High linear growth rate of the pendulous lichen *Usnea angulata* Ach. in Sierra Chaco Forest of Central Argentina

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The purpose of this study was to identify the growth rate of the pendulous lichen *Usnea angulata* in the Sierra Chaco forest using transplanted and non transplanted thalli of different initial sizes. Fifty trees with *U. angulata* thalli were selected in a protected forest in central Argentina. On each thallus, we selected the two longest branches (BSL and BL) and we cut fragments of 10 cm and 5 cm (FL and FSL) and attached them to the side. In addition, we randomly selected 96 thalli of *U. angulata* from the surrounding environment and we cut a fragment of 10 cm (FT). The fragments were attached to four different trees, and located in the same area. The linear growth of cut branches and fragments were measured for three years at intervals of six months. On average, the growth of *U. angulata* was 23.5 mm per year. The FT growth rate was significantly higher. In comparison with previous studies, the growth rate found is high. More studies are needed to determine the effect of the transplant method and the initial size of thalli at growth.

Key words: lichens, transplantation, linear growth, pendant.

The growth of lichens is of central interest to different areas of applied Lichenology. There are works on lichenometry (Easton 1994), on conservation (Armstrong 1975, McCune *et al.* 1996, Caldiz 2004) and on the evaluation of the effect of different environmental conditions on lichen growth. Some studies show growth response in lichens under stress induced by environmental pollution (Vagts *et al.* 1994) and not induced (Lawrey & Hale 1979).

To measure growth in crustose and foliose lichens, different techniques have been used such us photographic techniques (Rhoades 1976, Hooker & Brown 1977, McCarthy & Zaniewski 2001) and tracing techniques (Hale 1973). To study fruticose and foliose lichen growth, transplant and biomass methods have been developed (McCune *et al.* 1996, Hill 2002, Keon & Muir 2002, Jansson *et al*. 2009). It is not clear, however, whether the use of the transplant method to asses lichen growth can modify the growth rates.

Differences exist in the literature regarding the effect of initial thallus size on growth rate. Some authors observed that the initial stage (when the thallus is small) is slow (Rydzak 1961, Hale 1973) while others reported no differences related to the size of the thallus (Caldiz 2004). Brodo (1965) recognized that the condition of juvenile depends on each group of lichens. For this reason, the differences need to be analysed in particular cases.

Research about lichen growth has concentrated mainly in the northern hemisphere and temperate forests (Keon & Muir 2002, Coxson & Stevenson 2007). There are few studies of lichen growth in the southern hemisphere (Caldiz 2004) and no studies in arid or semi - arid environments.

Here, we report the growth rate of the fruticose lichen *Usnea angulata* Ach. in Sierra Chaco forest of central Argentina and we discuss the differences in growth between transplanted and non transplanted thalli of different initial sizes. This is, to our knowledge, the first report on lichen growth rate in a semi-arid environment in South America.

Material and methods

The species

Usnea angulata Ach. is an exclusively corticolous fruticose lichen, the habit is pendulous with parallel branches growing from an holdfast that fixes the thallus to the substrate. The branching system is mainly anisotomic, and thallus length can be up to 150 cm. The main characteristics of species members are the alate segments in transversal section and the numerous fibrils growing perpendicularly with the main branches (Herrera Campos *et al.* 1998). The reproduction is asexual through soredia, isidia or fragments; some specimens, however, form apothecia. The distribution is cosmopolitan; in South America, *U. angulata* is known from Argentina (Calvelo & Liberatore 2002), Brazil, Uruguay, and Venezuela (Moytka 1936–1938). In Argentina, this lichen grows in forests and shrublands in temperate to subtropical climates. In the study region it is commonly used for ornamental or dyeing purposes.

Study Area

The study was conducted in a protected area (Reserva Natural Cultural Cerro Colorado, 30° 0.4´S; 63° 54´W) that belongs to the phytogeographic province of Chaco (Cabrera 1971). The vegetation of the reserve belongs to the belt of mountain woodland and the transition with the Chaco lowland forest, where typical species from the Chaco woodland are found. Apart from species characteristic for the Sierra Chaco forest such as *Lithraea ternifolia* (Gill.) Barkley & Rom., *Celtis tala* Gill. ex Planchon, and *Prosopis alba* Gris., also *Myrcianthes cisplatensis* (Camb.) Berg. and *Trithrinax campestris* (Burmeist.) Drude & Grises. can be found there (Luti *et al*. 1979). Among the commonest lichens in this region are representatives of *Canoparmelia, Heterodermia, Parmotrema, Physcia, Ramalina*, and *Usnea*. For a detailed description of the lichen community at this study site see Quiroga *et al*. (2008). The study site was selected due to the presence of *U. angulata* specimens. The climate is semi-desert next to semi-dry according to Capitanelli (1979). Precipitation is influenced by the height. Cerro Colorado has an annual average precipitation of 745.6 mm.

Sample selection and growth measurement

Fifty trees (phorophytes) with the presence of *U. angulata* were selected along a 2 km transect. All thalli were at least 15 cm long and were growing at a height between 1,5–2 m from the ground. The phorophytes belonged to one of three species: *Acacia caven (Molina) Molina*, *A. praecox Griseb*. and *Prosopis alba Griseb*., with a DAP above 20 cm. Each tree was geopositioned and marked on the field for its location.

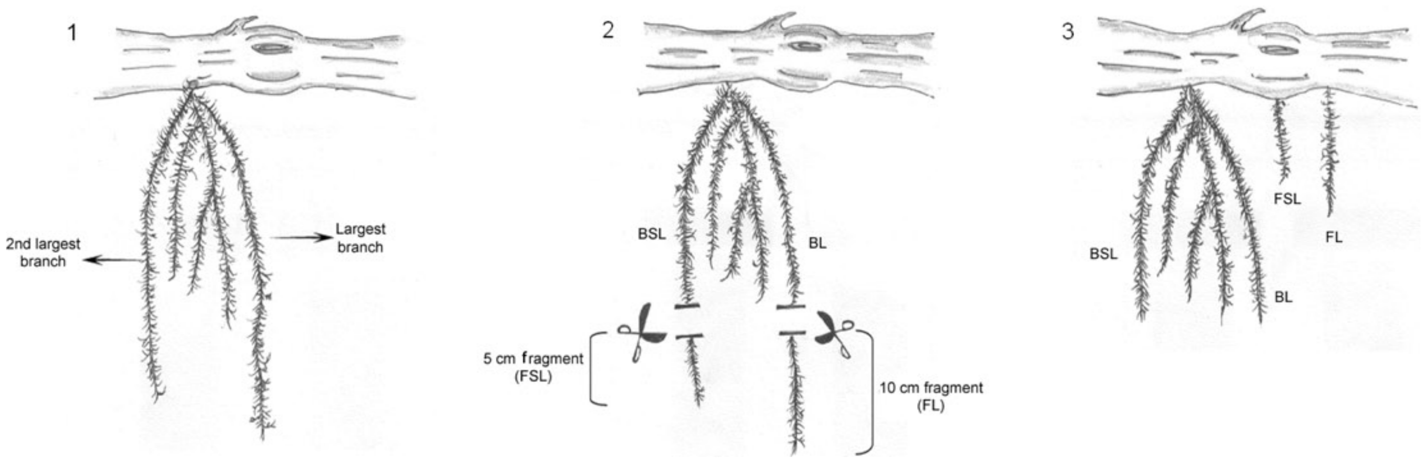
For each sample of *U. angulata*, the length of the longest branch (BL) and the second longest branch (BSL) were measured. A fragment of 10 cm (FL) was cut off from the longest branch, and from the second longest branch a fragment of 5 cm (FSL). Both fragments (FL and FSL) were stuck adjacent to the selected sample to imitate the original position (Figs. 1–3). Glue and adhesive tape were used to attach the thalli onto the substrate and the cutting place was marked with permanent ink.

Growth in length was measured every six months, from July 2006 until February 2009, and all measurements were made at least one week after the last rainfall registered.

At the same time 96 fragments of 10 cm were randomly collected from thalli of *U. angulata*, independently of their size (FT). These fragments were placed adjacent to each other on eight different phorophytes (twelve per tree) as described above.

Statistical analysis

Five periods of six months were measured for the sectioned thalli and their transplanted fragments (RL, RSL, FL, and FSL), and three periods of 6 months for the rest of the transplants (FT, after the third period all thalli were lost). With this information, annual growth rate was calculated in mm.year^{-1} for the sectioned thalli and all their fragments.



Figs. 1–3. – Methods used for the measurement of the linear growth rate in *Usnea angulata*. **1.** Selection of the two largest branches. **2.** Cut of 10 cm in the largest branch and cut of 5 cm in the second largest branch. **3.** Fragments attached next to the thallus.

Growth values lower than 10 mm or higher than 50 mm were excluded from the six-month period analysis and were considered as anomalous data that, very likely, originated from fragmentation of thalli or measurement errors. Due to the non-parametric distribution of some data sets (Shapiro-Wilks Normality test $p > 0.05$), no parametrical tests were applied. The Kruskal Wallis Test ($p \leq 0.05$) was performed using the statistical software Infostat, version 2009 to evaluate significant differences among the growth rates of the five data series (BL, BSL, FL, FSL, FT).

Results and Discussion

This work was carried out in order to assess the growth of *Usnea angulata* for a potential use as renewable resource in a semi-arid area.

In literature, different methods are reported for measuring growth in lichens (Hill 2002), however, there are no studies on measuring fruticose lichens *in situ* without transplant. While biomass is one of the most appropriate methods for growth measurements (McCune *et al.* 1996), the lichen biomass can not be measured without removing the thallus from its substrate.

The loss percentages of thalli were 60 % for BL and 58 % for BSL, and that of fragments 60.5 % for FL and 60 % for FSL. Hundred percent of the FT fragments were lost in the third period of measurement. The loss rate observed in this study was very high, even in non-transplanted thalli. In contrast to these results, previous studies have reported survival rates between 59 % and 81 % (Caldiz 2004) or missing thallus percentages of 12 % to 31 % (Sillett 1994). In each growth period, many thalli were found on the ground or folded on other branches or trees, even the non-transplanted ones. The dispersal and colonization ability of lichens with this habit depend on wind and rainfall that move the branches or fragments (Esseen & Renhorn 1998). Particularly, *U. angulata* lichens are widely used by animals to build nests (Chatellenaz & Ferraro 2007), or are removed by cattle grazing. Possibly, all these factors influenced the high loss rate of lichens observed in this study.

The average growth rate was 23.5 mm per year. Growth rates for the different treatments are indicated in Fig. 4.

The Kruskal Wallis test provided significant differences between FT and the rest of the treatments ($p > 0.05$). Transplantation treatments revealed the highest growth rates on average.

In our study, the growth values were higher compared to that of foliose lichens (Brodo 1965, Hale 1973) and are similar to those measured for *Usnea longissima* (Keon & Muir 2002).

Studies in favourable environmental conditions (open and wet forests), however, resulted in much higher growth rates (26 % to 61 %

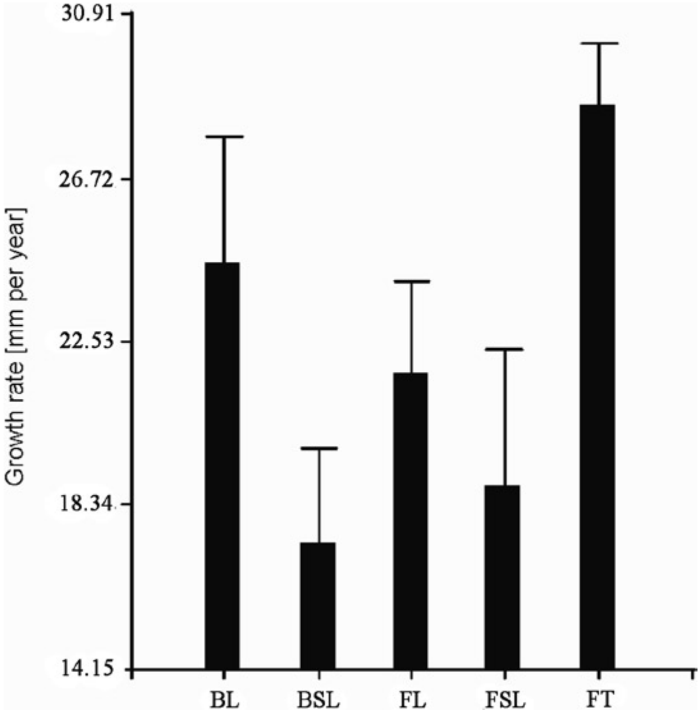


Fig. 4. – *Usnea angulata*. Average growth rates and standard errors for thalli (BL and BSL) and transplanted fragments (FL, FSL, and FT)

in average) for fruticose lichens (Rolstad & Rolstad 2008). To our knowledge, the response of *U. angulata* in a semi-arid environment is reported here for the first time.

The growth rates of smaller branches (BSL and FSL) do not differ significantly from the larger branches (BL and FL) (Fig. 4). Similar findings in *Pseudocyphellaria* (Caldiz 2004) do not indicate a relationship between the initial weight of the transplanted thalli and their growth rate. Studies in *Usnea longissima*, however, evidenced lower growth rates in smaller transplanted thalli (Jansson *et al*. 2009). Likewise, similar results were reported for *Stereocaulon paschale* by Kytöviita & Crittenden (2002). Additional support for growth, independent from initial size, comes from the work of Rolstad & Rolstad (2008) who demonstrated that *Usnea longissima* presented not only apical growth but also intercalary growth. Further research on growth patterns of *Usnea* species in different environmental conditions has still to be done.

Only for fragments, which were transplanted and placed in similar conditions (FT), we measured a higher growth rate. We suggest that microclimatic factors such as moisture or light availability are involved and may have a positive or negative influence on growth. In support of this, Jansson *et al.* (2009) attributed the greatest growth in *Usnea* thalli to microclimatic factors generated by forests edges, whereas Sillet (1994) found lower growth rates in cyanolichens in forest edges. Dahlman & Palmqvist (2003) recognized that internal factors such as the chlorophyll content of lichens can explain the differences in growth rate. We hypothesize that internal and external factors as mentioned above are playing an important role for the growth potential in the different branches in one fruticose thallus.

In conclusion, the growth rate of *U. angulata* in a semi-arid region is comparably high. We recommend the transplant method should be carefully used for the assessment of lichen growth. The effect of the initial size on lichen growth remains unclear for *U. angulata*, but the role of microclimatic factors on it is essential.

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