CIÊNCIA e NATURA

UFSM

Ci. e Nat., Santa Maria v.42, e12,
Special Edition: 40 anos, p. 1-17, 2020
DOI:10.5902/2179460X40157
ISSN 2179-460X

40 years - anniversary

Received: 04/10/19 Accepted: 17/10/19 Published 03/09/20

A review of anatomical, physiological, biological characteristics and uses of *Plectranthus neochilus*

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ABSTRACT

Plectranthus neochilus' tea is widely used for medicinal purposes like digestive disorders, liver problems, hangover and to a lesser extend, for treating respiratory infections. It is one type of "boldo" used in different corners of the world because it has a year-round growth, easy adaptation and environmental resistance, tolerating intense sun and demanding little manipulation. This review aims to compile the up-to-date information about *P. neochilus* obtained from scientific databases (ScienceDirect, Springer, Google Scholar and PubMed). The plant was recently identified and differentiated anatomically and microscopically from anothers also called "boldo". Many compounds were identified in their extracts (aqueous, ethanolic, hexane among others). The most recent studies point out the importance of its essential oil, rich in mono and sesquiterpenes. Some activities presented by these extracts or essencial oil are: antioxidant, insecticidal, antibacterial, antifungal, anticancer and antischistosomal activity. In relation to the non-traditional use of the plant, it is used to promote phytoremediation or to be used in green roof. *P. neochilus* has versatility use and high valuable biological character therefore, more studies are necessary with more extracts and formulations of their oil in order to verify activities in different experimental models.

Keywords: Extracts; Essential oil; Biological activity

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1 INTRODUCTION

The genus *Plectranthus,* of family *Lamiaceae*, belongs to the subfamily *Nepetoideae*, tribe *Ocimeae*, subtribe *Plectranthinae*. This genus has approximately 300 species of perennial herbs and shrubs native to tropical regions of Africa, Asia and Australia (Codd, 1985; Rice et al., 2011). The name *Plectranthus* comes from the Greek words *plektron* (spur) and *anthos* (flower), describing a spur the flowers have at their base (figure 1) (Waldia et al., 2011).

About 85% of *Plectranthus* species are used for medicinal purposes (Rice et al., 2011). In Brazil, the use of these plants is mainly directed to digestive disorders and hepatic complaints (Bandeira et al., 2010; Bandeira et al., 2011; Lukhoba et al., 2006). Among the species identified, around 62 of the genus *Plectranthus* are used worldwide for medicinal or ornamental purposes, along with a rich diversity of ethnobotanical uses (Waldia et al., 2011). Popular uses of these species worldwide include: treatments for headaches, wounds, burns, dermatitis, allergies, insect and scorpion stings, and also as an antiseptic agent. Plants of the genus are important sources of new bioactive compounds and potential medicines, perfumery and cosmetics (Ascensão et al., 1998; Ascensão, Mota and Castro, 1999). The study of Abreu et al. (2015) about *Plectranthus amboinicus* (Lour.) Spreng, *Plectranthus barbatus* (Andrews) and *P. neochilus*, in Northeastern Brazil, showed that *P. neochilus* are the most known medicinal plants considering they were mentioned by 47% of the interviews.

The *P. neochilus* is a herbaceous plant known as “boldinho”, “boldo da folha miúda”, “boldo”, or, "boldo-gambá", according to traditional medicine in Brazil. This plant is an aromatic herb of easy territorial adaptation which grows during all year and its leaves are widely used in the form of tea in traditional medicine (Couto, 2006). In South Africa, this species is very cultivated mainly because it is a plant that grows rapidly by cuttings and requires little maintenance, it is widely used for the development of new gardens, as well as for ground cover, therefore, it assists in the accumulation of mulch that fertilizes the soil, retains moisture and competes with weeds (Pooley, 1998; Van Jaarsveld and Thomas, 2006). At the same time, in domestic use it works as an air purifier (Pooley, 1998).

This review will address the following subjects: 1) anatomical, morphological and microscopic characteristics of *P. neochilus*; 2) chemical composition of its extracts and essential oil; 3) traditional and non-traditional uses of this species.

2 CHARACTERISTICS AND MORPHOLOGY OF PLECTRANTHUS NEOCHILUS

2.1 Anatomy and development of plant

P. neochilus has an important role in human health due to its uses for healing purposes in the folk medicine through tea infusions, especially for the treatment of hepatic failure and dyspepsia (Couto, 2006; Lorenzi and Matos, 2002). However, its traditional use goes beyond that, an ethnomedical research in rural communities of South Africa showed that this species is used to treat respiratory infections (chills, cough and a runny or blocked nose) taken orally (York et al., 2011).

In this sense, through the vast use of this medicinal plant, the identification of *P. neochilus* had already been done by some authors, although they focused only in the morphological characteristics of the plant. Whereas many species are called boldo because they are used for stomach aches and liver problems, Duarte and Lopes (2007) analyzed the stem and leaf anatomy of *P. neochilus,* making possible possible to distinguish more clearly "Brazilian Boldo" (*P. barbatus* Andrews), "Japanese Boldo" (*Vernonia condensata* Baker, Asteraceae) (Lolis and Milaneze-Gutierre, 2003) and the “Chilean Boldo” (*Peumus boldus* Molina, Monimiaceae) from *P. neochilus* (boldo-gambá). So, the union of the oldest researches with the new ones contributed with the creation of a list containing the peculiar characteristics (morphological, anatomic, and others) for *P. neochilus*, as can be seen in table 1:

Table 1 - Characteristics of growth and development, morphological, anatomic, and others of *P. neochilus*

Characteristic	Description	Reference
Growth and development	Perennial, sometimes annual plant, prostrate and erect, usually very branched and dense. The species does not produce seeds and its vegetative propagation by cuttings enables the production of seedlings in less time, with greater uniformity and standardization. The plant can be planted at any time of the year.	Codd, 1985; Coelho et al., 2014; Couto, 2006; Lorenzi e Matos, 2002
Anatomical	Succulent grass measuring 0.12-0.5 m in height, with moderate to densely villous branches.	Codd, 1985; Coelho et al., 2014; Couto, 2006; Lorenzi e Matos, 2002
Leaves	Petiolate and have juicy blades, usually viscous. It also tends to fold along the central vein, being egg-shaped, but with the apex wider than the base (20-50 x 15-35 mm), pubescent, with orange glands beneath the surface, obtuse apex, narrow, acute base and margin with some teeth.	Codd, 1985, Duarte and Lopes, 2007
Odor	Leaves and flowers: are strong and the taste is bitter.	Lorenzi e Matos, 2002
Flowers	Petiole measures 5-15 mm in length, has inflorescence racemosa with violet coloring, and tuberous roots. Inflorescence terminal racemic type (70-150 mm), bracts (25 ° angle), greenish with purple tip, early deciduous. Flowers in 3 sessions, forming whorls of six flowers, dense whorls above, flexible and 5-15 mm to the bottom and erect pedicels. Chalice 6 mm long in fruit, tube slightly geniculate on the middle and expanded to the throat. Upper lip bluish white, 2 mm long; boat-shaped lower lip (8-11 mm). Stamens 8-11 mm long, attached at the base 2-3 mm.	Codd, 1985

These characteristics can be seen in figure 1 (a) and (b).

Figure 1 – Photos of *Plectranthus neochilus* and its inflorescence. Figure 1 (a) Drawing of the anatomy of *P. neochilus*. Figure 1 (b) *P. neochilus* with inflorescence

a) b)

Source (a): Duarte and Lopes, 2007. Source (b): Author

A peculiar characteristic in relation to its strong odor was that bees are the effective pollinators of this plant in South African region, according to the study of Stirton (1997). Among the genera of the bees, five species of *Megachile*, three species of *Xylocopa*, one species of *Anthophora* (now genus *Amegilla*) and *Apis mellifera* (all *Hymenoptera, Apidae*) were considered to be effective pollinators. The author also listed other insects known as non-effective pollinator: a family of flies *Diptera: Bombyliidae*, a specie flower flies (*Diptera: Syrphidae*) and a butterfly *Macroglossa trichilioides (Lepidoptera: Sphingidae*).

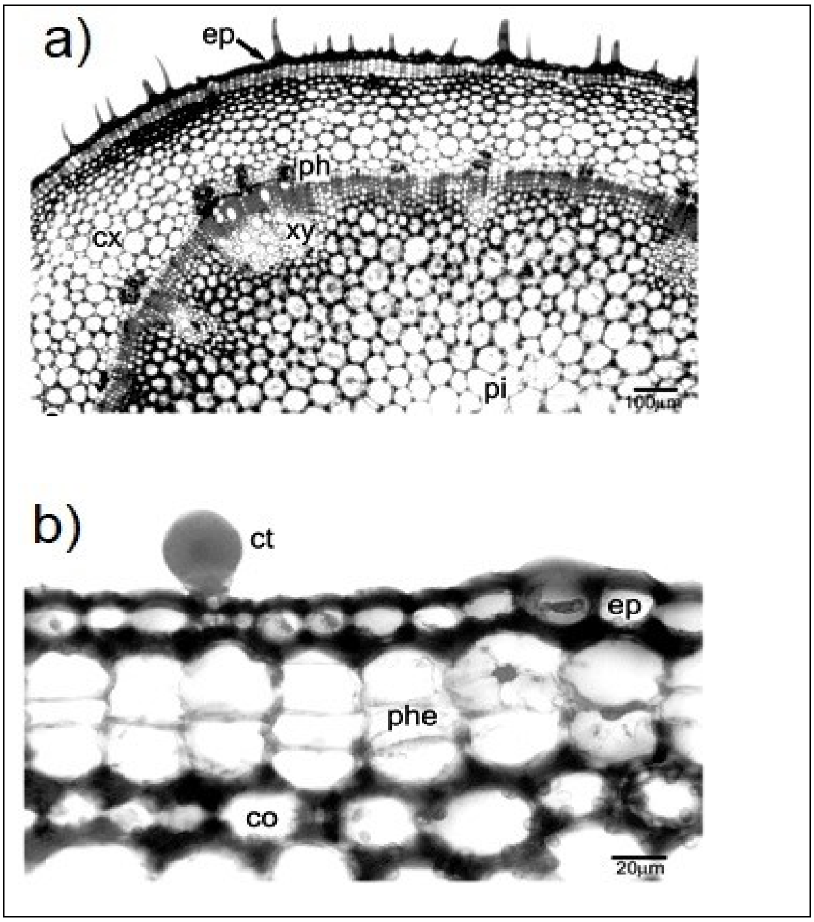
Regarding the best conditions of growth and development of the plant, the study of Lima et al. (2018) showed differences in the development of this plant when it was cultivated in two conditions of solar intensity (50% and 100%). Under 50% of the availability of sunlight, the "boldo" increases its leaf area and the internodes of distance for the best use of the luminosity in the photosynthetic process, while under full sunlight the plant produces less leaf area and reduces the distance between leaves that are practically superimposed to avoid stress due to excessive light.

In order to produce plants with greater synthesis of secondary metabolites potentiated by traditional genetic improvement or genetic engineering, the technique of tissue culture in aromatic and medicinal plants should be considered (Swain et al., 2010). In this sense, Mota et al. (2010) aimed to evaluate the organogenic capacity of leaf explants of *P. neochilus* to obtain plants for future studies of metabolites and potential use in the genetic transformation of plants. So, through the protocol produced, the report demonstrates that shoots and full plants, in this case *P. neochilus*, could be efficiently induced leaves when plants are *in vitro* cultivated in medium supplemented with 0.2 mg/dm-3 NAA (α-naphthaleneacetic acid) and 4.7 to 5.3mg/dm-3 BAP (6-benzilaminopurine).

2.2 Histology

In relation to the microscopic anatomy of this plant, Duarte and Lopes. (2007) observed that *P. neochilus* has a stem with quadrangular rod in transection and reveals an incipient secondary growth at the analyzed level (Figure 2.a). The epidermis is unisserized with polygonal cells in the front shape, being more tangential than radially and, remains as the dermal system, although the phellogen has been established (Figure 2.b). In the cortex , below the phellogen, of this same organ, a continuous strand of collenchyma is found (Figures 2.a and 2.b). It is angular and comprises three or four rows. The multilayered cortical parenchyma has chloroplasts and shows small intercellular spaces. The innermost boundary of the cortex is represented by a single layer of large parenchymatous cells, whose tangential and radial walls are impregnated with lipophilic substances. The vascular cambia form xylem inward and phloem outward, being active mainly in the fascicular region and toward the xylem, although collateral bundles can be distinguished (Figure 2.a). The pith consists of thin walled parenchymatic cells, comparatively greater, containing many amyloplasts and forming small intercellular spaces (Figure 2.a).

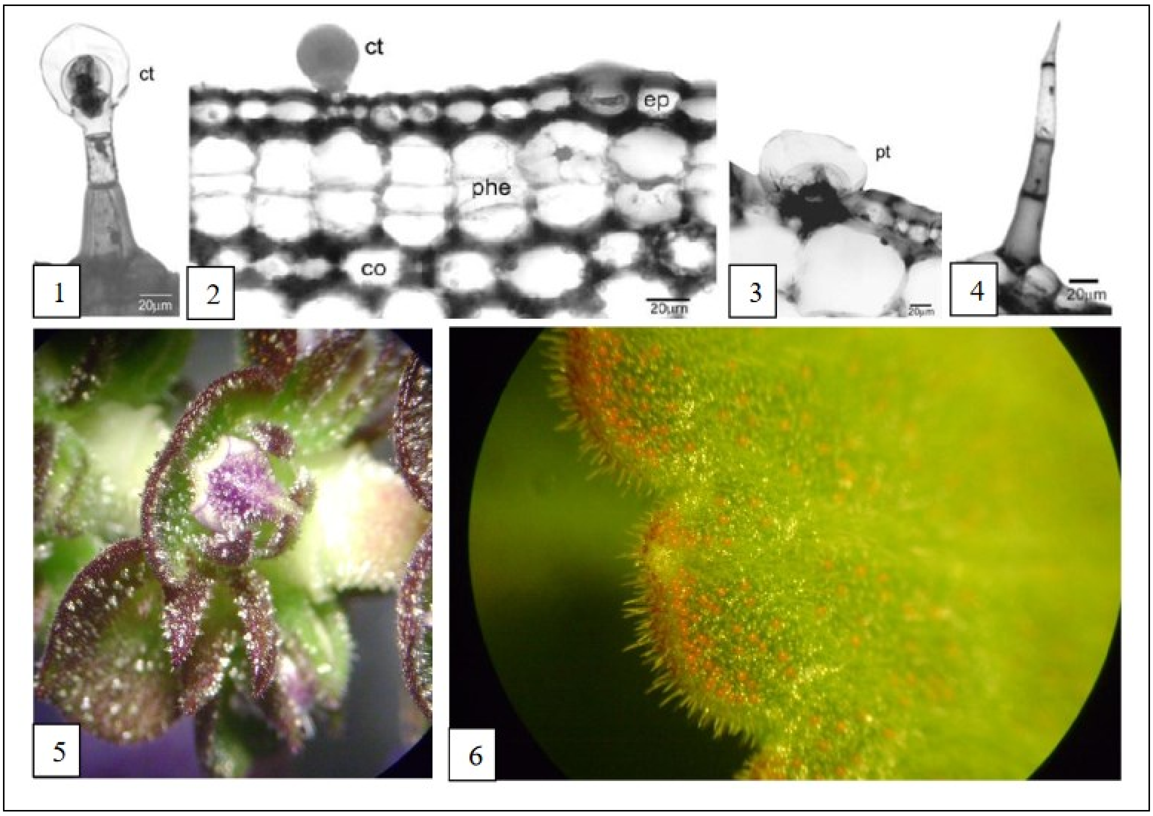
Figure 2 - Transection microscopy of *Plectranthus neochilus*. A) Transection of stem in secondary growth. B) Caulinar dermal system and collenchyma



Legends: ep - epidermis; cx - cortex; ph - phloem; xy - xylem; pi - pith.
Source: Duarte and Lopes (2007)

Viana (2011) observed that *P. neochilus* has some trichomes in the leafs that represent tissues that, in a functional level are the producers of essential oils. This production is responsible for both protection against herbivores and pathogens, and for attraction of pollinators in floral parts. These are checked for their internal anatomical characteristics and can be visualized in Figure 3.

Figure 3 - Transection microscopy of trichomes found in Plectranthus neochilus. 1 - trichome capped with short peduncle, 2 - tricohme capped with short peduncle, detail of the caulinar dermal system and collenchyma, 3 - peltate trichome, 4 - non-glandular trichome, 5 - trichomes in the inflorescence, 6 - trichomes in the leaf limbus



Legend: ct - capitate trichome; ep - epidermis; phe - phellogen; co - collenchyma; pt - peltate trichome.
Source: Duarte and Lopes (2007) and Viana (2011)

Briefly, more morphologically similar species (*P. neochilus*, *P. barbatus*, *P. boldus* and *Veronia condensata*) can be distinguished in the following manner: *P. neochilus* and *P. barbatus* resemble the stem organization, but differ in leaf characteristics. *P. barbatus* has leaves with polygonal epidermal cells in surface view, anomocytic stomata, comparatively more trichomes and dorsiventral mesophyll. *P. neochilus* differs from *P. boldus* because the latter exhibit hypostomatic leaf, stellate trichomes, hypoderm, secretory cells and dorsiventral mesophyll. And, finally, *P. neochilus* differs from *V. condensata* by chlorenchyma organization, that also occurs in *V. condensata* leaf, but the latter has tetracytic or anomocytic stomata, T-shaped non-glandular trichomes and calcium oxalate crystals (Duarte and Lopes, 2007).

Microscopic analysis are very useful, not only for identification purposes, but for toxicity studies of pollutants in plants. In this sense, the work of Campos, Azevedo and Sant'Anna-Santos (2010) characterized, visually and microscopically, the leaf damage caused by potassium fluoride. The authors showed that there was accumulation of fluoride in leaves of “boldo-gambá”, but no visual symptoms were observed in the leaves, only microscopic changes. These modifications occurred in the form and turgidity of the epidermal cells, in the rupture of the cuticle. In addition, the apical cell of the secretory trichomes was deformed and in the stomata there was alteration of the cellular turgidity and rupture of the stomatal crest. The tectorial trichomes were flaccid and folded in the cell wall of the basal cell. Besides that, it was observed that the content of the pollutant present in the tea solution was 8.49 mg/g. Therefore, these results indicate that tea from this species can contribute significantly to the intake of fluoride, depending on the level of consumption of the beverage and the conditions in which the plants are exposed.

3 COMPOSITION AND CONSTITUENTS: ESSENTIAL OIL AND EXTRACTS

3.1 Compounds of essential oil

According to Correa, Scheffer and Ming (2006), the chemical compounds elaborated by the secondary metabolism of medicinal plants give them their value. A characteristic that stands out of *P. neochilus* is the composition of its volatile oils, as previously mentioned in the histology (section 2.1). In this way, several studies were carried out with the essential oil of this plant in different places, like Africa, Brazil and Portugal, and, *P. neochilus* showed to be rich in mono and sesquiterpenes constituents. However, these researches presented differences in the constituents and/or concentrations of the major compounds according to the study site. The table 2 summarizes the relevance of compounds according to location.

These differences are considered accepted according to that Correa, Scheffer and Ming (2006) mentioned on environmental factors (altitude, latitude, temperature, relative air humidity, day length, soil, availability of water and nutrients) and techniques (season and planting form) that influence the production of secondary compounds by plants.

Table 2 - Places of study with *P. neochilus* and constitution of major compounds

Place	Major compounds	Reference
Southern Africa	Predominance of monoterpenes, with citronellyl formate, linalool and isomenthone	Lawal and Hutchings, 2010
Brazil	Predominance of sesquiterpenes, with α and/or β-caryophyllene, trans caryophyllene, germacrene D, or caryophyllene oxide; or half monoterpenes and half sesquiterpenes	Aguiar et al.2018; Baldin et al., 2012; Bandeira et al., 2011; Caixeta et al., 2011; Crevlin et al., 2015; Medeiros et al., 2016
Portugal	Predominance of monoterpenes, with α-thujene, α-pinene , and β-pinene	Mota et al., 2014

In the study by Lima et al., 2018, (cited in section 2.1), that analyzed the percentage of light/shadow in the growth of "boldo" and its development, the results showed that 50% of light had a good influence in biomass production and constituents of essential oil too. In the research of Rosal et al. (2011) the application of different organic fertilizer sources in a light-protected environment were compared, and it was observed the production of biomass, content and quality of essential oil. The following results were obtained: the plants were more responsive when submitted to fertilization with poultry manure than those that were not fertilized or fertilized with bovine and organic manure. The results were very significant, with the amount of essential oil with poultry manure being 11.36 times higher than with non-fertilized plants, 1.76 and 4.59 times higher than bovine and/or organic manure, respectively. In addition, differences were found in the chemical composition of the volatile compounds, being higher for the treatment without fertilizer (27 compounds) than with the treatments using bovine manure (12) and poultry manure (18). This research suggested that the plant suffered stress due to lack of fertilizer for its growth and development, which generated this variation in the composition of volatile compounds treatment without fertilizer. A similar study was found by Medeiros et al.

(2016), which used liquid humus from bovine solid humus at concentrations of 5, 10 and 20%. In this case, the use of liquid humus in different concentrations was not related to the increment of dry and fresh matter, only a decrease in root length in the highest concentration of liquid humus.

3.2 Compounds of extracts

Regarding the analysis of the compounds present in the extracts with organic solvents with the different types of “boldos” there are many works in the literature, for example: Gupta et al. (2013) found caffeic acid, coumaric acid, rutin, quercetin and gallic acid in the acetone extract from the *Plectranthus amboinicus* Benth (Lamiaceae), although in the extract with ethyl acetate from the same plant, these authors found caffeic acid, coumaric acid, rutin, quercetin and gallic acid; Lara-Fernández et al (2013) efficiently extracted the main bioactive component of the “Chilean boldo” (*Peumus boldus*), the boldine, through a hydroethanolic extraction. However, there are few studies about the compounds founded in the *P. neochilus* extracts, but, in the work of Ramborger et al. (2017) it was possible to identify caffeic acid, ferulic acid and coumaric acid in the aqueous extract, and Brito et al. (2018) identified rosmarinic acid, which mimicked the use of traditional tea by decoction. In the study of Viana (2011) the following compounds were found in hexane extract from leaves and stems: friedelin, α-amirine fatty acid ester, sitosterol and stigmasterol. While flavone cirsimaritin could be isolated from the ethanolic extract. It can be seen in table 3 (section 4.2).

4 BIOLOGICAL ACTIVITIES OF P. NEOCHILUS

4.1 Effects of essential oil

The relevance of the studies with the extraction of its essential oil goes beyond the analysis of the constituents, since many studies have identified different biological activities attributed to it. In this way, the essential oil of the leaves of *P. neochilus* obtained a promising activity against causing cavities bacteria (moderate activity against *Enterococcus* *faecalis* - MIC = 250 μg/mL and *Streptococcus salivarus* - MIC = 250 μg/mL, significant activity against *Streptococcus sobrinus* - MIC = 62.5 μg/mL, *Streptococcus sanguinis* - MIC = 62.5 μg/mL, *Streptococcus mitis* - MIC = 31.25 μg/mL, and *Lactobacillus casei* - MIC = 31.25 μg/mL, and interesting activity against *Streptococcus mutans* - MIC = 3.9 μg/mL) (Crevelin et al., 2015). Besides being antibacterial, the oil has antifungal activity with MIC = 125 μg/mL against *R. stolonifera* (Aguiar et al., 2018). Other activities that have already been attributed to essential oil of "boldo" were the antischistosomal properties *in vitro,* where the concentration of 100 μg/mL killed 100% of the adult worms of *Schistosoma mansoni* (Caixeta et al., 2011), and caused reduction in female egg laying and oviposition inhibitor of *Bemisia tabaci* type B whitefly in tomato (Baldin et al., 2013; Fanela et al., 2016). In relation to its essential oil of leaves and stem in the flowering phase, Rosal et al. (2011) analyzed the TBARS assay (thiobarbituric acid reactive substances) to verify the lipid oxidation prevention capacity. The results showed that the essential oil obtained 60% inhibition at the concentration of 1 mg/mL, meaning a reasonable antioxidant action. These researches are listened in table 3 (section 4.2).

4.2 Effects of extracts

By the fact that this plant is widely used in traditional medicine, in the form of tea in substitution of the *Peumus boldus* (Duarte and Lopes, 2007), one study of aqueous extract of leaves obtained good results concerning antioxidant activity (14.7%) (Rijo et al., 2014). This was very good in relation to others types of extracts, as the results found in the work of Viana (2011) which shows smaller antioxidant activity by DPPH method, in methanolic, ethyl acetate and hexane extracts of the leaves and stems. Viana (2011) found 11% of methanolic extract from leaves and stems, 7% of ethyl acetate extract from leaves and stems and, 4% of hexane extract from leaves and stems. In the work of Ramborger et al. (2017), when "boldo" was put in contact with the herbicide 2,4-D (in soil and water), the total antioxidant capacity of the leaves in aqueous extract was decreased in both environments indicating the toxicity of the compound to this plant. It corroborates with what Correa, Scheffer and Ming (2006) mentioned about the environmental and chemical conditions can alter the constituents of the plants, in this case, the antioxidant activity.

When the flower extracts were studied, the results obtained of its methanolic extract showed inferior antioxidant activity (5%) in relation to the leaves and stem which was confirmed by the phenolic content of the extracts. But, Viana (2011) obtained good results for Acetylcholinesterase (AChE) activity of leaves, stem and flower extracts of *P. neochilus* due to the inhibition of AChE enzyme for all extracts tested.

It is known that the most common ethnobotanical use of *Plectranthus* envolves digestive purposes and also, but not so expressive, the cure of hangover. In this sense, a very interesting study of Brito et al. (2018) investigated the compound that the species of *Plectranthus* possessed in common and that justified those traditional uses. For this justification, this study explains that the effects of inhibition of the enzyme AChE, at muscular level, are responsible for catalyzing the hydrolysis of the neurotransmitter acetylcholine (transmit information for muscle contraction, in this case, intestinal motility), and inhibition of alcohol dehydrogenase (ADH), the enzyme responsible for the metabolism of alcohol. The nine species of *Plectranthus* which were studied (among them *P. neochilus)*, all had the compound rosmarinic acid in common. The inhibitory action for AChE by *P. neochilus* was IC_{50} 430 ± 50 μg/mL and by ADH, IC_{50} 95 ± 8 μg/mL.

Beyond this work, previous studies verified the effect of its extracts, like the study of Tempone et al. (2008) that showed methanolic extract of its leaves had a marked determination of the 50% effective concentration (EC_{50}) of 20.51 μg/mL, killing 100% of yeast (*C. krusei*) at the highest concentration. In the work of Antinarelli et al. (2015), the methanolic extract of *P. neochilus* leaves presented promising leishmanicidal activity, exhibiting IC_{50} values below 20 μg/mL in the *L. chagasi* species. The ethanolic extract of *Plectranthus neochilus,* in study of Arcanjo et al. (2012), showed an indication of antitumor activity, due to the lethality of the crustacean *Artemia salina*. The artemia lethality bioassay (*Artemia salina* Leach) is used for quality control of botanical products. This test promotes a correlation with antitumor activity (cytotoxicity) and can be used to monitor the activity of natural bioactive products. Thus, the authors attributed this activity by association with antitumor and larvicidal

Table 3 - Summary of compounds identified in *P. neochilus* extractions and their respective biological activities

Extraction	**Part of plant and compounds identified**	**Biological activity**	**Reference**
Aqueous	Leaves: caffeic acid, ferulic acid and coumaric acid	Antioxidant activity (DPPH and Phosphomolibdenic complex)	Ramborger et al., 2017
	Leaves: chlorogenic acid and rosmarinic acid	Antioxidant activity (DPPH)	Rijo et al., 2014
	Leaves: rosmarinic acid	AChE at muscular level and ADH	Brito et al., 2018
Methanolic	Leaves: -	Antioxidant activity, AChE	Viana (2011)
		Antifungal (*C. krusei*)	Tempone et al., 2008
		Leishmanicidal activity	Antinarelli et al., 2015
Ethanolic	Leaves and stems: -	Cytotoxic (lethality *Artemia salina)*	Arcanjo et al. 2012
	Leaves: Caffeic acid derivatives	Cytotoxic (cell lines of epidermoid carcinoma of head and neck)	
Hexanic	Leaves: friedelin and others), steroidal compounds (sitosterol, among others), diterpenes and sesquiterpenes	Cytotoxic (tongue carcinoma cells: SCC-25)	Borges et al. 2016
	Leaves and stems: friedelin, α-amirine fatty acid ester, sitosterol and stigmasterol	Antioxidant activity (DPPH), AChE	Viana, 2011
Ethyl acetate	Leaves and stems: flavone cirsimaritin	Antioxidant activity (DPPH), AChE	
Essential oil	Monoterpenes and sesquiterpenes	Antibacterial (Enterococcus faecalis, Streptococcus salivarus, Streptococcus sobrinus, Streptococcus sanguinis, Streptococcus mitis, Lactobacillus casei, Streptococcus mutans)	Crevelin et al., 2015
		Antifungal (R. stolonifera)	Aguiar et al., 2018
		Antischistosomal properties *in vitro*	Caixeta et al., 2011
		Reduction in female egg laying and oviposition inhibitor of Bemisia tabaci type B whitefly in tomato	Baldin et al., 2013; Fanela et al., 2016
		Antioxidant action (TBARS)	Rosal et al., 2011

Note: "-" means that authors who did not mention the compounds in this extract.

5 NON TRADITIONAL USES OF P. NEOCHILUS: DOMESTIC AND INDUSTRIAL APPLICATIONS

Although the traditional use of *P. neochilus* is widely reported in various parts of the world to treat stomach and liver problems, this plant has been shown to have utilities that are not taxed in medical terms, but ecological. In this case, the studies related to this aspect are about the phytoremediation capacity and the green roof technology.

5.1 Phytoremediation

The phytoremediation is a low-cost technique and a solution with less environmental side effects, which utilizes plants for the purification or decontamination of aquatic and/or terrestrial environments contaminated (Cunningham and Berti,1993; Islam et al., 2007). The interesting thing about phytoremediation is that it allows the removal of both organic and inorganic pollutants. The organic ones are those produced by the man and they cause damages to the organisms for being, in the majority, toxic and even carcinogenic. Depending on their properties, the organic pollutants can be degraded in the root zone of the plants and when absorbed they can be degraded, sequestered or volatilized. Inorganic matter occurs as natural elements in the earth's crust or in the atmosphere and can not be degraded, but phytoremediated by stabilization or sequestration by the tissues of plants that are treated later (Pilon-Smits, 2005). In order to perform the phytoremediation process it is necessary that the plants meet one or more requirements, such as: deep and dense root system; accelerated growth rate; easy harvest; which have resistance to the pollutant, pests and diseases; be adaptable to the site to be remediated, easy control or subsequent erradication (Pilon-Smits, 2005, Procópio et al., 2009).

In this sense, since *P. neochilus* has the characteristic of being able to be planted and grow throughout the year (Couto, 2006), a study pointed out that for this reason and with its capacity to be strongly resistant to climate and temperature changes, it is able to promote phytoremediation (Ramborger et al., 2017). In this case, the plant promoted the remediation of water contaminated with the acid 2,4-dichlorophenoxyacetic (2,4-D) pesticide. Likewise, in the study of Pereira (2018) the “boldo” also demonstrated this peculiarity, as it promoted the phytoremediation of the herbicide sulfentrazone also in water. One interesting detail of these two works, which aimed at the environmental remediation with this plant, is that they also showed an adaptation of the “boldo” in the water. Although it is a terrestrial plant, it showed an ability to stay alive and healthy throughout the experiment, being in contact only with tap water.

5.2 Green roof technology

The green roof technology consists in building roofs made of waterproofed slabs, followed by a draining layer and substrate, where small and medium-sized plant species are planted. The green roof technology is a viable and sustainable alternative to the traditional roofs and slabs because it provides shade, removes heat from the air, and reduces temperatures of the roof surface and surrounding air (EPA, 2019).

In this way, the research of Morau, Libelle and Garde (2012) used plants to perform an extensive green roof on Réunion Island (Indian Ocean - influenced by a humid tropical climate). According to the authors, the criteria for selecting the plants of the study were succulent plants exhibiting a strong capacity to store water in their leaves and to be highly resistant to drought. The plants listed for this study were *Plectranthus neochilus, Kalanchoe thyrsiflora* and *Sedum reflexum.* As result, the *P.neochilus* showed capacity to decrease the temperature in the surface of the roof and contributed for an exchange of flow of low heat in this green roof. Therefore, *P. neochilus* presented significant results for its use as green roof, however it did not obtain the best performance comparing to other plants studied for this purpose.

6 CONCLUSIONS

In conclusion, *Plectranthus neochilus* has peculiarities according to the location, culture and climate where it is inserted. Its main use is in the traditional way, in the form of tea, however, recent studies of its essential oil or from solvents extraction have shown a greater applicability like in medicine use, to combat certain bacterial strains, schistosomiasis and fly, as well as for environmental remediation (phytoremediation) and environmental temperature control (green cover). Although this plant is extremely versatile, more comprehensive studies of its compounds in extracts are indispensable in specific pharmacological activities for experimental studies, because *P neochilus* is a plant with increasing use and research, having a promising future.

ACKNOWLEDGMENTS

The authors thank CNPq for the grant given to the first author. They also would like to thank the reviewers, collaborators and Federal University of Pampa, Post-Graduate Program in Biochemistry.

REFERENCES

ABREU DBO, SANTORO FR, DE ALBUQUERQUE UP, LADIO AH, DE MEDEIROS PM. Medicinal plant knowledge in a context of cultural pluralism: A case study in Northeastern Brazil. Journal of Ethnopharmacology. 2015; 175, 124–130. https://doi.org/10.1016/j.jep.2015.09.019.

AGUIAR GP, LIMA KA, SEVERIANO ME, GROPPO M, AMBRÓSIO SR, CREVELIN EJ. Antifungal activity of the essential oils of *Plectranthus neochilus* (Lamiaceae) and *Tagetes erecta* (Asteraceae) cultivated in Brazil. Int J Complement Alt Med. 2018; 11, 31–35. 10.15406/ijcam.2018.11.00343.

ANTINARELLI LMR, PINTO NC, SCIO E, COIMBRA ES. Antileishmanial activity of some Brazilian plants, with particular reference to *Casearia sylvestris*. An. Acad. Bras. Ciênc. 2015; 87, 733-742. http://dx.doi.org/10.1590/0001-3765201520140288.

ARCANJO DDR, ALBUQUERQUE ACM, MELO-NETO BB, SANTANA LCLR, MEDEIROS MGF, CITÓ AMGL. Bioactivity evaluation against *Artemia salina Leach* of medicinal plants used in Brazilian Northeastern folk medicine. Braz. J. Biol. 2012; 72, 505-509. http://dx.doi.org/10.1590/S1519-69842012000300013.

ASCENSÃO L, FIGUEIREDO AC, BARROSO JG, PEDRO LG, SCHRIPSEMA J, DEANS SG, SCHEFFER JJC. *Plectranthus madagascariensis*: morphology of the glandular trichomes, essential oil composition, and its biological activity. J. Plant Sciences. 1998; 159, 31-38. 10.1086/297518.

ASCENSÃO L, MOTA L, CASTRO M. Glandular trichomes on the leaves and flowers of *Plectranthus ornatus*: morphology, distribution and histochemistry. Ann. Bot. 1999; 84, 437-447. https://doi.org/10.1006/anbo.1999.0937

BALDIN EL, CROTTI AEM, WAKABAYASHI KAL, SILVA JPGF, AGUIAR GP, SOUZA EF, VENEZIANI RCS, GROPPO M. Plant derived essential oils affecting settlement and oviposition of *Bemisia tabaci* (Genn.) biotype B on tomato. J Pest Sci. 2013; 86, 301–308. https://doi.org/10.1007/s10340-012-0462-x.

BANDEIRA JM, BIANCHI VJ, RUBIN S, PETERS JA, BRAGA EJB. Genetic similarities among four species of the *Plectranthus* (L'Hér.) genus. Acta Sci. Biol. Sci. 2010; 32, 43-48 10.4025/actascibiolsci.v32i1.880.

BANDEIRA JM, BARBOSA FF, BARBOSA LMP, RODRIGUES ICS, BACARIN MA, PETERS JA, BRAGA EJB. Composição do óleo essencial de quatro espécies do gênero *Plectranthus*. Revista Brasileira de Plantas Medicinais. 2011; 13, 157-164. http://dx.doi.org/10.1590/S1516-05722011000200006.

BORGES GA, FERREIRA JF, ELIAS ST, GUERRA ENS, SILVEIRA D, SIMEONI LA. Cytotoxic effect of *Plectranthus neochilus* extracts in head and neck carcinoma cell lines. African Journal of Pharmacy and Pharmacology. 2016; 10, 157-163. 10.5897/AJPP2015.4355.

BRITO E, GOMES E, FALÉ PL, BORGES C, PACHECO R, TEIXEIRA V, MACHUQUEIRO M, ASCENSÃO L, SERRALHEIRO MLM. Bioactivities of decoctions from *Plectranthus* species related to their traditional use on the treatment of digestive problems and alcohol intoxication. Journal of Ethnopharmacology. 2018; 28, 147-154. https://doi.org/10.1016/j.jep.2018.04.006.

CAIXETA SC, MAGALHÃES LG, DE MELO NI, WAKABAYASHI KA, AGUIAR GDEP, AGUIAR DDEP. Chemical Composition and *in vitro* Schistosomicidal Activity of the Essential Oil of *Plectranthus neochilus* Grown in Southeast Brazil. Chemistry & Biodiversity. 2011; 8, 149-157. http://dx.doi.org/10.1590/S0102-695X2013000600004.

CAMPOS NV, AZEVEDO AA, SANT'ANNA-SANTOS BF. Acúmulo e efeitos fitotóxicos do flúor em folhas de boldo-gambá e capim-cidreira utilizadas para chás. Pesquisa Agropecuária Brasileira. 2010; 45, 646-653. https://dx.doi.org/10.1590/S0100-204X2010000700003.

CODD LE. Lamiaceae, in: Leistner, O.A. (Ed.)., Flora of southern Africa. Botanical Research Institute. Pretoria, 1985.; pp 137–172.

COELHO MFB, ARRUDA RDAS, PEREIRA ED, BOMFIM AB, GERMANO EB. Propagation of *Plectranthus neochilus*. Schlechter. Journal of Global Biosciences. 2014; 3, 494-498, 2014.

CORREA JC, SCHEFFER MC, MING LC. Cultivo agroecológico de plantas medicinais, aromáticas e condimentares. In, Ministério do Desenvolvimento Agrário, Brasília. 2006.

COUTO MEO. Coleção de plantas medicinais, aromáticas e condimentares. In: Embrapa, Documentos. CPACT/Embrapa. Brasília, 2006.

CREVELIN EJ, CAIXETA SC, DIAS HJ, GROPPO M, CUNHA WR, MARTINS CHG, CROTTI AEM. Antimicrobial activity of the essential oil of *Plectranthus neochilus* against cariogenic bacteria. Evidence-Based Complementary and Alternative Medicine. 2015, 1-6. http://dx.doi.org/10.1155/2015/102317.

CUNNINGHAM SD, BERTI WR. Remediation of contaminated soils with green plants: An overview. In Vitro Cell Dev-Pl. 1993; 29:207–212.

DUARTE MR, LOPES JF. Stem and leaf anatomy of *Plectranthus neochilus* Schltr., Lamiaceae. Rev. Bras. Farmacogn. 2007; 17, 549-556. http://dx.doi.org/10.1590/S0102-695X2007000400013.

EPA. United States Environmental Protection Agency - USEPA, 2019. Using Green Roofs to Reduce Heat Islands. https://www.epa.gov/heat-islands/using-green-roofs-reduce-heat-islands (accessed 20 June 2019).

FANELA TL, BALDIN EL, PANNUTI LE, CRUZ PL, CROTTI AE, TAKEARA R, KATO MJ. Lethal and inhibitory activities of plant-Derived essential oils against *Bemisia tabaci gennadius* (Hemiptera: aleyrodidae) biotype B in tomato. Neotrop. Entomol. 2016; 45, 201–210 DOI 10.1007/s13744-015-0356-8.

GUPTA SK, BHATT P, JOSEPH JS, NEGI PS, VARADARAJ MC. Phenolic constituents and biological activities of leaf extracts of traditional medicinal plant *Plectranthus amboinicus* Benth (Lamiaceae). Tang. 2013; 3, 1-6. http://dx.doi.org/10.5667/tang.2013.0027.

GURGEL AP, DA SILVA JG, GRANGEIRO AR, OLIVEIRA DC, LIMA CM, DA SILVA ACP, OLIVEIRA RAG, SOUZA IA. In vivo study of the antiinflammatory and antitumor activities of leaves from *Plectranthus amboinicus* (Lour.) Spreng (Lamiaceae). Journal of Ethnopharmacology. 2009; 125, 361-363. http://dx.doi.org/10.1016/j.jep.2009.07.006.

ISLAM E, YANG X, LI T, LIU D, JIN X, MENG F. Effect of Pb toxicity on root morphology, physiology and ultrastructure in the two ecotypes of Elsholtziaargyi. J Hazard Mater1. 2007; 47, 806–816. 10.1016/j.jhazmat.2007.10.121.

KAPEWANGOLO P, MEYER D. *Plectranthus barbatus*; Antioxidant, and Other Inhibitory Responses Against HIV/AIDS. In: HIV/AIDS Oxidative Stress and Dietary Antioxidants. USA, 2018 pp 149-159. https://doi.org/10.1016/B978-0-12-809853-0.00013-4.

LARA-FERNÁNDEZ L, DE LA GARZA-TOLEDO H, WONG-PAZ JE, BELMARES R, RODRÍGUEZ-HERRERA R, AGUILA CN. Separation conditions and evaluation of antioxidant properties of “boldo” (*Peumus boldus*) extracts. J. Med. Plants Res. 2013; 15, 911-917. 10.5897/JMPR13.2562.

LAWAL OA, HUTCHINGS AH, OYEDEJI O. Chemical Composition of the Leaf Oil of *Plectranthus neochilus* Schltr. J .Essent. Oil Res. 2010; 22, 546-547. 10.1080/10412905.2010.9700396.

LIMA NRW, SODRÉ GA, LIMA HRR, MANCEBO SSS, CAMPOS LV, GIBSON A, SOUZA V, COUTO W, GIACOMO L, DI NARCIZO A, LOBÃO AQ, DELOU CMC. The Efficacy of a Practical Activity in the Construction of Knowledge of the Concepts of Species and Phenotypic Plasticity Using the “BoldoMirim” (*Plectranthus neochilus* Schltr.). Creative Education. 2018; 8, 2036-2048. 10.4236/ce.2017.813138.

LOLIS MIGA, MILANEZE-GUTIERRE MA. Morfo-anatomia das folhas de *Vernonia condensata* Baker (Asteraceae), o "figatil". Rev Bras Farmacogn. 2003; 13, 68-71. http://dx.doi.org/10.1590/S0102-695X2003000300002.

LORENZI, H, MATOS, FJA. Plantas medicinais no Brasil - nativas e exóticas 2.ed. Nova Odessa: Instituto Plantarum. 2002; pp 544.

LUKHOBA CW, SIMMONDS MS, PATON AJ. *Plectranthus*: A review of ethnobotanical uses. J. Ethnopharmacol. 2006; 103, 1-24. 10.1016/j.jep.2005.09.011.

MEDEIROS CH, RIBEIRO, LV, LÚCIO PDS, SCHIEDECK G. Enraizamento de *Plectranthus neochilus* em concentrações de húmus líquido. Rev. Cient. Rural. 2016; 18:18-28.

MORAU D, LIBELLE T, GARDE F. Performance evaluation of green roof for thermal protection of buildings in Reunion Island. Energy Procedia. 2012; 14, 1008 – 1016. 10.1016/j.egypro.2011.12.1047.

MOTA MS, BANDEIRA JM, BRAGA EJB, BIANCHI VJ, PETERS JA. *In vitro* shoot regeneration of “boldo” from leaf explants. Cienc. Rural. 2010; 40. http://dx.doi.org/10.1590/S0103-84782010005000173.

MOTA L, FIGUEIREDO AC, PEDRO LG, BARROSO JG, MIGUEL MG, FALEIRO ML, ASCENSÃO L. Volatile-oils composition, and bioactivity of the essential oils of *Plectranthus barbatus*, *P. neochilus*, and *P. ornatusgrown* in Portugal. Chem. Biodivers. 2014; 11, 719-732. http://dx.doi.org/10.1002/cbdv.201300161.

PEREIRA GC. Estudo de Viabilidade de Fitorremediação de Sulfentrazone (Boral 500) por “Boldo-Gambá” (*Plectranthus neochilus*) em Meio Aquoso. Dissertation (Master’s degre in Biochemistry). Universidade Federal do Pampa, Uruguaiana; 2018.

PILON-SMITS E. Phytoremediation. Annu Rev Plant Biol. 2005; 56, 15-39. 10.1146/annurev.arplant.56.032604.144214.

POOLEY EA. A field guide to wild flowers of KwaZulu-Natal and the eastern region. Natal Flora Publications Trust, Durban. 1998.

PROCÓPIO SO, PIRES FR, SANTOS JB, SILVA AA. Fitorremediação de solos com resíduos de herbicidas. In EMBRAPA Tabuleiros Costeiros. Aracaju, 2009.

RAMBORGER BP, GOULARTE CAO, RODRIGUES DT, GAYER MC, CARRIÇO MRS, BIANCHINI CM, PUNTEL RL, DENARDIN ELG, ROEHRS R. The phytoremediation potential of *Plectranthus neochilus* on 2,4-dichlorophenoxyacetic acid and the role of antioxidant capacity in herbicide tolerance. Chemosphere. 2017; 188, 231-240. http://dx.doi.org/10.1016/j.chemosphere.2017.08.164.

RICE LJ, BRITS GJ, POTGIETER CJ, VAN STADEN J. *Plectranthus*: a plant for the future? South African Journal of Botany. 2011; 77, 947–959. https://doi.org/10.1016/j.sajb.2011.07.001.

RIJO P, MATIAS D, FERNANDES AS, SIMÕES MF, NICOLAI M, REIS CP. Antimicrobial Plant Extracts Encapsulated into Polymeric Beads for Potential Application on the Skin. Polymers. 2014; 6,479-490. 10.3390/polym6020479.

ROSAL LF, PINTO JEBP, BERTOLUCCI SKV, BRANT RS, NOCULAU ES, ALVES BP. Effect of organic fertilizer sources on biomass and essential oil production of *Plectranthus neochilus* Schlechter. Rev. Ceres (Impr.). 2011; 58, 670-678. http://dx.doi.org/10.1590/S0034-737X2011000500020.

STIRTON CH. Broad-spectrum pollination of *Plectranthus neochilus*. Bothalia - African Biodiversity and Conservation. 1997; 12, 229-230 10.4102/abc.v12i2.1402.

SWAIN SS, LAPAMUDA S, BARIK DP, CHAND PK. *Agrobacterium* x plant factors influencing transformation of ‘Joseph’s coat’ (*Amaranthus tricolor* L.). Scientia Horticulturae. 2010; 125, 461-468. https://doi.org/10.1016/j.scienta.2010.04.034.

TADESSE D, EGUALE T, GIDAY M, MUSSA A. Ovicidal and larvicidal activity of crude extracts of *Maesalan ceolata* and *Plectranthus punctatus* against *Haemonchus contortus*. Journal of Ethnopharmacology. 2009; 122, 240-244. http://dx.doi.org/10.1016/j.jep.2009.01.014.

TEMPONE AG, SARTORELLI P, TEIXEIRA D, PRADO, FO, CALIXTO IARL, LORENZI H, MELHEM MSC. Brazilian flora extracts as source of novel antileishmanial and antifungal compounds. Mem. Inst. Oswaldo Cruz. 2008; 103, 443-449. http://dx.doi.org/10.1590/S0074-02762008000500006.

VAN JAARSVELD, E, THOMAS, V. South African *Plectranthus* and the art of turning shade to glade. Simon's Town: Fernwood Press, South Africa. 2006.

VIANA AJS. Estudo químico e de atividade biológica de *Plectranthus neochilus* Schltr. (Lamiaceae). Dissertation (Master's degre in Organic Chemistry). Universidade Federal dos Vales do Jequitinhonha e Mucuri, Diamantina. 2011.

YORK T, DE WET H, VAN VUUREN SF. Plants used for treating respiratory infections in rural Maputaland, KwaZulu-Natal, South Africa. J Ethnopharmacol. 2011; 135, 696-710. 10.1016/j.jep.2011.03.072.

WALDIA S, JOSHI BC, PATHAK U, JOSHI MC. The genus *Plectranthus* in India and its chemistry. Chemistry & Biodiversity. 2011; 8, 244-252 10.1002/cbdv.201000048.