Fundación
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# Patterns of diversity of medicinal shrubs in the Monte desert in the Calchaquí Valleys (Tucumán, Argentina)

## Patrones de diversidad de arbustos medicinales del desierto de Monte en los Valles Calchaquíes (Tucumán, Argentina)

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## Abstract

In recent times, the population abundance of many of the native medicinal plant species in the Monte Desert in northwestern Argentina has been declining due to agricultural expansion, overgrazing, urbanization, increasing levels of harvesting, and changes in climatic conditions. Therefore, quantitative data on these species is necessary to design strategies that allow their conservation and sustainable use. This study aimed to determine the diversity patterns of some medicinal shrub species in a portion of the mountainous desert of the Calchaquí Valleys (Tucumán, Argentina). Throughout a standardized protocol, the plant communities from four localities (two sampling sites for each locality, S1 and S2) were surveyed (Ampimpa, Tío Punco, Fuerte Quemado, and Los Poleos). Relative density, relative frequency, dominance, and the species importance value index (IVI) were calculated to determine the overall species performance and dominance. Of the species identified, twelve

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are popularly used as medicinal. *Austroflourensia fiebrigii, Pentaphorus glutinosus, Larrea cuneifolia,* and *Zuccagnia punctata*, four medicinal plant species, were dominant in Ampimpa S1. *Larrea cuneifolia, Larrea divaricata,* and *Z. punctata* are within the medicinal plant species with the highest IVI. These plant species are used as anti-inflammatory, antirheumatic, antitumoral and to treat fungal and bacterial infections. Our study seeks to provide a significant foundation for documenting future changes in these plant communities and to promote conservation strategies and multiplication of them *in situ*.

**Keywords:** Diversity patterns; medicinal plants; Monte desert; phytosociological parameters; Calchaquí Valleys.

## Resumen

En los últimos tiempos, la abundancia poblacional de muchas de las especies de plantas medicinales nativas en el desierto de Monte en el noroeste de Argentina ha disminuido debido a la expansión agrícola, el pastoreo excesivo, la urbanización, a los crecientes niveles de recolección y a los cambios en las condiciones climáticas. Por lo tanto, para diseñar estrategias que permitan su conservación y uso sustentable es necesario contar con datos cuantitativos sobre estas especies. El objetivo de este trabajo fue determinar los patrones de diversidad de especies arbustivas medicinales en una porción de la región del desierto montañoso de los Valles Calchaquíes (Tucumán, Argentina). A través de un protocolo estandarizado, se relevaron las comunidades vegetales de cuatro localidades: Ampimpa, Tío Punco, Fuerte Quemado y Los Poleos, en dos sitios por localidad, S1 y S2. Se calculó la densidad relativa, la frecuencia relativa, la dominancia y el índice de valor de importancia de las especies medicinales (IVI) para determinar el desempeño general de la especie y la dominancia. De las especies identificadas, doce son usadas popularmente como medicinales. De las especies medicinales relevadas, *Austroflourensia fiebrigii, Pentaphorus glutinosus, Larrea cuneifolia* y *Zuccagnia punctata*, fueron dominantes en Ampimpa S1. *Larrea cuneifolia, Larrea divaricata* y *Z. punctata* se encuentran entre las especies de plantas medicinales con el IVI más alto. Estas especies de plantas se utilizan popularmente como antiinflamatorias, antirreumáticas, antitumorales y para tratar infecciones fúngicas y bacterianas. Nuestro estudio busca proporcionar una base significativa para documentar los cambios futuros en estas comunidades de plantas y promover estrategias de conservación y multiplicación de las mismas *in situ*.

**Palabras clave:** Desierto de Monte; parámetros fitosociológicos; patrones de diversidad; plantas medicinales; Valles calchaquíes.

## INTRODUCTION

The Monte ecosystem, also known as the Monte Desert, is a subtropical and temperate arid region that spans approximately 467000 km$^2$ (Oyarzabal *et al.*, 2018). It stretches from 24º35'S in Salta to 44º20'S in Chubut, and from 62º54'W along the Atlantic coast to 69º50'W (Morello, 1958). Its climate, characterized by aridity and semi-aridity, varies significantly along with its latitudinal and altitudinal extent. The dominant vegetation is shrub steppes (characterized by the presence of the genus *Larrea*) and *Prosopis* forests, whose composition and diversity vary with altitude and other environmental factors. Like other temperate drylands, the Monte Desert is recognized as a biodiversity hotspot, characterized by moderate to high levels of species richness and endemism (Olson *et al.*, 2001; Eíias & Aagesen, 2016; Baranzelli *et al.*, 2017). This is likely attributed to its unique environmental conditions (Turchetto-Zolet *et al.*, 2013; Camps *et al.*, 2018). Monte desert is commonly divided into two sectors: the Northern Monte (approximately between 23°00' S and 32°50' S), known as the "Monte de Sierras y Bolsones", where the present study was conducted; and the Southern Monte (approximately between 31°30' S and 44°20' S), known as the "Monte de Llanuras y Mesetas". In northern Monte, plant species heterogeneity is primarily driven by the interaction between geomorphological factors and water availability (Wysocki *et al.*, 2000; Casalini & Bisigato, 2017; Casalini *et al.*, 2019). This arid region is home to species highly adapted to harsh environmental conditions, such as *Zuccagnia punctata* Cav., *Larrea cuneifolia* Cav., and *Larrea divaricata* Cav., commonly known as "jarillas" (Casalini & Bisigato, 2017; Casalini *et al.*, 2019).

Recently, the population abundance of numerous native species in the Monte Desert has declined due to agricultural expansion, overgrazing, urbanization, and increased harvesting. Some of these species, endemic to the Monte ecoregion, have medicinal value and have been included in the red list of endemic plants at risk of extinction in Argentina. *Z. punctata* and *L. cuneifolia* are classified in Categories 3 and 1, respectively (Lista Roja Preliminar de las Plantas Endémicas de la Argentina [PlanEAr], 2010; Ceballos & Perea, 2014; Máthé & Bandoni, 2021).

Since the propagation of native species is not currently employed as a self-sufficiency strategy, further studies on the populations of these species are necessary. This information will be valuable for the development of both *in situ* and *ex situ* conservation strategies, as well as for the establishment of sustainable use practices. In this sense, several studies on the population distribution of some of these species have been conducted, most of which focus on the Southern Monte-Patagonia ecotone (Casalini & Bisigato, 2017; Casalini *et al.*, 2019). However, there is a limited body of research concerning the Calchaquí Valleys, with notable exceptions such as the studies by Ceballos & Perea, (2014) and Dip *et al.* (2020).

Climate change is generally projected to reduce ecosystem diversity (Weiskopf *et al*., 2020). The vulnerability of ecosystems and species is partly determined by the rapid rate of climate change relative to the resilience of these systems (Schneider *et al*., 2007). For the Monte Desert, some authors have demonstrated that the region has experienced significant climate change in the past, showing warming trends and precipitation variations over the last century (Labraga & Villalba, 2009). Furthermore, reduced precipitation in wetter areas has been reported to negatively impact the habitat suitability of *L. cuneifolia*, while higher temperature seasonality is predicted to affect the habitat suitability of *L. divaricata* (Souto *et al*., 2024). In this context, quantitative data on the vegetation of regions hosting species of medicinal importance are therefore essential for designing strategies aimed at their restoration, conservation, and sustainable use.

To address these concerns, the United Nations established the 2030 Agenda for Sustainable Development, which includes combating desertification and promoting restoration efforts. These goals are particularly relevant to drylands—arid, semi-arid, and sub-humid ecosystems—that comprise approximately 40% of the planet's surface (15 billion hectares) (United Nations Convention to Combat Desertification [UNCCD], 2020).

Based on the above, this study hypothesized that the current distribution patterns of medicinal shrub species in the Monte Desert are primarily influenced by environmental variables, particularly water availability and microclimatic conditions. Identifying these patterns is essential for informing species conservation strategies and guiding future restoration and cultivation efforts. This study aimed to analyze diversity patterns in medicinal shrubs within a segment of the mountainous desert in the Calchaquí Valleys, located in Tucumán, Argentina.

## MATERIAL AND METHODS

### Study area

The study area is located within the Monte ecoregion in northwest Argentina, a mountainous desert situated at an altitude between 1700 and 2400 meters above sea level (m asl). This region is characterized by a landscape of mountains and valleys that create diverse microenvironments. The average annual precipitation is approximately 200 mm, and its distribution is strongly influenced by the topography of the environment. Soils in the study area are predominantly sandy, poorly developed, and shallow, with minimal or no horizon differentiation (Puchulu & Fernández, 2014). study was carried out in four localities belonging to the Calchaquí Valleys: Ampimpa (26°35'33.3" S 65°51'25.0" W, 2310 m asl), Tío Punco (26°31' 58.4" S 65°57'53.0" W; 1823 m asl), Fuerte Quemado (26°34'31.3" S 66°03' 00.1" W; 1855 m asl), and Los Poleos (26°37'33.1" S 65°57'33.3" W; 1954 m asl) (Fig. 1 and 2). For each location, altitude was recorded, and solar/

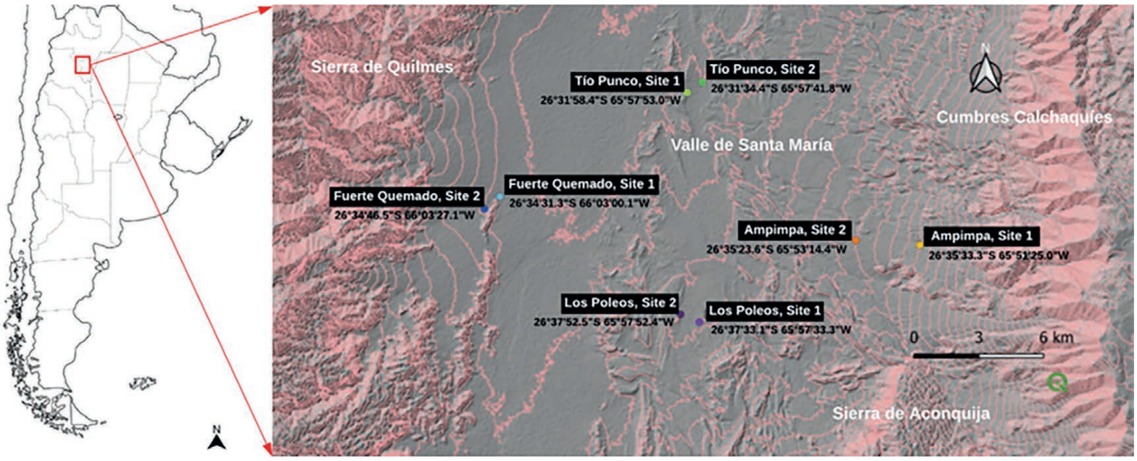


**Fig. 1.** Location of sampling sites in the Valles Calchaquíes, Tucumán, Argentina.

**Fig. 1.** Ubicación de sitios de muestreo en los Valles Calchaquíes, Tucumán, Argentina.

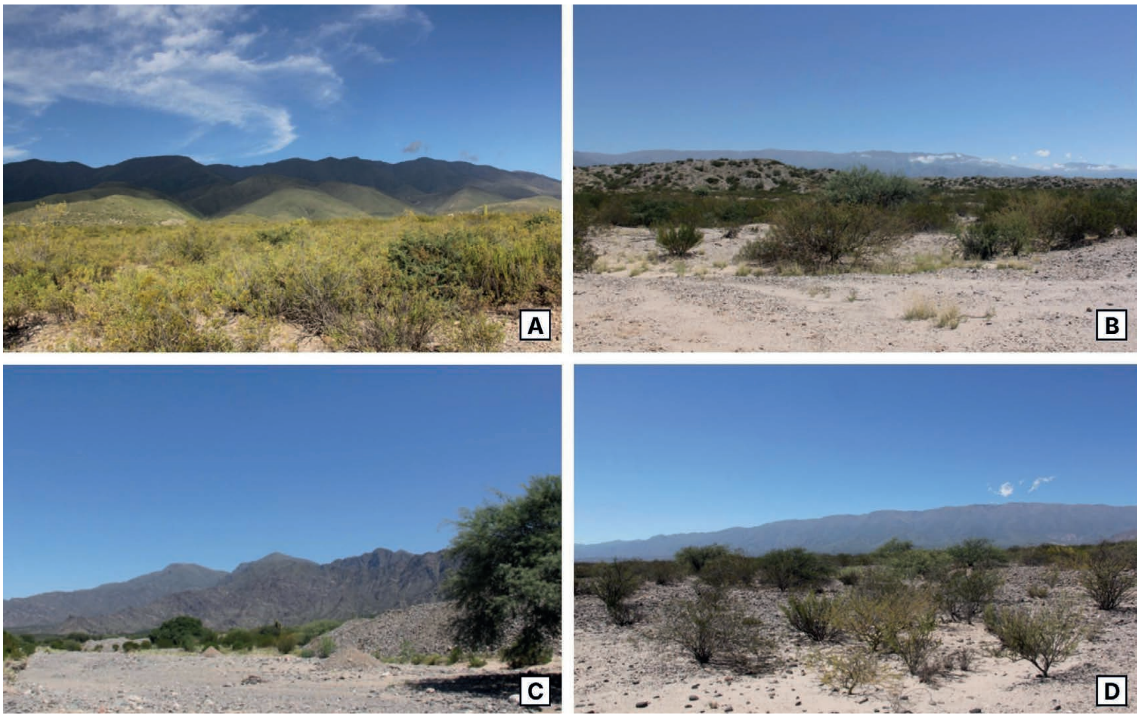


**Fig. 2.** Sampled localities in the Valles Calchaquíes, Tucumán, Argentina. A) Ampimpa. B) Tío Punco. C) Fuerte Quemado. D) Los Poleos.

**Fig. 2.** Localidades muestreadas en los Valles Calchaquíes, Tucumán, Argentina. A) Ampimpa. B) Tío Punco. C) Fuerte Quemado. D) Los Poleos.

**Table 1.** Localities of collection of plant material in Valles Calchaquíes (Tucumán, Argentina): coordinates, altitude, solar and ultraviolet radiation. S1: Site 1. S2: Site 2. AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos. m asl: meter above sea level.

**Tabla 1.** Localidades de recolección de material vegetal en los Valles Calchaquíes (Tucumán, Argentina): coordenadas, altitud, radiación solar y ultravioleta. S1: Sitio 1. S2: Sitio 2. AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos. m snm: metros sobre el nivel del mar.

| Location | Site | Latitude | Longitude | Altitude | Solar radiation | Ultraviolet radiation |
|---|---|---|---|---|---|---|
| AMP | S1 | -26.3533 | 65.5125 | 2310 | 1254 | 407 |
| AMP | S2 | -26.3523 | 65.5314 | 2109 | 1217 | 406 |
| TP | S1 | -26.3158 | 65.5753 | 1823 | 1009 | 342 |
| TP | S2 | -26.3134 | 65.5741 | 1816 | 1004 | 334 |
| FQ | S1 | -26.3431 | 66.0300 | 1855 | 1070 | 379 |
| FQ | S2 | -26.3446 | 66.0327 | 1866 | 1078 | 384 |
| LP | S1 | -26.3733 | 65.5733 | 1954 | 1124 | 402 |
| LP | S2 | -26.3752 | 65.5752 | 1949 | 1123 | 400 |

ultraviolet radiation was measured using a solar radiometer (LUTRON SPM-1116SD) and an ultraviolet radiometer (LUTRON UV-340A), respectively (Table 1).

## Vegetation sampling

In each locality, two sampling sites were established (Site 1: S1 and Site 2: S2), each consisting of five plots of 64 m$^2$ (8 m × 8 m). The size of each plot was determined using the minimum area method, which identifies the smallest area required to include the species composition representative of the plant community (Mostacedo & Fredericksen, 2000). According to Mueller-Dombois & Ellenberg (1974), to mathematically determine the minimum area, the slope between successive points on the cumulative species number versus area curve was calculated using the following equation:

$$P = \frac{S_i + 1 - S_i}{A_i + 1 - A_i}$$

Where:
$P$: slope
$S$: n° species
$A$: area

We considered the minimum area to be reached when the slope reached 0 species/m$^2$ in three successive increments. Sampling was conducted in early March 2022, at the end of the rainy season, a period when both deciduous and evergreen species were actively growing. Within each quadrat, data were recorded on species richness, the number of individuals per species, and percentage cover.

### Phytosociological parameters

Plant species were identified through the analysis of freshly collected and preserved specimens, with reference to the Phanerogamic Herbarium of the Miguel Lillo Foundation (LIL). Only shrub species were included in the survey. Relative density (RD) was calculated as the proportion of individuals of a particular taxon relative to the total number of individuals sampled. Relative frequency (RF) was determined based on the absolute frequency (AF) of a given species compared to the total frequency (TF), which is the sum of all absolute frequencies. Relative dominance (RDo) was expressed as the percentage of absolute dominance (AD) of a given species relative to the total dominance (TD). Finally, the importance value index (IVI) for each species was calculated as the sum of RF, RD, and RDo (Mostacedo & Fredericksen, 2000).

### Statistical Analysis

A clustering analysis was conducted using a heatmap with an associated dendrogram. This analysis aimed to group the sampled sites based on their abundance and floristic composition to identify differences in both species composition and relative abundance. To prevent dominant species from biasing the results, the data were pre-standardized. Given this standardization and the use of quantitative abundance data, Euclidean distance was selected as the dissimilarity measure, as it is well-suited to detect overall multivariate differences when all variables contribute equally to the overall variation. Subsequently, the Ward clustering algorithm, which minimizes within-group variance and is compatible with Euclidean distance, was applied to generate a coherent cluster. The analysis was performed in R software version 3.0.2 (RStudio Team, 2020).

## RESULTS AND DISCUSSION

Plant collection for identification was conducted during the summer at four locations: Ampimpa, Tío Punco, Fuerte Quemado, and Los Poleos. This period was chosen as both deciduous and perennial species exhibiting optimal morphological characteristics. Most specimens were in a fertile state, which facilitated accurate identification. A total of 18 plant species, distributed across seven families, were recorded (Table 2). The family Fabaceae was the most represented, with six species, followed by Cactaceae (four species) and Zygophyllaceae (three species). Asteraceae accounted for two species, while Acanthaceae, Capparaceae, and Solanaceae were represented by one species each.

**Table 2.** List of species and absolute abundance in each sampled site of Valles Calchaquies of Tucuman Province, Argentine. CN: common name. S1: Site 1. S2: Site 2. AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos.

**Tabla 2.** Listado de especies y abundancia absoluta en cada sitio muestreado de los Valles Calchaquíes de la Provincia de Tucumán, Argentina. CN: nombre común. S1: Sitio 1. S2: Sitio 2, AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos.

| Plant species | Number of individuals of each plant species | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | AMP | | TP | | FQ | | LP | |
| | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| *Atamisquea emarginata* ex *Capparis atamisquea* Miers ex Hook. & Arn.<br>CN: atamisqui | | | | | | | 2 | 1 |
| *Bulnesia schickendantzii* Hieron. Griseb.<br>CN: monte negro | | 24 | 12 | 5 | 6 | 7 | | 3 |
| *Cereus aethiops* Haw.<br>CN: cardón | | 2 | | | | 2 | | |
| *Austroflourensia fiebrigii* ex *Flourensia fiebrigii* (S.F. Blake) J.C. Ospina & S.E. Freire<br>CN: chilca, maravilla | 99 | | | | | | | |
| *Gymnocalycium spegazzinii* Britton & Rose | 1 | 12 | 14 | | | | 2 | 1 |
| *Justicia xylosteoides* Griseb. | 9 | 7 | | | | | | |
| *Larrea cuneifolia* Cav.<br>CN: jarilla macho | 44 | 48 | 30 | 3 | 2 | 2 | 13 | 14 |
| *Larrea divaricata* Cav.<br>CN: jarilla hembra | | | | 10 | 21 | 24 | | 3 |
| *Lycium chilense* Miers ex Bertero.<br>CN: piquillín de las víboras | | | | | | 4 | | 2 |
| *Neltuma nigra* Sin. *Prosopis nigra* (Griseb.) C.E. Hughes & G.P. Lewis.<br>CN: algarrobo negro | | | | 3 | | | | |
| *Opuntia sulphurea* Gillies ex Salm-Dyck.<br>CN: penca, tunilla | 5 | 9 | 26 | 3 | 5 | 4 | 1 | |
| *Parkinsonia praecox* Sin *Cercidium praecox* (Ruiz & Pav. ex Hook.) Hawkins<br>CN: brea, chañar brea | | | 3 | 4 | 5 | 7 | | 8 |
| *Pentaphorus glutinosus* Sin. *Gochnatia glutinosa* (D. Don) Hook. & Arn.<br>CN: jarilla sacancia | 19 | | | | | | | |
| *Strombocarpa torquata* Sin. *Prosopis torquata* (Cav. ex Lag.) Hutch.<br>CN: tintitaco | 7 | 12 | | 3 | | | 1 | |
| *Senna aphylla* (Cav.) H.S. Irwin & Barneby var. *aphylla*<br>CN: pichana, retamilla, jarilla | | | | | | | | 2 |
| *Senna rigida* (Hieron.) H.S. Irwin & Barneby.<br>CN: retama | 49 | 21 | 11 | 3 | | 3 | 6 | 3 |
| *Trichocereus atacamensis* (Phil.) Backeb.<br>CN: cardon | | 1 | | | | | | |
| *Zuccagnia punctata* Cav.<br>CN: pus pus, lata, jarilla macho, jarilla pispito | 25 | 21 | 19 | 3 | | | 29 | 16 |
| **Total number of individuals per site** | **258** | **157** | **115** | **37** | **39** | **53** | **54** | **53** |

In terms of the phytosociological parameters measured, sites Ampimpa S1 and S2 showed together the highest abundance values in the studied stratum, followed by Tío Punco S1 and Los Poleos S1.

The data were correlated with the Importance Value Index (IVI) values observed for the species at each site. The most significant species were identified as those with IVI values exceeding the average IVI calculated for each site. The average IVI was determined excluding species with an IVI of 0 (Table 3).

**Table 3.** The importance value index of species (IVI) at the different localities and sampling sites. S1: Site 1. S2: Site 2. AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos.

**Tabla 3.** Índice de valor de importancia de las especies (IVI) en las diferentes localidades y sitios de muestreo. S1: Sitio 1. S2: Sitio 2. AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos.

| Family | Plant species | Importance value index of species (IVI) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | AMP | | TP | | FQ | | LP | |
| | | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| Acanthaceae | *Justicia xylosteoides* | 15.66 | 11.13 | 0 | 0 | 0 | 0 | 0 | 0 |
| Asteraceae | *Austroflourensia fiebrigii* | 67.75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Pentaphorus glutinosus* | 32.43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cactaceae | *Trichocereus atacamensis* | 0 | 6.01 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Opuntia sulphurea* | 10.76 | 15.22 | 37.88 | 13.99 | 35.34 | 22.38 | 8.52 | 0 |
| | *Gymnocalycium spegazzinii* | 3.33 | 10.98 | 32.49 | 0 | 0 | 0 | 10.37 | 6.43 |
| | *Cereus aethiops* | 0 | 7.94 | 0 | 0 | 0 | 13.86 | 0 | 0 |
| Capparaceae | *Atamisquea emarginata* | 0 | 0 | 0 | 0 | 0 | 0 | 16.06 | 9.06 |
| Fabaceae | *Neltuma nigra* | 0 | 0 | 0 | 23.35 | 8.98 | 0 | 0 | 0 |
| | *Parkinsonia praecox* | 0 | 0 | 19.41 | 27.41 | 31.69 | 49.91 | 0 | 37.05 |
| | *Strombocarpa torquata* | 21.06 | 47.39 | 0 | 20.25 | 0 | 0 | 8.52 | 0 |
| | *Senna aphylla* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14.23 |
| | *Senna rigida* | 41.08 | 32.52 | 26.65 | 23.54 | 0 | 20.45 | 26.81 | 10.38 |
| | *Zuccagnia punctata* | 43.27 | 46.45 | 61.83 | 41.42 | 0 | 0 | 153.62 | 116.8 |
| Solanaceae | *Lycium chilense* | 0 | 0 | 0 | 0 | 0 | 16.01 | 0 | 9.43 |
| Zygophyllaceae | *Larrea cuneifolia* | 64.65 | 84.32 | 95.82 | 23.54 | 31.38 | 23.18 | 76.09 | 65.68 |
| | *Larrea divaricata* | 0 | 0 | 0 | 103.74 | 142.31 | 123.07 | 0 | 13.79 |
| | *Bulnesia schickendantzii* | 0 | 38.05 | 25.92 | 22.75 | 50.3 | 31.13 | 0 | 17.14 |

Based on this analysis, *Austroflourensia fiebrigii* exhibited the highest Importance Value Index (IVI), yet it was surprisingly recorded at only one site (AMP S1). *Larrea cuneifolia*, *Larrea divaricata*, and *Zuccagnia punctata* remain dominant species, characteristic of the climax vegetation of the Monte Desert (Cabrera, 1976), despite the intense extractive pressure they endure.

Fig. 3 shows a heatmap illustrating a comparative analysis of abundance, which reveals clustering that groups the sampled sites into three categories.

On the one hand, TP S2, FQ S1, and FQ S2 clustered together, where *L. divaricata*, *Parkinsonia praecox*, and *Bulnesia schickendantzii* were dominant species. On the other hand, TP S1 was distinct due to the dominance of *L. cuneifolia*, *Opuntia sulphurea*, and *Z. punctata*. Finally, the remaining sites formed a separate group characterized by non-uniform dominance: *Z. punctata* in LP S1 and S2, *A. fiebrigii* in AMP S1, and *L. cuneifolia* in AMP S2. The heatmap further indicated that *L. cuneifolia* was the only species present across all sites.

In terms of species richness at the sampled sites, AMP S1 and S2, LP S2, and TP S2 exhibited the highest numbers of species per unit area, with 9, 10, 10, and 9 plant species, respectively. Several factors may explain the higher species richness observed at AMP and LP, including their higher positions along the altitudinal gradient considered (2310–2109 m asl), proximity to intermittent rivers, and the presence of rocky soils.

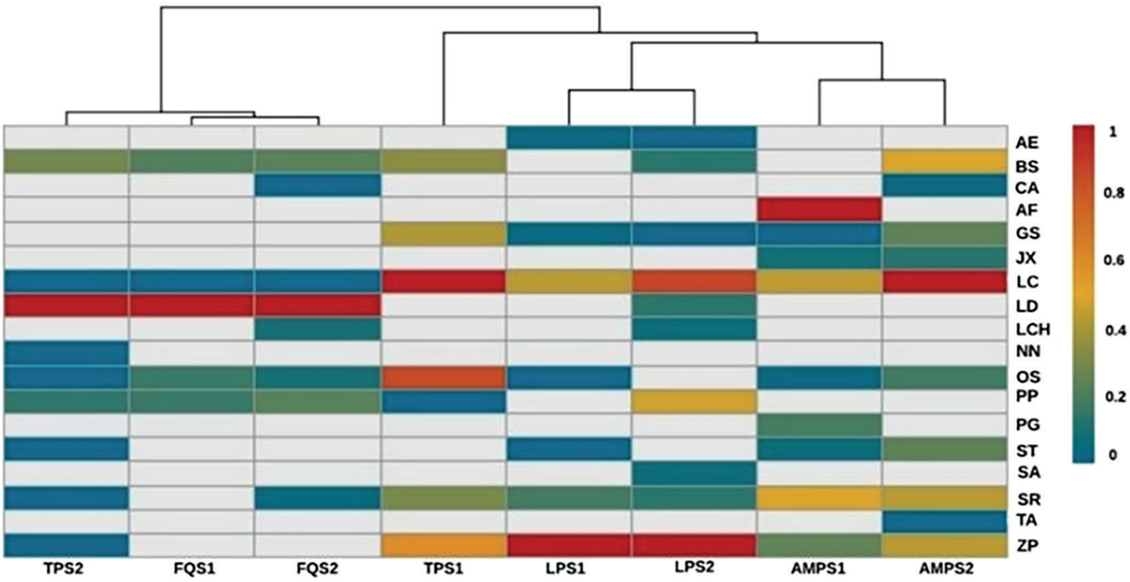


**Fig. 3.** Heatmap showing abundance and presence/absence in the eight sites of Valles Calchaquíes. AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos. S1, site 1. S2, site 2. Species (AE: *A. emarginata.* BS: *B. schickendantzii*. CA: *C. aethiops*. AF: *A. fiebrigii*. GS: *G. spegazzinii*. JX: *J. xylosteoides*. LC: *L. cuneifolia*. LD: *L. divaricate*. LCH: *L. chilense*. NN: *N. nigra*. OS: *O. sulphurea*. PP: *P. praecox*. PG: *P. glutinosus*. ST: *S. torquate*. SA: *S. aphylla*. SR: *S. rigida*. TA: *T. atacamensis*. ZP: *Z. punctata*).

**Fig. 3.** Mapa de calor que muestra abundancia y presencia/ausencia en los ocho sitios de los Valles Calchaquíes. AMP: Ampimpa. TP: Tío Punco. FQ: Fuerte Quemado. LP: Los Poleos. S1, sitio 1. S2, sitio 2. Especie (AE: *A. emarginata.* BS: *B. schickendantzii.* CA: *C. aethiops.* AF: *A. fiebrigii.* GS: *G. spegazzinii*. JX: *J. xylosteoides*. LC: *L. cuneifolia*. LD: *L. divaricata*. LCH: *L. chilense.* NN: *N. nigra.* OS: *O. sulphurea.* PP: *P. praecox.* PG: *P. glutinosus.* ST: *S. torquata.* SA: *S. aphylla*. SR: *S. rigida*. TA: *T. atacamensis*. ZP: *Z. punctata*).

These soils enhance moisture retention and regulate temperature, both of which are limiting factors for the persistence of plant populations in the Calchaquí Valleys. The lowest species richness was recorded at FQ S1, with only five plant species (Table 2).

According to its geomorphology, FQ is situated on an ancient riverbed characterized by sandy soils with low water retention capacity, leading to limited water availability for plants. This factor is likely a significant determinant of the observed lower species richness. Similarly, Flores *et al.*, (2019) documented a comparable trend in lacustrine landforms within the arid central region of the Monte Desert.

Of the identified species, twelve (67%) are commonly used as medicinal by the indigenous community of Amaicha del Valle and other local settlers. Additionally, scientific records validate some of these traditional uses (Table 4). According to the ecological apparency hypothesis proposed by De Albuquerque & Farias Paiva de Lucena (2005), the identified plant species are likely apparent plants, typically represented by dominant perennial trees and shrubs. This hypothesis suggests that apparent species are more frequently utilized than non-apparent plants, thereby experiencing higher anthropogenic pressure.

De Albuquerque & Farias Paiva de Lucena (2005), in their work across six areas of Caatinga in northeastern Brazil, found that the relative importance of species negatively correlated with their relative density and frequency. Based on this, we conclude that the status of a species as an "apparent plant" does not necessarily imply greater utilization, since, in our study, the species with the highest Importance Value Index (IVI) corresponded to those most frequently used by local communities, including *L. divaricata*, *L. cuneifolia*, *Z. punctata*, and *A. fiebrigii*.

Reported traditional uses include purgative, expectorant, anti-inflammatory, anti-rheumatic, hypotensive, rubefacient, diaphoretic, febrifuge, oxytocic, emmenagogue, antitussive, antiparasitic, and treatments for fungal and bacterial infections. Several scientific studies validate some of these uses (Table 4). These four species could be classified as herbal medicines of traditional use according to Argentine regulations established by the "Administración Nacional de Medicamentos, Alimentos y Tecnología Médica" [ANMAT] (2015).

Recently was also demonstrated the potential use of *L. divaricata* and *Z. punctata* as beverage functional (Isla *et al*., 2021a, 2021b; Correa Uriburu *et al*., 2023). It is important to note that, in addition to the traditional use that local communities make of these species, *L. divaricata* is exploited directly from the environment by wild harvesting for the development of cosmetic commercial products for dandruff and hair loss (Davicino *et al*., 2010a; Iannicelli *et al*., 2018). These extractive practices can have negative effects on population abundance, so it is necessary to consider propagation methods aimed at maintaining the population abundance of the species. In this sense, some propagation assays with *L. divaricata* and *Z. punctata* have been carried out using *in vitro* culture techniques such as micropropagation, and indirect regeneration through callus and cell cultures, although to date the production of seedlings and rustication have not been achieved (Palacio *et al*., 2008, 2011, 2012; Álvarez *et al*., 2024). Furthermore, it was reported that the persistence of the germination capacity over time of seed of *L. divaricata*, confirms that both species can provide a very high seed supply for restoration purposes (Hernandez *et al*., 2020).

Our results underscore the need for population studies of these medicinally important species, emphasizing the necessity of large-scale cultivation to ensure an adequate supply of raw materials for potential formulations without compromising natural populations. This is particularly critical for species with commercial potential. Through the establishment of management plans for their sustainable use, these medicinal resources could satisfy local consumption demands while generating income for the valley community.

**Table 4.** Medicinal properties of plant species of Mount Desert (Calchaquí Valleys, Tucumán, Argentina).

**Tabla 4.** Propiedades medicinales de especies vegetales del Desierto del Monte (Valles Calchaquíes, Tucumán, Argentina).

| Plant species | Popular medicinal use | Biological activity | Reference |
|---|---|---|---|
| ***Justicia xylosteoides***  | Anti-rheumatic, anti-inflammatory | Non-Registered | Ceballos & Perea, 2014. |
| ***Austroflourensia fiebrigii***  | Purgative, expectorant, anti-rheumatic, anti-inflammatory | Anti-rheumatic, anti-inflammatory, antibacterial, antibiofilm, antioxidant | Verni *et al.*, 2011, 2024; Leal *et al.*, 2021. |
| ***Pentaphorus glutinosus***  | Antifungal, anti-inflammatory | Antiseptic, anti-inflammatory, antioxidant, antileishmaniasis | Del Vitto *et al.*, 1997; Nekoei *et al.*, 2022; Leal *et al.*, 2023. |
| ***Trichocereus atacamensis***  | Properties linked to stomach painkillers | Antioxidant | Julián & Soto, 2013; Barbarich *et al.*, 2022. |
| ***Atamisquea emarginata***  | Gallbladder calculations, anti-rheumatic, anti-inflammatory, indigestion, postpartum. | Antiulcer | Ceballos & Perea, 2014; Taboada *et al.*, 2022. |
| ***Neltuma nigra***  | Bites, cough | Antioxidant, anti-inflammatory, syndrome metabolic enzymes inhibition, antifungal | Cardozo *et al.*, 2010; Ceballos & Perea, 2014; Pérez *et al.*, 2014, 2020; Picariello *et al.*, 2017; Sharifi-Rad *et al.*, 2019; Puppo & Felker, 2021; Sequin *et al.*, 2023; Cattaneo *et al.*, 2024. |

**Table 4.** Medicinal properties of plant species of Mount Desert (Calchaquí Valleys, Tucumán, Argentina).

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| Plant species | Popular medicinal use | Biological activity | Reference |
|---|---|---|---|
| ***Parkinsonia praecox***  | Liver, premenstrual pains, Vomiting (and nausea), flu / cold, cough<br>Food use: candy | Antioxidant, anti-proliferative, antibacterial, anticancer, antioxidant | Ceballos & Perea, 2014.; Suárez, 2019; López-Romero *et al*., 2022; Ordaz-Hernández *et al*., 2024. |
| ***Strombocarpa torquata***  | | Phytoestrogenic effect | Carrasco *et al*., 2010; Diaz *et al*., 2015. |
| ***Senna aphylla***  | Antiparasitic<br>In veterinary: Moquillo (Distemper) | Antifungal, antityrosinase | Ladio & Lozada, 2009; Carpinella *et al*., 2010; Chieli *et al*., 2010; Loizzo *et al*., 2012; Castillo & Ladio, 2017; Zolghadri *et al*., 2019; Fabbroni *et al*., 2022. |
| ***Zuccagnia punctata***  | Foot antiseptic; rubefacient, antibacterial, antifungal, asthma, arthritis, rheumatism, inflammations, tumors. | Antibacterial, antifungal, antioxidant, anti-inflammatory, nematicide, antihypertensive, Inhibition of drug resistance mechanisms, antigenotoxic, cytotoxic, antitumoral | Zampini *et al*., 2005, 2008, 2012; Ladio & Lozada, 2009; Moran Vieyra *et al*., 2009; Nuño *et al*., 2014, 2017; D'Almeida *et al*., 2015; Moreno *et al*., 2015; Isla *et al*., 2016, 2021a; Carabajal *et al*., 2017, 2020a, 2020b, 2021; Roco *et al*., 2017, 2018; Cantero *et al*., 2019; Valoy *et al*., 2023a, 2023b; Romero *et al*., 2024. |
| ***Larrea divaricata*** <br>***Larrea cuneifolia***  | Anti-inflammatory, antirheumatic, hypotensive, rubefacient, diaphoretic, febrifuge, oxytocic, emmenagogue, dental, antitussive and to treat alopecia, fungal and bacterial infections.<br>In veterinary, wounds, pasmo, Mal seco (Grass sickness) | Gastric antiulcerogenic, anti-inflammatory activities, antibacterial, antifungal, antigenotoxic, cytotoxic, antitumor, antioxidant, immunomodulatory activities and effect on hair growth | Anesini *et al*., 1996a, 1996b, 2001; Alonso & Desmarchelier, 2005; Pedernera *et al*., 2006; Stege *et al*., 2006; Davicino *et al*., 2007, 2010a, 2010b, 2011a, 2011b; Zampini *et al*., 2007; Barboza *et al*., 2009; Davicino & Anesini, 2009; Ceballos & Perea, 2014; Carabajal *et al*., 2017; 2020a, 2020b, 2021; Castillo & Ladio 2017; Álvarez Echazú *et al*., 2018; Moreno *et al*., 2018a, 2018b; |

However, achieving this goal requires a comprehensive assessment of resource availability, experimental approaches to species propagation, productivity potential, sustainable harvesting techniques, possibilities for domestication, market valuation of promising species, and, most importantly, the equitable benefit-sharing frameworks outlined in the Nagoya Protocol.

The comparative heatmap analysis of species abundance revealed a second-level clustering that distinguishes *L. divaricata*, *P. praecox*, and *B. schickendantzii* as dominant in TP S2, FQ S1, and FQ S2, respectively. *P. praecox* is a native tree species that produces a phloematic exudate known as "brea gum," which exudes from the trunks and branches of wounded plants. This gum is traditionally used as candy by various local communities (Von Müller *et al*., 2010). Brea gum shares chemical properties with additives extensively utilized in the food, medicinal, and cosmetic industries, such as gum arabic (Sznaider *et al*., 2023). This characteristic has facilitated its recognition as a novel non-timber forest product, contributing to the diversification of income for small-scale farmers. Recently, brea gum was incorporated into the Argentine Food Code (Article 1398), (Código Alimentario Argentino [CAA], 2021). However, further studies are necessary to evaluate its sustainable management potential (Von Müller *et al*., 2010).

## CONCLUSION

In all the surveyed sites, *Z. punctata*, *L. cuneifolia*, *L. divaricata*, *A. fiebrigii*, and *P. glutinosus* were identified as the medicinal species with the highest Importance Value Index (IVI). Among these, *Z. punctata*, *L. cuneifolia*, and *L. divaricata* were present in most sampled localities, whereas *A. fiebrigii* and *P. glutinosus* predominantly occurred in higher areas, particularly on upper slopes, where microenvironmental conditions favor greater moisture retention. These findings suggest that the mentioned species should be prioritized for restoration studies and cultivation aimed at medicinal applications. The Monte Desert region emerges as a critical reservoir of plant biodiversity, particularly for species of pharmacological interest. In this context, the presented data gain significance for informing management strategies that integrate conservation and sustainable use of plant resources. Such strategies could alleviate harvesting pressure on these species while ensuring a consistent supply of biomass for medicinal purposes.

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## CONFLICTS OF INTEREST

Authors declare no conflicts of interest.

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