic and pharmacological relevance, with a high potential in many essential aspects of the modern society.

Keywords: *Tillandsia* spp; Bromeliaceae; Cycloartane triterpenes; Ethnobotany; Medicinal plants; Phytopharmacology.

Resumen: El género *Tillandsia* L. comprende 649 especies, con diferentes usos en diferentes épocas. *T. usneoides* L. se han reportado desde el arcáico tardío hasta las culturas precolombinas. En los siglos XIX-XX, *T. usneoides* se usó en productos manufacturados: como abrasivo y embalaje de fruta. Como medicina tradicional, el género *Tillandsia* se reporta para leucorrea, reumatismo, úlceras, hemorroides, remedio antidiabético, emético, analgésico, purgante, anticonceptivo, antiespasmódico y diurético. Su composición química incluye triterpenos de tipo ciclo-artano e hidroxi-flavonoides, presentes en al menos 24 especies. Los extractos y compuestos del género *Tillandsia* se han reportado con propiedades antineoplásicas, hipolipidémicas, antifúngicas, anti-HSV-1, hipoglucemiantes y microbicidas. Esta revisión comunica la importancia económica, etnobotánica, composición química y las actividades biológicas del género *Tillandsia*, y analiza su perspectiva biológica y potencial económica. *Tillandsia* tiene importancia cultural, económica y farmacológica, con gran potencial en muchos aspectos esenciales de la sociedad moderna.

Palabras clave: *Tillandsia* spp; Bromeliaceae; Triterpenos cicloartano; Etnobotánica; Plantas medicinales; Fitofarmacología.

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INTRODUCTION

Bromeliaceae family includes 57 genera and 3,350 species (Luther, 2006). They are distributed predominantly in the Neotropical region, from southern Mexico through Chile and reaching the North-American Southeast (Manetti *et al*., 2009). Except for *Pitcairnia feliciana* (A. Chev.) Harms & Mildbraed, Bromeliaceae is considered an endemic family of the Americas (Givnish *et al*., 2007) that comprises eight subfamilies: Pitcairnioideae, Tillandsioideae, Bromelioideae, Puyoideae, Navioideae, Hechtioideae, Lindmanioideae, and Brocchinioideae. They differ for: growth habit, trichrome, type of fruit, seed, leaflet, photosynthesis, and pollinator; as well as its epiphytes, growth, and the chlorenchyma (Crayn *et al*., 2004; Givnish *et al*., 2007; Vasconcelos *et al*., 2013; Givnish *et al*., 2014).

Tillandsia genus has over 649 species and includes members with distinctive morphological and physiological characteristics (Pickens *et al*., 2006; Gouda *et al*., 2016; Granados *et al*., 2016). Most of the species of the genus are epiphytes of trees or live on rocky slopes, preferring to settle in *Quercus* spp. tree branches, because of its rough bark. They possess leaves covered with peltate trichomes and are arranged in rosettes; whereas the inflorescences are bracteates with bright colors (Diego-Escobar *et al*., 2013). All *Tillandsia* species are epiphytes, living independently of the soil, on trees or inert substrates, such as electric power-line wires (Brighigna *et al*., 1997). In these species, the lack of an absorbing root system is substituted by a specialized structure named trichrome that is essential for water uptake and other nutrients (Papini *et al*., 2011). It is known that around 27.614 species are vascular epiphytes, with 913 genera in 73 families (Zots, 2013), representing approximately 13% of the species of vascular plants (Kress, 1986; Douglas *et al*., 1987).

Tillandsia genus is the most primitive and xerophyte of all Bromeliaceae family (Garth, 1964). Carl Linnaeus called to the genus '*Tillandsia*' in honor of his Finnish teacher Elias Tillands (Vasconcelos *et al*., 2013). From the beginning of the formal investigation of *the Tillandsia* genus, it has awakened much interest. Authors like Dubois (1917) mentioned the extreme adaptability of *T. usneoides* in their host as 'carnivorous plant.' Also, Billings (1904) reported the great versatility of *T. usneoides*, which during the dry spell in the spring of 1902, was exposed to a period during without rain during two months without suffer injury. Nowadays, *Tillandsia* species has been reported with qualities for pollutants environmental monitoring (Capannesi *et al*., 1987; Figueiredo *et al*., 2004; Elias *et al*., 2006; Cardoso-Gustavson *et al*., 2016).

Although, *Tillandsia* genus species possesses cultural relevance, economic importance, and unique ecological features, also is used in traditional medicine, with repercussions in the treatment of human illness. In the present review, we report the historical uses, customs, chemistry, economic importance as well as biological activities of *Tillandsia* genus species, empathizing the most relevant since the point of view ethnomedicinal and analyzing its biological and economic perspective.

Culture importance, uses, and customs in the Americas

There are different applications of the *Tillandsia* species reported in the Americas. Two of the plants more reported are *T. usneoides* and *T. recurvata*, commonly called 'Spanish moss' and 'Ball moss,' respectively. The first hint of the use of *Tillandsia* happened by *T. usneoides* fibers, which were found in the pottery-making societies of North America before our era (Smith & Trinkley, 2006; Gilmore, 2015). The interest in *Tillandsia* plants was confirmed in the 19th and 20th centuries.

One of the first uses of *T. usneoides* was proposed throughout a patent for treatment and cure of the decomposition of the bark of the trees (Cummings, 1880). In the early 20th century in Louisiana, Florida USA, *T. usneoides* was used in the winter by farmers when the pastures were scarce, whose often chop downed trees and allow the cattle to feed on the moss (Halligan, 1909). *T. recurvata* was used with the same purpose in Brazil (Vasconcelos *et al*., 2013). In this same century, *T. usneoides* was suggested as a product very versatile in USA (Schorger, 1927), as for tanning hides (Hall & Tuttle, 1918), and as a possible source for a hard-natural wax and for processing of upholstering fibers (Feurt & Fox, 1953a; Feurt & Fox, 1955). Besides, the waste material from the processing of threads for the upholstery industry was suggested as a source of estrogens for cattle, to improve meat quality and the efficiency of feed utilization (Feurt & Fox, 1953b). *T. usneoides* was also used to eliminate the bitter taste of citrus for use in animal feed (Sokoloff & Redd, 1951).

Interestingly, the cultural importance of the *Tillandsia* plants is prominently most wide in the different Latin America countries that in other parts of the Americas. Avila (2012) reports that *Tillandsia* spp. was probably known as *'chicōm-ācatl*' in pre-Columbian cultures, which was used in Aztec temples as decoration (Pierce, 2000). Other *Tillandsia* species, like *T. purpurea* Ruiz and Pav. are depicted on pre-Incan Mochica pottery of northern Peru, often within a magical context (Arslanian *et al*., 1986). Also, in Peru, *T. usneoides* was used to wrapping fruit and fragile objects, as well as filling pillows and mattresses (Pierce, 2000).

Tillandsia species can propagate and live in trees of economic importance as cacao and shrubs as well as in power-line poles. Due to that *Tillandsia* species grow in other plants with more significant commercial o social value, they were considered parasitic plants (Rodriguez, 1955), and some herbicides against *T. recurvata* and *T. usneoides* were proposed (Rodriguez, 1955; Cole, 1959; Cardenas, 1971; Johnson & Halliwell, 1973). Fortunately, this practice has disappeared in some regions thanks to a better knowledge of the cultural, ecological and economic importance of the *Tillandsia* genus.

Ethnobotany

While in the USA the plants of *Tillandsia* genus were used practically in everyday needs, in Latin America the past knowledge of this genus affected on the culture of these countries, particularly in its traditional medicine. For instance, in Peru were reported several *Tillandsia* spp. with magical connotations, and some species are used in rituals as adornment, especially: *T. usneoides* (salvagina), *T. walterivar* (Sara-Sara), *T. cauligera* (huiccontoi) and *T. walteri* (pasto verde) (Arslanian *et al*., 1986).

In México, *T. usneoides* had an essential use in Azteca society and posteriorly in post-Colombian time like decoration in scenes of nativity in Chiapas (Gardner, 1982), as well as *T. religiosa* in Morelos (Hernández-Cardenas *et al*., 2014). In Tarahumara community, *T. mooreana* L.B.Sm., usually named 'waráruwi' together with the 'peyote' (*Lophophora williamsii*), are important plants used in its rituals (Bye, 1979). Recently, the Otomi community of San Bartolo Tutoltepec, Puebla, use this resource as part of their wardrobe flying in the '*Danza de Los viejos*,' this to show himself as one of the old of vegetation, in an ancient dance in the community (Stresser-Peann, 2011). Today, these plants can purchase in markets mainly for ornamental purposes (Monteiro *et al*., 2011).

Economic importance

The Bromeliaceae family is of horticultural interest, mostly due to their growth forms and brightly colorful inflorescences (Vervaeke *et al*., 2004). Today, from Belgium and Holland millions of Bromeliaceae seedlings and tens of thousands of finished plants are imported into the USA (Cathcart, 1995). Only in Florida, the commercial crop of Bromeliaceae has been estimated at $20 million per year (Cathcart, 1995). However, some *Tillandsia* plants are endangered (CITES) (Bessler, 1997) and it has been sought techniques for its improvement and care. In Brazil has been improved the conditions of growth *Tillandsia* in the greenhouses due to the presence of the mosquito *Aedes aegypti*, which is vectorized by crows (Soares, 2005).

The plants of *Tillandsia* genus have received hormonal treatment with 6-benzylaminopurine (6-BA) as well as gibberellic acid, to accelerate the multiplication and propagation velocity of the growth (Chekanova, 1980; Bessler, 1997; Ding *et al.*, 2009; Ding *et al.*, 2014). Also, it has been developed a medium of culture to accelerate the propagation of the plant (Zheng *et al*., 2013), including a specific method with a particular medium of culture for *Tillandsia*, as well as many fertilizers suitable for its growth (Wrinkle, 1973; Sanchez, 2007; Ding *et al.*, 2013; Wang *et al.*, 2013; Wang *et al.*, 2014; Zheng *et al*., 2015a; Zheng *et al.*, 2015b; Wang, 2015; Zheng & Ding, 2015; Ding *et al*., 2015a; Li and Zheng, 2015; Zhang, 2016).

T. cyanea Linden ex K. Koch is used as organic fertilizer in many Asiatic countries (Zhang, 2016). Also, *T. usneoides* is used as a decorative arrangement in buildings (Wickham, 2013), as ornamental plants in vertical type support, as air purification indoors (Kim, 2011a; Kim, 2011b) as well as green plant curtain (Yu *et al.*, 2009). Interestingly, a portable container accessory for clothing transportation of *Tillandsia* plants has developed (Sadaki, 2006). Also, with plants of *Tillandsia* have been made 'live pictures' and jewelry for women (Bliό, 2013).

The speciation also has been of commercial interest for the genus, and it has been developed hybrids to commercialize them (Skotak, 2016), and new cultivars of *Tillandsia* ornamental plants with economic importance developed. Some varieties known are: 'Mora' of *T. leiboldiana* Schltdl. (Bak & Steur, 2011), 'Jose' from *T. cyanea* (Van der Velden, 2009) and 'Tilstsil' from *T. stricta* Sol. Ex Sims

(Osada, 2004). This activity satisfied the use of technology for promoting the growth of the plants (Ding *et al*., 2015b; Zheng *et al*., 2015b), which reflexing the interest for improving and developing crop in this genus.

Tillandsia genus possesses importance also in the cosmetic industry. Aerial part extracts of *T. usneoides*, *T. cyanea*, *T. tectorum*, *T. ionantha*, and *T. stricta* improve rough skin and keeping moisture (Ohara & Hori, 2001; Shoji *et al*., 2003; Kurokawa *et al*., 2004; Yokozeki, 2010). Moreover, from *T. usneoides* has been developed an anti-aging cosmetic, which promotes the keratinocyte differentiation in the skin (Kwon *et al*., 2013; Jung *et al*., 2015). All this denote the commercial interest associated with *Tillandsia* plants, whose potential real in this area should be explored in further studies.

Medical traditional use of Tillandsia

In traditional medicine people mainly recommends the use of aerial parts (leaves and stems), only leaves or the complete plant to prepare remedies for many ailments. Also, it has been reported the use of inflorescences and roots, including preparations from fresh plants. In South Louisiana, USA, people use the decoction of *T. usneoides* in diabetes mellitus control (Keller *et al.*, 1981) and for hemorrhoid treatment (Agra *et al*., 2008). In Latin America, *T. recurvata* is usual for leucorrhea (Adonizio *et al*., 2006), rheumatism, ulcers, hemorrhoids, eye infections, gallbladder, and as antispasmodic agent (Paz *et al*., 1995; Agra *et al*., 2007; Agra *et al*., 2008; Vasconcelos *et al*., 2013). *T. recurvata* is used in Bolivia for kidney inflammation (Bourdy *et al*., 2004). Meanwhile, *T. streptocarpa* Baker as purgative and laxative (Agra *et al*., 2008), emetic, analgesic and anti-inflammatory remedy in Brazil (Delaporte *et al*., 2004), as well as contraceptive agent (Delaporte *et al*., 2006). *T. loliacea* Mart. ex. Schult. f. is used in the treatment of external ulcers (Agra *et al*., 2008), as an anti-rheumatic, and for obstructed liver (Braga, 1976). Additionally, *T. stricta* is used in the vicinity of the Parana River as a diuretic, in gonorrhea treatment and as an anti-inflammatory (Lucietto *et al*., 2006).

In Mexican traditional medicine, there are more than 30 *Tillandsia* plants reported (Table No. 1), being the most critical *T. recurvata* and *T. usneoides*, which are used for cough, bronchitis, rheumatism, ulcers, and hemorrhoids, among other (Bennett, 2000; Acebey *et al*., 2006; Grijalva, 2006; De Fátima *et al*., 2008; Zamora, 2009; Hornung-Leoni, 2011; Mondragón *et al*., 2011). Moreover, in the traditional medicine of Amatlan, Veracruz, *T. recurvata* is used for menstruation concerns (Smith & Downs, 1977; Smith-Oka, 2007; Smith-Oka, 2008). Also, the leaves of *T. imperialis* E. Morren ex Mez are used for digestive disorders, respiratory tract, hemorrhoids, inflammation and burns (Sandoval-Bucio *et al*., 2004; Vite-Posadas *et al*., 2011). However, in most cases, little attention has been placed on the experimental validation of their medicinal properties.

Table No. 1
***Tillandsia* plants with uses in the Mexican traditional medicine**.

Taxon	Medicinal use/illness	Reference
Tillandsia aeranthos (Loisel.) L. B. Sm.	Antispasmodic and ocular infections	Benzing, 1980; Hornung-Leoni, 2011.
Tillandsia andrieuxii (Mez) L. B. Sm.	Cough, bronchitis swelling, headache and backache	Sandoval-Bucio *et al*. 2004; Mondragón *et al*., 2011.
Tillandsia balbisiana Schult. f	Bronchitis	Sandoval-Bucio *et al*., 2004; Mondragón *et al*., 2011; Ucan 857 *(MEXU).
Tillandsia brachycaulos Schltdl.	Medicinal properties	Mondragón *et al*., 2011.
Tillandsia bulbosa Hook.	Migraine in women post-partum	Sandoval-Bucio *et al*., 2004; Mondragón *et al*., 2011; Gutiérrez 132 *(MEXU).
Tillandsia capillaris Ruiz & Pav.	Medicinal properties	Bennett, 2000; Acebey *et al*., 2006.
Tillandsia dasyliriifolia Baker	Cough and bronchitis	Sandoval-Bucio *et al*., 2004; Hornung-Leoni, 2011; Mondragón *et al*., 2011; Ucan *et al*., 1996 *(MEXU).
Tillandsia didisticha (E. Morren) Baker	Medicinal properties	Acebey *et al*., 2006.

Tillandsia duratii Vis.	Cardiotonic	Acebey *et al*., 2006.
Tillandsia elongata Kunth	Bronchitis	Hornung-Leoni, 2011; Ucan 711 *(MEXU).
Tillandsia erubescens Schltdl.	Coughing, anaemia and kidney problems	Bennett, 2000; Sandoval-Bucio *et al*., 2004; Mondragón *et al*., 2011.
Tillandsia fasciculata Sw.	Abscess, inflammation and ear diseases	Sandoval-Bucio *et al*., 2004; Mondragón *et al*., 2011.
Tillandsia festucoides Brongn ex Mez	Bronchitis	Sandoval-Bucio *et al*., 2004; Mondragón *et al*., 2011; **(ENCB).
Tillandsia guatemalensis L. B. Sm.	Majbenal, spiritual illness	Sandoval-Bucio *et al*., 2004; Mondragón *et al*., 2011; Breedlove **(ENCB).
Tillandsia imperialis E. Morren ex Mez	Bath "burned child"	Hornung-Leoni, 2011; Mondragón *et al*., 2011.
Tillandsia karwinskyana Schult. f.	Medicinal properties	Mondragón *et al*., 2011
Tillandsia loliacea Mart. ex Schult. f.	Uterine bleeding and external ulcers	Acebey *et al*., 2006; De Fátima *et al*., 2008.
Tillandsia multicaulis Steud.	Medicinal properties	Mondragón *et al*. 2011.
Tillandsia oaxacana L. B. Sm.	Medicinal properties	Mondragón *et al*., 2011.
Tillandsia plumosa Baker	Medicinal properties	Mondragón *et al*., 2011.
Tillandsia polystachia (L.) L.	Medicinal properties	Sandoval-Bucio *et al*., 2004.
Tillandsia prodigiosa (Lem.) Baker	Medicinal properties	Mondragón *et al*., 2011.
Tillandsia recurvata (L.) L.	Burns, cough, bronchitis, back pain, antidiuretic, pimples, rheumatism, ulcers, hemorrhoids, irregular menstruation and antiangiogenic properties	Hernández *et al*., 1991; Bennett, 2000; Sandoval-Bucio *et al*., 2004; Acebey *et al*., 2006; De Fátima *et al*., 2008; Hornung-Leoni, 2011; Mondragón *et al*., 2011.
Tillandsia recurvifolia Hook.	Medicinal properties	Acebey *et al*., 2006.
Tillandsia schiedeana Steud.	Headache and fever	Bennett, 2000; Mondragón *et al*., 2011.
Tillandsia splendens Brongn.	Medicinal properties	Londoño, 2011.
Tillandsia streptocarpa Baker	Purging, laxative, emetic	De Fátima *et al*., 2008.
Tillandsia streptophylla Scheidw. ex C. Morren	Headache	Sandoval-Bucio *et al*., 2004; Ucan and Flores 929 *(MEXU).
Tillandsia usneoides (L.) L.	"Persona tapeada", hemorrhoids, dandruff, digestive ailments due to overeating, body inflammation, antiepileptic and astringent, gastritis, throat placenta, accelerate childbirth, infant epilepsy, astringent, antipyretic, cough, hernias, measles, ulcers, arthritis, lung conditions, Liver, kidney, heart, contraceptive	Zamora, 2009; Bennett, 2000; Sandoval-Bucio *et al*., 2004; Acebey *et al*., 2006; Grijalva, 2006; De Fátima *et al*., 2008; Mondragón *et al*., 2011.
Tillandsia vernicosa Baker	Medicinal properties	Acebey *et al*., 2006.
Tillandsia xiphioides Ker Gawl.	Medicinal properties	Bennett, 2000; Acebey *et al*., 2006.

***MEXU: The National Herbarium of Mexico-National Autonomous University of Mexico (UNAM).**

****ENCB: The National School of Biological Sciences-National Polytechnic Institute (IPN).**

Chemistry

In general, the compounds from the plants of the *Tillandsia* genus have been isolated from organic extracts, mainly alcoholic (methanol and ethanol), although also acetone, chloroform, hexane, and benzene were used. Some extracts have been explored by CO_2 supercritical fluid, and minor attention has been put in the more polar compounds in aqueous extracts; hemisynthesis has also been practiced for some reported compounds the genus (Table No. 2). The primary compounds in *Tillandsia* genus are triterpenoids and sterols (51%), flavonoids (45%) and cinnamic acids (4%) (Clemes *et al*., 2008; Vasconcelos *et al*., 2013). Historically, in 1861 ash content for *T. usneoides* resulted in chemical properties (Schorger, 1927). However, the investigation about the chemical of the *Tillandsia* genus was initiated at the beginning of the XX century by American society. Thus, *T. usneoides* was initially reported containing as main constituents, water (15.95%) and carbohydrates (69.50%) (Halligan, 1909; Schorger, 1927; Seldon & Feurt, 1953), cellulose, (Wise & Meer, 1936), proteins (Pickell, 1890; Halligan, 1909), and wax, which represented a possible commercial source for natural wax (Schorger, 1927; Seldon & Feurt, 1953).

The first chemical analyses of ash of Spanish-moss *T. usneoides* were reported containing Na_2O, K_2O, MgO, CaO, Fe_2O_3, SiO_2, P_2O_5 and SO_3 (Halligan, 1909; Wherry & Buchanan, 1926; Wherry & Capen, 1928). *T. usneoides* was reported containing sugars and other non-identified chemical constituents with potential commercial value (Marsden, 1918) and a sample of this species, which was recollected in the winter season, it was reported with 15 mg/g and 46 mg/g of carotene and ascorbic acid, respectively, representing nutritional levels of interest for cattle (French & Abott, 1948). *T. aeranthos* (Loisel) L.B. Sm. was reported containing polysaccharides (Moyna & Tubío, 1977).

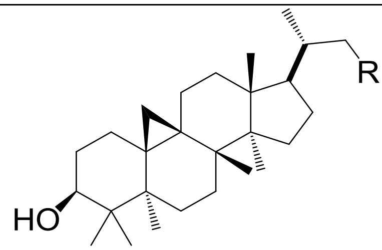
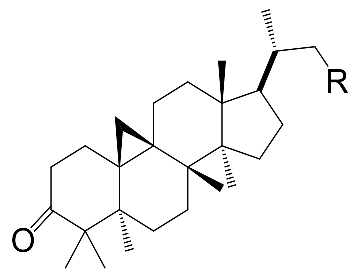
Although the value mineral, bromatological and nutrimental of *T. usneoides* was already known, its first secondary metabolite, a phenol methyl ether glucoside, was described for Schorger in 1927, who also reported chlorophyll and a sterol (Schorger, 1927). The corolla of *T. fragrans* André (Salgues, 1955) contained 0.18% of essential oil and 74% of several free alcohols as citronellol (52%), geraniol (20%), and nerol (2%), as well as 18% of esters. These findings allow hypothesizing about the possible obtaining from *T. fragrans* of a fragrance of cosmetic interest, which also should be explored in other *Tillandsia* plants.

Until the 60s and 70s, the chemistry of *Tillandsia* was more addressed toward its biological activities, probably due to the development of tools and techniques for the identification assertive of molecules.

Table No. 2 enlists the chemical compounds in distinct *Tillandsia* species. McCrindle and Djerassi (1961) and Djerassi and McCrindle (1962) reported 15 cycloartanes triterpenoids isolated of *T. usneoides* (compounds **1-15**). Ten years later, Atalla and Nicholas (1971) reported similar compounds, sharing at least three compounds **19**, **20**, and **21**). Later, Lewis and Mabry (1977) reported the first poly-hydroxylated molecule: 3,6,3’,5’-tetramethoxy-5,7,4’-trihydroxyfla-vone, corresponding to a compound iso-flavonoid type (Table 2).

From the decade of the 90s, the growing interest for the *Tillandsia* plants in the scientific society increased the number of reports. Cabrera *et al*. (1995, 1996), Cabrera & Seldes (1995, 1997) Cantillo-Ciau (2001, 2003), Delaporte *et al*. (2004), Delaporte & Laverde (2006), and Lowe *et al.* (2012a, 2013c) confirmed the presence of cycloartanes triterpenoids in *Tillandsia* species. Also, Wollenberger *et al*. (1992), Queiroga *et al*. (2004), Delaporte *et al*. (2006) as well as Lowe *et al*. (2014c), reported the presence of phenolic compounds in different *Tillandsia* plants (Table No. 2). The chemical properties confirmed into the genus also permitted delving in the knowledge of its biological effects, supporting several of its traditional medical use (Table No. 3).

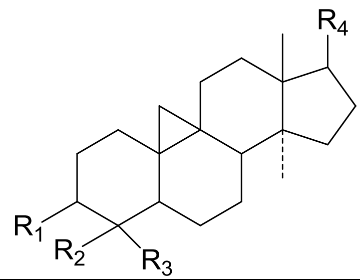
Table No. 2
Chemistry of *Tillandsia* spp.

Tillandsia	Chemistry and biological activity	Author
usneoides	1. $CH=CH-C[(2CH_3)-(OH)]$ 2. $CH=CH-C[(2CH_3)-(OCH_3)]$ 3. $CH_2-CH=C[2(CH_2)]$ 4. $CH_2-CH(OH)-CH [(CH_3)(CH_2)]$ 5. $CH_2-CH (OAc)-CH[(CH_3)(CH_2)]$ 6. $CH_2-CO-CH[(CH_3)(CH_2)]$ 7. $CH_2-CH_2-C[(2CH_3)(OH)]$ (s) 8. 2 $(CH_2)-CH [2(CH_3)]$ 9. $CH (OH)-CH(OH)-C[(2CH_3)-(OH)]$ 10. CHO 11. CO_2H(s) 12. $CO_2 CH_3$(s) 13. $CH_2-CO-CH[2(CH_3)]$ 14. CH_2-CH 15. $CH_2-CO-C[(CH_3) CH_2)]$(s)   As well as friedelin and β-sitosterol s: semi-synthesis	McCrindle & Djerassi, 1961; Djerassi & McCrindle, 1962

	R_1	R_2	R_3	R_4	Author
16	O	CH_3	CH_3	$CH(CH_3)-2(CH_2)-CH=C [2 (CH_3)]$	Atalla & Nicholas, 1971
17	OH	CH_3	CH_3	$CH(CH_3)-2(CH_2)-CH=C [2 (CH_3)]$	
18	OH	CH_3	CH_3	$CH(CH_3)-2(CH_2)-CO-CH[(CH_3) (CH_2)]$	
19	OH	CH_3	CH_3	$CH(CH_3)-2(CH_2)-CH(OH)-CH[(CH_3) (CH_2)]$	
20	OH	CH_3	CH_3	$CH_3CH(CH_3)-CH_2-CH=CH-C[2(CH_3)-(OH)]$	
21	OH	CH_3	CH_3	$CH(CH_3)-CH_2-CH=CH-C[2(CH_3)-(OCH_3)]$	
22	OH	CH_3	H	$CH(CH_3)-2(CH_2)-C(CH_2)-CH [2(CH_3)]$	
23	OH	CH_3	CH_3	$CH(CH_3)-2(CH_2)-C(CH_2)-CH[2(CH_3)]$	
24	OH	CH_3	CH_3	$CH(CH_3)-2(CH_2)-CH(CH_3)-CH[(CH_3) (CH_2)]$	
25	OH	CH_3	CH_3	$CH(CH_3)-2(CH_2)-C(CH_3)-CH [2(CH_3)]$	

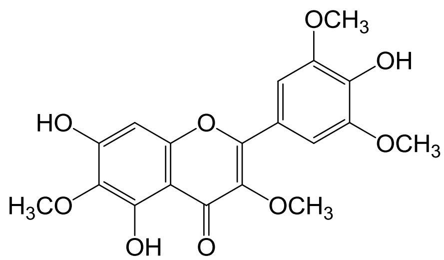
As well as cholestane, cholesterol, campesterol, stigmasterol, β-sitosterol, and 2 triterpene alcohol.

In conclude: 24-methylene cycloartanol is the major triterpene alcohol



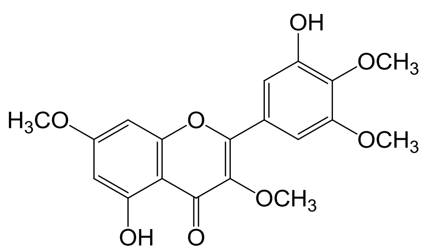
3,6,3’,5’-tetramethoxy-5,7,4’-trihydroxyflavone
In conclude: new compound

Lewis & Mabry, 1977



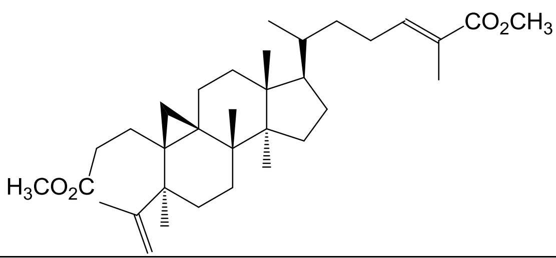
Myricetin-3,3',4',7-tetramethyl
In conclude: The lipophilic flavonoids as exudate constituents, deposited externally, on leaf and stem surfaces ether

Wollenberger *et al.*, 1992

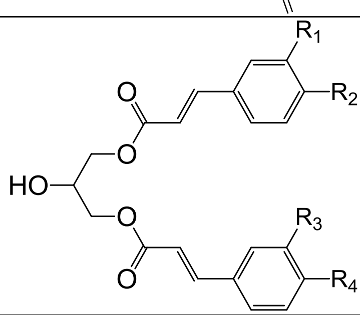


Dimethyl 3,4-seco-cycloart -4(29), 24E-diene-3,26-dioate
In conclude: New compound

Cabrera *et al.*, 1995



Strepto-carpa

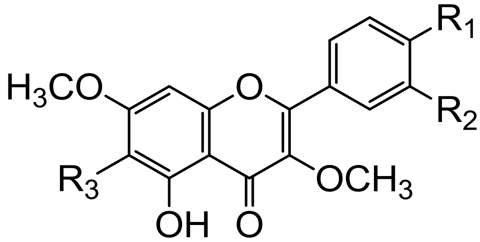
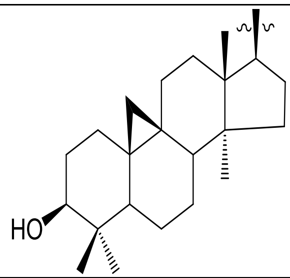
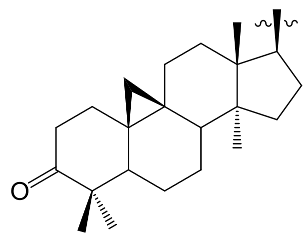
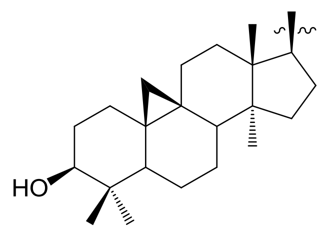
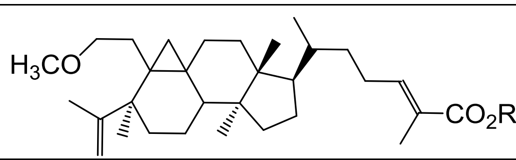
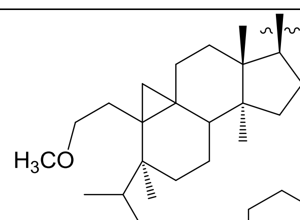
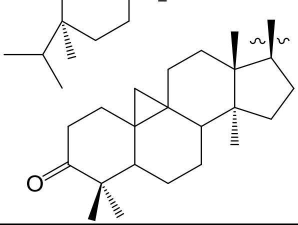


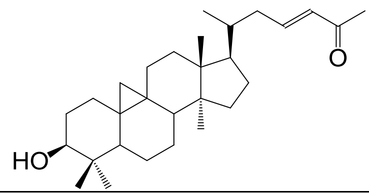
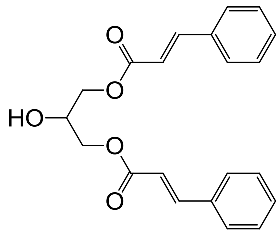
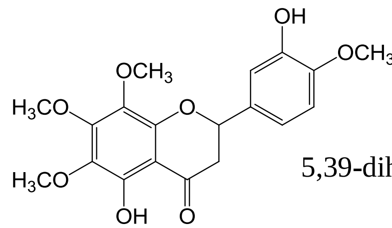
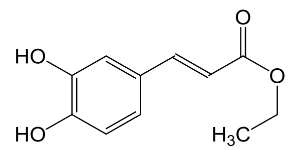
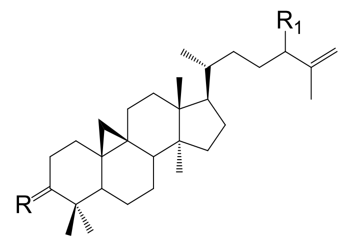
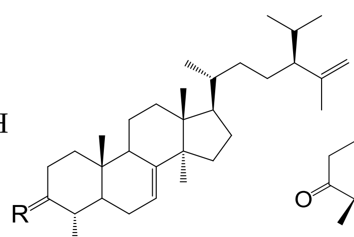
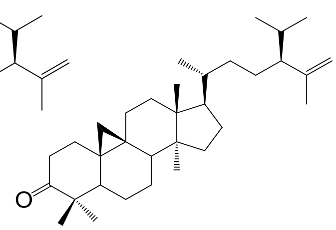
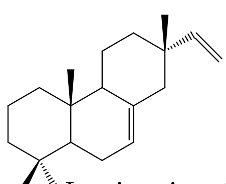
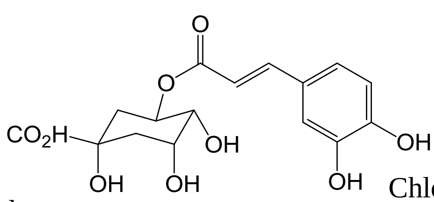
In conclude: Phenylpropanoid glycerols in *Tillandsia* genus.

	R_1	R_2	R_3	R_4	R_5
26.	H	OCH_3	H	OCH_3	OCH_3
27.	H	OH	OCH_3	H	OCH_3
28.	OCH_3	OH	H	H	OH

Delaporte *et al.*, 2004; Delaporte *et al.*, 2006

As well as other mixture compounds methoxylated 5-hydroxyflavones

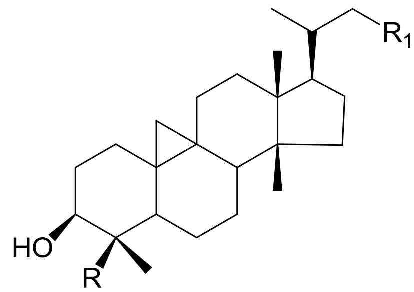
purpurea	 R$_1$ R$_2$ R$_3$ 29. OH H OCH$_3$ 30. OCH$_3$ OCH$_3$ H 31. OCH$_3$ OCH$_3$ OCH$_3$	Arslanian *et al.*, 1986
recurvata	 32. CH(CH$_3$)-CH$_2$-CH=CH-C[(2 CH$_3$)(OOH)] 33.CH(CH$_3$)-2 (CH$_2$)-CH (OOH)-CH[(CH$_2$)(CH$_3$)] 34. CH(CH$_3$)-CH$_2$-CH=CH- C[(2 CH$_3$)(OH)] 35. CH(CH$_3$)-2(CH$_2$)-CH (OH)-C[(CH$_2$)(CH$_3$)] 36. CH(CH$_3$)-2(CH$_2$)-CH=CH-C[2(CH$_3$)]	Cabrera & Seldes, 1995
usneoides	37. CH(CH$_3$)-CH=CH-CHO 38. CH(CH$_3$)-2(CH$_2$)-CH=C[(CHO)(CH$_3$)] 39.CH(CH$_3$)-2(CH$_2$)-CH (OH)-C[(CH$_2$) (CH$_3$)] 40. CH(CH$_3$)-CH$_2$-CH=CH-C[(2CH$_3$)(OCH$_3$)] 41. CH(CH$_3$)-CH$_2$-CH=CH-C[(2CH$_3$)(OOH)] 42. CH(CH$_3$)-3(CH$_2$)-OH 43. CH(CH$_3$)-2(CH$_2$)-CH=C[(CO$_2$H)(CH$_3$)] 44. CH(CH$_3$)-CH$_2$-CH=CH-C[(2CH$_3$)(OH)] 	Cabrera *et al.*, 1996
	45. CH(CH$_3$)-2(CH$_2$)-CH(OH)-CH[(CH$_2$)(CH$_3$)] 46. CH(CH$_3$)-CH$_2$-CH=CH-C[(2CH$_3$)(OOH)] 47. CH(CH$_3$)-CH$_2$-CH=CH-C[(2CH$_3$)(OH)] 48. CH(CH$_3$)-CH$_2$-CH=CH-C[(2CH$_3$)(OCH$_3$)] 49. CH(CH$_3$)-2(CH$_2$)-CH(OOH)-C[(CH$_2$)(CH$_3$)] 50. CH(CH$_3$)-2(CH$_2$)-CO-CH[(CH$_2$)(CH$_3$)] 51. CH(CH$_3$)-2(CH$_2$)-CH=CH-C[(CH$_3$)(CHO)] 	
	52. R= H 53. R= CH$_3$ 	
	54. CH(CH$_3$)-CH$_2$-CH=CH.C[(2CH$_3$)(OH)] 55. CH(CH$_3$)-(CH$_2$)-CH=CH-C[(2CH$_3$)(OCH$_3$)] 56. CH(CH$_3$)-2(CH$_2$)-CH (OH)-C[(CH$_3$)(CH$_2$)] 	
	57. CH(CH$_3$)-3(CH$_2$)-CO-CH$_3$ 58. CH(CH$_3$)-CH$_2$-CHO 59. CH(CH$_3$)-2(CH$_2$)-CHO 	

	In conclude: The short side-chain cycloartanes are the majority compounds 27-nor-3β-hydroxycycloart-23-en-25-one 	Cabrera & Seldes, 1997
Recurvata	Ethyl ester of caffeic acid 1,3-Di-O-cinnamoylglycerol   5,39-dihydroxy-6,7,8,49-tetramethoxyflavanone  As well as: Cycloartenone, cycloartanone, 24-methylenecycloartanone, cycloartanol, 24-methylenecycloartanol, lanosterol, lanostenol, and 24-ethylcholest-4-en-3	Queiroga *et al.*, 2004
fasciculata	R / R1 60. O / β-iPr 61. β-OCOH, α-H / CH3 62. O / CH3 63. β-OCOH, α-H / CH3 64. β-OAc, α-H / CH3 	Cantillo-Ciau *et al.*, 2001
brachy-caulos	R 65. β-OH, α-H 66. β-OAc, α-H 67. O   Tillandsinone  Isopiramic acid  Chlorogenic acid Microbicide (10 µl of a 5% (w/v) toward *S. aureus*, *B. subtilis*, *S. agalactiae*, *E. colli*, *P. aeruginosa*, *K. pneumoniae*, *S. flexneri* serotype 4, *C. albicans*, *S. cerevisiae*, *A. niger* and *T. mentagrophytes*. Compound 60 was obtaining from compound hemi synthesis, without biological activity.	Cantillo-Ciau *et al.*, 2003

recurvata

R R$_1$

68. H CH=CH-CO-CH_3
69. CH_3 CH=CH-C[(2 CH_3)(OOH)]
70. CH_3 (*E*) CH=CH-C [(2 CH_3)(OH)]
71. CH_3 CH=CH-CH[(CH_3) (CH_2)]
72. CH_3 2 (CH_2)-CO-CH_3
73. CH_3 CH_2-CHO
74. CH_3 CH_2-CH(OOH)-C[(CH_3)(CH_2)]
75. CH_3 CH_2-CH(OH)- C[(CH_3)(CH_2)]
76. CH_3 CH_2-CH=C[2(CH_2)]
77. CH_3 CH_2-CH (OH)-C[(2 CH_3)(OH)]
78. H CH_2-C (CH_2)-Pr-i.
79. CH_3 (*Z*) CH=CH-C [(2 CH_3)(OH)]

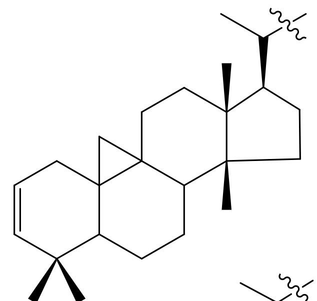


In conclude: Cycloartane showed inhibition toward kinase and angiogenesis in prostate cancer cells, without causing excessive damage to normal cells

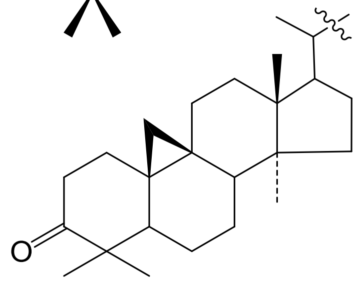
Lowe *et al*., 2013c

R R$_1$

80. CH_2-CH=CH-CO-CH_3
81. CH_2-CH=CH-CH= CH_2
82. 2 (CH_2)-CH (OOH)-C [(CH_3) (CH_2)]
83. 2 (CH_2)-CH(OH)-C [(CH_3) (CH_2)]
84. CH_2-CH=CH_2
85. 18. CH_2-CH(=O)
86. 19. CH=CH_2
87. 20. 3 (CH2)-CO- CH_3
88. 21. 3 (CH_2)-CH= CH_2
89. 22. 2 (CH_2)-CH=C [2 (CH_3)]



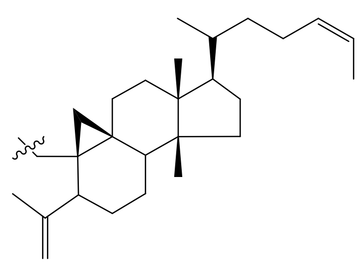
90. CH_2-CO-CH=C (CH_3)-COOH
91. 2 (CH_2)-CH (OH)-C [(2 CH_3) (OH)]
92. CH_2-CH=CH-C [(2 CH_3) (OH)



In conclude: Therapeutic cycloartane extract from *T. recurvata*, for use in regressing cancerous tumors and/or for anti-inflammatory effect, as well as the method for inhibiting prostate cancer (killed 99.1% of B-16 cells)

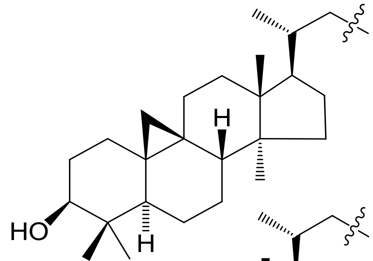
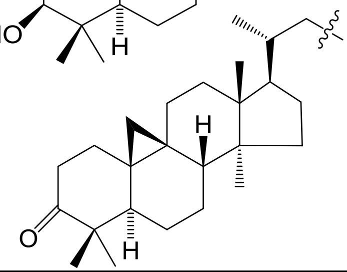
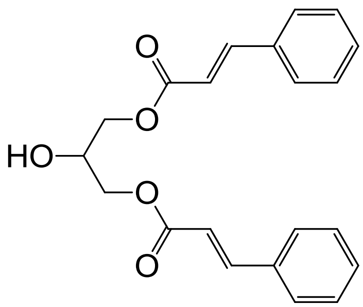
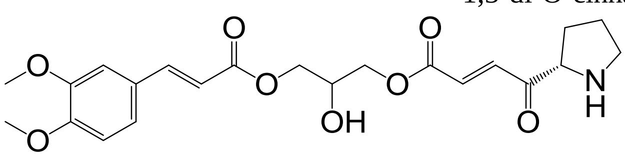
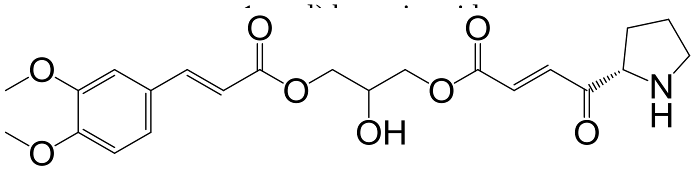
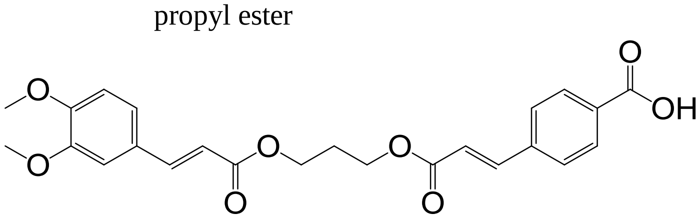
93. CH_2-COOH
94. 2 (CH_2)-COOH
95. CH_2

And other four triterpenes

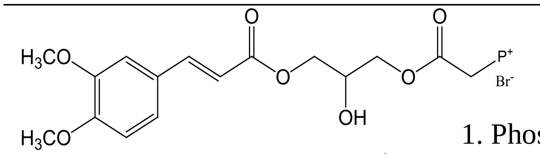


Compounds 89, 90, 92, 93, were active as well as extract MeOH toward HL-60, K562, MOLM-14, monoMac6 (IC_{50}= from 1.83 μM to 18.3 μM). Compounds 89-93 were active toward myotonic dystrophy kinase-related Cdc42-binding kinase (MRCK). Compound 91 was poorly soluble

Lowe and Bryant, 2013

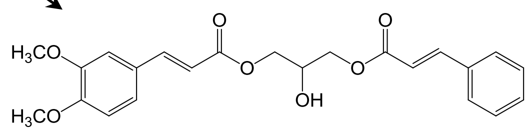
96. CH=CH-C [(2 CH_3) (OH)] 97. CH_2-CH (OH)-C [(2 CH_3) (OH)] 98. CH_2-CH (OH)-C [(CH_3) (CH_2)] **In conclude:** The majority of cycloartanes type triterpene were active against leukemia cancer. 99. CO-CH=CH-C [(COOH) (CH_3) 100. CH_2-CH(OH)-C [(2 CH_3) (OH)] 101. CH=CH-C [(2 CH_3) (OH)]	 	Lowe *et al.*, 2014a
Hemi-synthesis  1,3-di-O-cinnamoyl-glycerol  2-acetoxy-5-((*E*)-3-(3-((*E*)-3-(3,4-dimethoxy phenyl) acryloyloxy)-2-hydropropoxy)- 3-  3-(3,4-dimethoxy-phenyl)-acrylic acid 2-hydroxy-3-(3-ptolyl-acryloyloxy)-propyl ester  4-((*E*)-3-(3-((*E*)-3-(3,4-dimethoxy phenyl) acryloyloxy)-2-hydropropoxy)-3-oxoprop-1-enyl) benzoic acid	*in situ* to the Wittig reagent **In conclude:** The compounds did not show anticancer activity	Lowe *et al.*, 2014b

Lowe, 2014

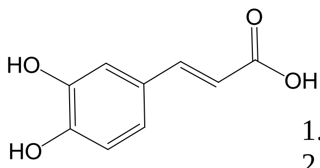


((*E*)-(2-(3-(3-(3,4-dimethoxy phenyl) acryloyloxy)-2-hydroxypropoxy)-2-oxoethyl) triphenyl phosphonium bromide)

1. Phosphonium bromide
2. Wittig reaction

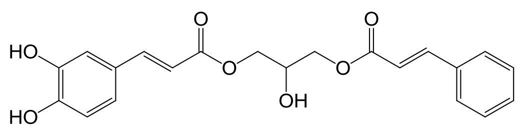


(*E*)-3-(cinnamoyloxy)-2-hydroxypropyl 3-(3,4-dimethoxyphenyl) acrylate

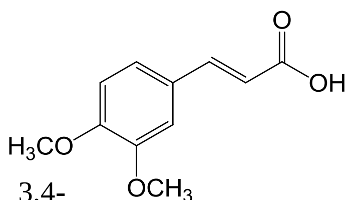


Caffeic acid

1. Acetic anhydride
2. varying the molar ratio of 2,3-diacetylcaffeic

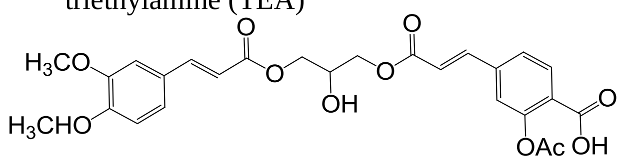


(*E*)-3-(cinnamoyloxy)-2-hydroxypropyl 3-(3,4-dihydroxyphenyl) acrylate



3,4-Dimethoxycaffeic acid

1. Acetylation of 4-formyl-2-hydroxybenzoic acid
2. Acetic anhydride (AC_2O) and triethylamine (TEA)



2-acetoxy-4-((*E*)-3-(3-((*E*)-3-(3,4-dimethoxy phenyl) acryloyloxy)-2-hydroxy propoxy)-3-oxoprop-1-enyl)

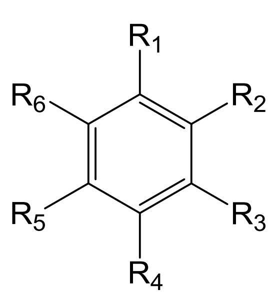
In conclude: B-16-cell line. Activity of analogous compounds, cytotoxic activity with anticancerogenic potential.

fasciculate

Exposure to mercury vapors-saturated, during 10 days

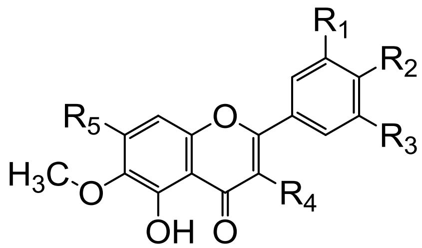
Siegel *et al.*, 1987

	R_1	R_2	R_3	R_4	R_5	R_6
Pyrogallol	OH	OH	OH	H	H	H
Gallic acid	H	COOH	H	OH	OH	OH
Guaiacol	H	OH	OCH_3	H	H	H
Dymethoxyphenol	H	OCH_3	OCH_3	OH	H	H
p (N-methylamino) phenol	H	H	NH-CH_3	H	H	H



In conclude: Increment of peroxidase activity due at phenol compounds

utruculata	As well as C-glycosyl flavones with apigenin skeletons	Ulubelen & Mabry, 1982



In conclude: The first report on the occurrence of the phenylpropanoid glycerols in *Tillandsia* genus

Reported compounds: 1. cycloart-23-ene-3β ,25-diol; **2**. 25-methoxycycloart-23-en-3β-ol; **3**. Cycloartenol; **4**. cycloart-25-ene-3β,24(α or β)-diol; **5**. Acetate of cycloart-25-ene-3β,24(α or β)-diol; **6**. 3β-hydroxycycloart-25-en-24-one; **7**. 25-hydroxycloartanol; **8**. Cycloartanol; **9**. 3β -acetoxycycloart-23, 24, 25-triol; **10**. nd; **11**. nd; **12**. Methyl 3β-hydroxy-24,25,26,27-tetranorcycloartan-23-oate; **13**. 3 β-hydroxy-cycloartan-24-one; **14**. Cycloartenone; **15**. Cycloartenol; **16**. Cycloartenone; **17**. Cycloartenol; **18**. 3β-hydroxycycloart-25-ene-24-one; **19**. cycloart-25-ene-3 β,24 (α or β)-diol; **20**. Cycloart-23-ene-3β,25-diol; **21**. 25-methoxycycloart-23-ene-3β-ol; **22**. Cycloeucalenol; **23**. 24-methylenecycloartanol; **24**. Cyclolaudenol; **25**. 24-methycycloartanol; **26**. 6-Hydroxykaempferol 3,6,7.4'-tetramethyl ether; **27**. Cirsilineol; **28**. Jaceosidin; **29**. Penduletin 4’-0-methyl ether (5-hydroxy-3,6,7,4‘-tetramethoxyflavone); **30**. Artemetin (5-hydroxy-3,6,7,3’,4’-pentamethoxyflavone); **31**. Retusin (5-hydroxy-3,7,3’,4’-tetramethoxyflavone); **32**. 25-hydroperoxycycloart-23-en-3β-ol; **33.** 24-hydroperoxycycloart-25-en-3β-ol; **34.** Hemisynthesis 1 cycloart-23-ene-3β, 25-diol; **35.** Hemisynthesis 2 cycloart-25-ene-3β,24(α or β)-diol**; 36.** Cycloartenol; **37**.(22*E*)-25,26,27-trisnor-3-oxocycloart-22-en-24-al; **38**. (24*E*)-3-oxocycloart-24-en-26-al; **39**. 24-hydroxycycloart-25-en-3-one, **40**. (23*E*)-25-methoxycycloart-23-en-3-one; **41**. (23E)-25-hydroperoxycycloart-23-en-3-one; **42**. 25,26,27-trisnor-24-hydroxycycloartan-3-one; **43.** schisandronic acid; **44**. Hydroxycycloart-23-en-3-one,25; **45**. cycloart-25-ene-3β,24(α or β)-diol; **46**. (23*E*)-cycloart-23-ene-3â,25-diol; **47**. cycloart-23-ene-3β ,25-diol; **48**. (23E)-25-methoxycycloart-23-en-3â-ol; **49**. 24-hydroperoxycycloart-25-en-3β-ol; **50**. 3β-hydroxycycloart-25-en-24-one; **51**. 24(*E*)-3α-hydroxycycloart-24-en-26-al; **52**. Methyl (24*E*)-26-carboxy-3,4-seco-cycloarta-4(29),24-dien-3-oate; **53**. Dimethyl 3,4-seco-cycloart -4(29), 24(*E*)-diene-3,26-dioate; **54**. Methyl (23*E*)-25-hydroxy-3,4-seco-cycloart-23-en-3-oate; **55**. 7. methyl (23*E*)-25-methoxy-3,4-seco-cycloart-23-en-3-oate; **56**. methyl 24-hydroxy-3,4-seco-cycloart-25-en-3-oate; **57**. 27-nor-cycloartan-3,25-dione; **58**. 24,25,26,27-tetranor-3-oxo-cycloartan-23-al; **59**. 25,26,27-trisnor-3-oxocycloartan-24-al; **60**. Tillandsinone (24-isopropenylcycloartan-3-one); **61**. Cyclolaudenyl formate; **62**. Cyclolaudenone; **63**. Cyclolaudenol; **64**. Cyclolaudenyl acetate; **65**. (24*S*)-24-isopropenyl-29-nor-5α-lanosta-7-en-3β-ol; **66**. (24*S*)-24-isopropenyl-29-nor-5α-lanosta-7-en-3β-yl-acetate; **67**. (24*S*)-24-isopropenyl-29-nor-5α-lanosta-7-en-3-one; **68**. 27-nor-3β-hydroxycycloart-23-en-25-one; **69**. (23*E*)-cycloart-23-ene-3â,25-diol; **70**. cycloart-23-ene-3β ,25-diol; **71**. 3β-hydroxycycloart-25-en-24-one; **72**. nd; **73**. Wrightial; **74**. 24-hydroperoxycycloart-25-en-3β-ol; **75**. cycloart-25-ene-3β,24(α or β)-diol; **76**. Cycloartenol; **77**. Cycloartane-3,24,25-triol; **78**. Cycloeucalenol; **79**. Sterculin; **80**. nd; **81**. nd; **82.** nd; **83**. nd; **84**. nd; **85**. nd; **86**. nd; **87**. 27-nor-cycloartan-3,25-dione; **88**. nd; **89**. nd; **90**. 3 ,23-Dioxo-9,19-cyclolanost-24-en-26-oic acid; **91**. 24,25-Dihydroxycycloartan-3-one; **92**. Hydroxycycloart-23-en-3-one,25; **93**. nd; **94**. nd; **95**. nd; **96**. Cycloart-23-ene-3,25-diol; **97**. Cycloartane-3,24,25-triol; **98**. Cycloart-25-ene-3,24-diol; **99**. 3,23-Dioxo-9,19-cyclolanost-24-en-26-oic acid; **100**. 24,25-Dihydroxycycloartan-3-one; **101**. Hydroxycycloart-23-en-3-one,25-ol.

Pharmacological activities

The medicinal uses of *Tillandsia* in many cultures have satisfied the use of several experimental models for its study. Mainly, *in vitro* (microbicide, antiviral and cytotoxic) and *in vivo* (hypoglycemic, anticancer, and anti-inflammatory), whereas clinical studies there are not yet available. Table No. 3 enlists the ethnobotanic data and primary pharmacological studies in distinct *Tillandsia* species in order of importance. In Table 4, the similar studies that have been carried out with different *Tillandsia* species are listed. Weld (1945) and Webber *et al*. (1952) reported a flavonol-type glycoside as microbicide agent from *T. usneoides* extracts. Also, Feurt & Fox (1952) indicated the effect estrogenic of eight species of *Tillandsia*, which induced estrus in male rats (two to the last row in Table 2). Posteriorly, Williams (1978) observed in a wide variety of *Tillandsia* species the presence of quercetin and flavonols hydroxylated, among other compounds, which are enlisted in the Table No. 4.

Keller *et al*. (1981) and Medon *et al.* (1985) reported the hypoglycemic effect of *T. usneoides* in rats. Simultaneously, Ulubelen & Mabry (1982), Arslanian *et al*. (1986) and Siegel *et al*. (1987) reported poly-hydroxylated flavonoids isolated from *T. purpurea*, *T. fasciculata*, and *T. utriculata* (Table 2). Siegel *et al*. (1987) informed the induction of antioxidant compounds in *T. fasciculata* due to the presence of mercury vapors, which incremented the peroxidase activity.

Witherup *et al*. (1995) confirmed the use of *T. usneoides* against diabetes, being the 3-hydroxy-3-methyl glutaric acid (HMG), the molecule active (Table No. 3). Cantillo-Ciau (2003) and Vite-Posadas *et al*. (2011) retaken the pharmacological study of the plants of the *Tillandsia* genus (Weld 1945 and Webber *et al*., 1952) as a microbicide in human pathogen organisms (Cantillo-Ciau *et al*., 2003; Vite-Posadas *et al*., 2011). Cantillo-Ciau et al. (2001) also reported the compounds **60-64** from *T. brachycaulos*. Delaporte *et al.* (2004) reported several compounds from *T. streptocarpa* (cycloartenol, 4',5-dihydroxy-3',7-dimethoxyflavone, and compounds **26-28**), which is used in medicine traditional as analgesic and anti-inflammatory, which inhibited the ear edema in the rat. In both cases existed a positive correlation between the traditional uses of this plant and the experimental data.

Posteriorly, Andrighetti-Fröhner *et al*. (2005) reported the antiviral activity (HSV-1) of polyphenol compounds from *T. usneoides*, which in traditional medicine was indicated for the treatment of ophthalmic illnesses, again validating the relationship between conventional use and experimental data. The molecules in *T. buseri*, β-sitosterol, 4-methylcholesterol, and lanosterol, showed utility as biomarkers for the reconstruction of vegetation in the past (Jansen *et al*., 2007). More recently, Lowe *et al.* (2008, 2012a, 2013b, 2014a) reported *T. recurvata* organic extracts against leukemia and prostate cancer that is the sixth leading cause of death in men (Stennett & White 2013), conferring biological activity to the cycloartane triterpenes, to the phenolics compounds and the soyasaponin molecule (compounds **68-101**).

On the other context, it was also reported that a fungus (*Xylariaceae* sp.), which is a host of *T. usneoides*, synthesizes cytochalasin, a metabolite with cytotoxic effect in human tumor cell lines (Xu *et al.*, 2015). Also, 1,3-di-O-cinnamoyl-glycerol failed as an anticancer drug, which was isolated from $CHCl_3$ extract, although this extract if it was active, Therefore, other compounds in the extract. Also, several derivates by hemisynthesis were obtained which also were studied (Table No. 2).

Thus, *T. usneoides* and *T. recurvata* are the plants most studied of the *Tillandsia* genus; however, other *Tillandsia* species exhibited a similar chemical content as well as biological effects of interest, such as anti-diabetic, bactericide, microbicide, anti-inflammatory, antiviral, and anti-cancer, which should be studied in depth including clinical studies. Therefore, the future is promising for exploring more biological effects of other *Tillandsia* plants against various diseases.

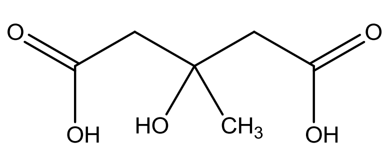
Some other medical applications of *Tillandsia* plants, particularly of *T. usneoides*, have been practiced since the mid-twentieth century. Dean (1943) and Metzger (1943) reported that extracts of *T. usneoides* possessed antigenic properties against rhinitis and asthma, without an allergic reaction. Nowadays, many Chinese medicinal preparations based in *T. usneoides* as post-treatment in craniotomy surgery (Lin, 2013), post-dural puncture headache (Li & Cui, 2013) and hiatal hernia (Wang, 2013) have been proposed. In addition, a method to obtain nucleus in suspension for investigation from *Tillandsia* plants was proposed (Jin *et al.*, 2014), including the use of *T. recurvata* in processes of harvesting, packaging, transportation, and production of capsules and tablets, and as an alternative medicament against AIDS-related diseases (Aizpurua, 1998).

Tillandsia genus: the future

The future of *Tillandsia* research is uncertain and paradoxically disastrous in many Latin-American countries. For instance, in Mexico, particularly in some communities at Queretaro, State of Mexico and Veracruz, the people responsible for the care of the Protected Natural Areas depleted the *Tillandsia* plants due to the erroneous conception of that are parasitic plants. Fortunately, nowadays we are proposing as a strategy the environmental education, to give more diffusion of the ecological, medicinal, social, economic and cultural importance of the plants of the *Tillandsia* genus. For instance, there are communities in which the care of *Tillandsia* species is a priority, as at Santa Catarina Ixtepeji and the community of 'El Mandimbo' in San Miguel del Puerto, Oaxaca, México. In these localities, native people under the tutelage of their traditional uses and customs, and their forests protect these plants against pillage and the deforestation. The acquisition of natural resources requires official permission. The goal will be to stop the harmful practices with this resource, which is relevant worldwide.

T. usneoides and *T. recurvata* also can have utility as atmospheric indicators (Wherry and Capen, 1928). Brazil and Mexico reported the efficiency of *T. usneoides* for this purpose (Cardoso-Gustavson *et al*., 2016; Castañeda *et al*., 2016). *T. velutina* Ehlers also is a good indicator of atmospheric pollutant formaldehyde (Li *et al*., 2015). The study of the *Tillandsia* genus as an indicator of environmental pollutants is a topic of high relevance that should be considered in further studies.

Table No. 3
Traditional use and pharmacological effects of *Tillandsia* spp.

Tillandsia	**Part used**	**Extract**	**Use, chemistry and biological activity**	**Author**
usneoides	nd	Alcoholic	Antibiotic action against *H. influenza*, *C. hominis*, *E. colli* and *B. proteus.* **In conclude:** Microbicide.	Weld, 1945
		Acetone	*M. pyrogenes* var. *aureus* (*S. aureus*) (0.2 ml sample showed a 1.0 to 1.5 cm inhibition zone) **In conclude:** microbicide; responsible molecule: flavonol-type glycoside.	Webber *et al*., 1952
	Whole plant	Aqueous (tea). In south Louisiana is used for diabetes	Blood glucose decrease (%) by oral administration of *T. usneoides* aqueous extract in rats. Dose (mg/kg)/ Time (h) — 4 — 8 125 — 28.7 — 19.4 250 — 20.2 — 27.2 500 — 21.2 — 27.1 **In conclude:** Hypoglycemic activity.	Keller *et al*., 1981
	nd	Aqueous/ EtOH	hypoglycemia (11.1% and 9.4%, respectively) at 7 day in rats. **In conclude:** Hypoglycemic effect.	Medon, *et al*., 1985
	Fresh moss	EtOH	Tea has been used in Louisiana to allay the symptoms of diabetes mellitus. 3-hydroxy-3-methylglutaric acid (HMG) decreased blood glucose (41.7%) in mice. **In conclude:** Hypoglycemic effect. **3-hydroxy-3-methylglutaric acid (HMG)** 	Witherup *et al*., 1995
	Water	Whole plant	Used traditionally for diabetes. **In conclude:** Hypoglycemic effect.	Marles and Farnsworth, 1995
	Aerial parts	CH_2CL_2 hexane, EtOAc,	Usos: Hypertesion, rheumatism, hemorrhoids, cholagogue, diuretic, renal and ophthalmic illnesses.	Andrighetti-Fröhner *et al*., 2005

		n-butanol	Extracts showed activity against Herpes simplex virus type 1 (HSV-1) Kos strain (CE_{50}= 10, 3, 3 µg/ml, respectively) as well as HSV-1 29-R strain (CE_{50}= 29, 23, 12 µg/ml, respectively). **In conclude**: Antiviral activity is due to polyphenol compounds.	
recurvata	Super-critic fluid Extracts CO_2/MeOH 70/30	nd	*In vitro*: Three bioactive fractions: cytotoxic 99.1% at 0.07-70 µg/ml in B16 cells (100% kill; 1 mg/ml); also inhibited: PC-3, K SIMM, BLym, BC.EC_{50}=70 ng/mL *In vivo*: Extract: 5-10 mg/kg subcutaneously during seven days. Apoptosis cell death. Decreased inflammatory process. **In conclude**: Anticancer properties from *T. recurvata* extract.	Lowe, 2008; Lowe *et al.,* 2012a; Lowe *et al.,* 2012c

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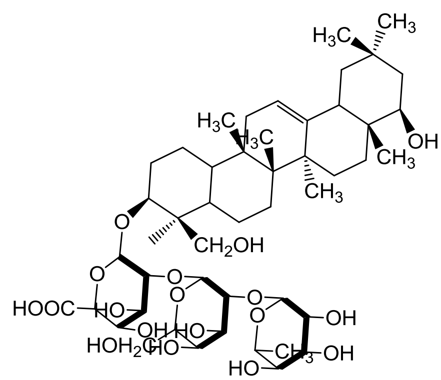


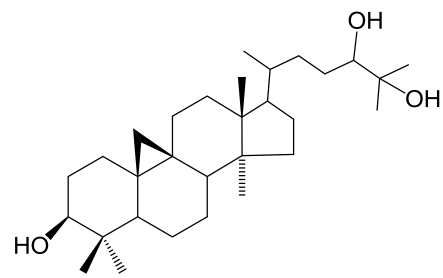
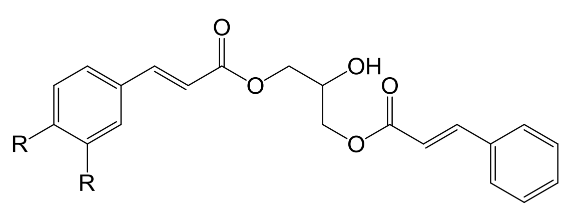
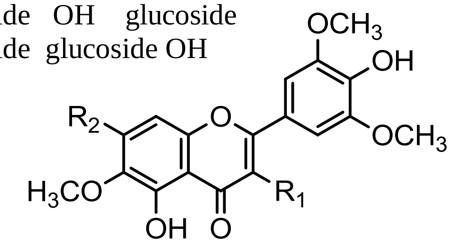
	Whole plant	$CHCl_3$	Extract inhibited MEK5, GAK, CSNK2A2, FLT and DRAK1 (Kd_{50}<20 µg/ml), as well as protein kinase 1 (DRAPK1, Kd_{50}=12 µg/ml). **In conclude**: Extract active against MEK5 and GAK (associated with prostate cancer). Cycloart-23-ene-3,25-triol inhibited MRCk (Kd_{50}= 0.26 µM), showing cytotoxicity toward PC-3 and DU145 (IC_{50}= 2.22 and 1.67 µM), respectively. **In conclude:** Cycloartane-3,24,25-triol has shown potential for development as an anti-cancer agent against prostate cancer. **Cycloart-23-ene-3,25-triol** 	Lowe *et al*., 2012a; Lowe *et al.,* 2012b
		$CHCl_3$	Aortic ring *ex vivo*: extract inhibited sprout formation (10-20 µg/ml). Cytotoxic activity in A375, MCF-7 and PC-3 (0.9, 40.51 and 5.97 µg/ml, respectively. In conclude: Anticancer activity of the extract by anti-angiogenesis effect. The compound C1 inhibited sprout formation with weak cytotoxic activity. C2 exhibited also weak cytotoxic activity. **C1**. 1,3-di-O-Cinnamoyl-glycerol (R=H). **C2**. (E)-3-(cinnamoyloxy)-2-hydroxypropyl 3-(3,4- dimethoxyphenyl) acrylate (R=OCH_3) 	Lowe et al., 2012d; Lowe et al., 2013a

Table No. 4
Similar studies that have been carried out with different *Tillandsia* species.

Tillandsia	Used part	Extract	Ethnobotanical data and pharmacological studies	Reference
aloifolia *balbisiana* *circinate* *fasciculata* *juncea* *simulata* *tenuifolia* *usneoides*	Fresh plant	Water, Benzene, EtOAc, $CHCl_3$	Adult female rats (1 mg of the crude extract) during 48 h, female albino rats (0.01 mg/30 g; extract/ body **In conclude:** induced estrus in ovariectomized male rats	Feurt & Fox, 1952

Compounds reported in MeOH extracts of leaf and steam of other *Tillandsias* spp — Williams, 1978

	R_1	R_2
6,3',5'-trimethoxy-3,5,7-4'-tetrahydroxyflavone	OH	OH
3,6,3',5'-tetramethoxy-5,7,4'-trihydroxyflavone 7-glucoside	OH	glucoside
6,3',5'-trimethoxy-3,5,7,4'-tetrahydroxyflavone 3-glucoside	glucoside	OH



Tillandsia	palutelin 3-glucoside	6-OH-flavonols	6-OH-luteolin	Quercetin	C-glycosides	Luteolin
caput-medusae		✓				
cyanea			✓			
aeranthos				✓	✓	
lindeniana			✓	✓		✓
morrenian			✓			✓
streptophyla		✓				
tricolor		✓				
brachycaulos				✓		
streptocarpa					✓	
recurvata					✓	
bulbosa	✓					

In conclude: Flavonoids present with hydroxylation or methoxylation at the 6 or 8 position

Tillandsia: aeranthos recurvata usneoides	nd	EtOH	Antispasmodic and against infection eye Antibiotic effects against *E. colli, S. aureus, P. aeruginosa, B. utilis* and *M. luteus* (10 mg/ml). **In conclude**: Direct relationship between traditional medicine and experimental study	Alonso *et al.*, 1995

Reported solvents: MeOH. Methanol; **EtOH; ethanol; $CHCl_3$; chloroform; CH_2Cl_2. Dichloromethane; EtOAc**. Ethyl acetate; **nd**: no determined

CONCLUSION

Tillandsia genus was used in ancient times as fiber in pottery. Nowadays it is mainly used as ornamental and as a medicinal remedy in Latin America. Also, as part of the rituals in some communities, even too as raw material for products of use to polish. *Tillandsia* genus has economic importance in emerging markets as well as is utilized in cosmetics products. From the chemical point of view, more than 40 compounds in 24 *Tillandsia* species have been proposed, such as cycloartane triterpenes and hydroxyflavones as majoritarian metabolites. Several compounds have been associated with biological activity: HMG as a hypoglycemic agent, polyphenols as antiviral and antioxidant properties, soyasaponin I and Cycloartane-3,24,25-triol, as anticancer agents, among others. Several compounds and extracts have been associated with biological activities that are promissory for the treatment of distinct disease conditions, like metabolic syndrome, cancer, AIDS, mycosis, and other infectious diseases. However, only around 10% of *Tillandsia* species has been explored, which makes the future of research for this genre promising. *Tillandsia* genus exhibits cultural, economic and pharmacological relevance, with good potential in many essential aspects of the modern society.

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