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Phenology, caudex growth and age estimation of *Cyathea corcovadensis* (Raddi) Domin (Cyatheaceae) in a subtropical forest in southern Brazil

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ABSTRACT

Cyathea corcovadensis (Raddi) Domin occurs in northeastern, southeastern and southern Brazil, being widely distributed in the last. This was a three-year study, conducted from August 2008 to July 2011, in which we evaluated *C. corcovadensis* in a subtropical forest in southern Brazil. For the first year (August 2008 to July 2009), we monitored 30 plants on a monthly basis in order to analyze phenological events (vegetative and reproductive) and caudex growth. We also estimated the ages of the plants. Except in June and July of 2009, monthly leaf emergence and senescence were continuous and irregular, which prevented total leaf abscission, during that first year. Leaf emergence, senescence and fertility correlated with photoperiod, temperature and plant height, whereas rainfall was not a good predictor of *C. corcovadensis* phenophase. Within the forest fragment studied, the high proportion of fertile individuals (63.3%) indicated that the population has the potential to increase in size. The mean annual caudex growth rate was 4.66-8.23 cm and was statistically equivalent among the three years evaluated. The number of leaves per plant remained stable throughout the study period. Among plants that were 4 m tall, the mean estimated age was 60.3 years when calculated on the basis of overall height and mean annual growth rate, compared with only 46.9 years when calculated on the basis of the number of total leaf scars or petiole remains on the caudex and mean annual leaf production.

Key words: growth rates, monitoring, tree fern, climatic variables

Introduction

Although tree ferns are prominent in tropical forest vegetation (Churchill *et al*. 1998), little is known about their phenological characteristics or the environmental triggers that affect leaf emergence, senescence and fertility (Mehltreter & García-Franco 2008) in most neotropical tree fern species. Phenology is the study of the periodicity of biological processes caused by intrinsic factors or triggered by extrinsic agents, especially the climatic variables temperature, photoperiod and rainfall, or some combination of the three (Mehltreter 2008).

In tropical environments, plants often have a seasonal variation in growth that is associated with a well-defined periodic dry season (Mehltreter 2008). However, seasonality in the phenology of tropical ferns occurs without well-defined rainfall seasonality (Schmitt & Windisch 2006a; Schmitt *et al*. 2009), which suggests that other climatic factors, such as photoperiod and temperature, are important determinants of phenology, as observed by Chiou *et al.* (2001) and Schmitt *et al*. (2009). In addition to climatic variables, phenological events also result from biotic factors (van Schaik *et al*. 1993), which include morphological aspects (Borchert 1983; Schmitt *et al*. 2009), as well as the activity of herbivorous animals (Aide 1993).

Tree ferns are found in several genera (Sharpe & Mehltreter 2010), and two major families (Cyatheaceae and Dicksoniaceae) harbor the highest number of species (Fernandes 2003), accounting for approximately 180 species occurring in the Neotropics (Tryon & Tryon 1982) and 17 species in southern Brazil, seven of which occur in the state of Rio Grande do Sul (Condack 2013; Windisch & Santiago 2013). In tree ferns, the growth of the caudex (perennial stem) varies greatly according to the habitat, and some species grow very slowly, as recorded by Schmitt & Windisch (2012) in the case of *Cyathea atrovirens* (Langsd. & Fisch.) Domin (1.19 cm year^{-1}), whereas others grow very rapidly, up to 89.7 cm year^{-1}, as reported for *C. trichiata* (Maxon) Domin (Bittner & Breckle 1995). Tree ferns constitute a special case, because they have vertical caudices on which leaf scars may provide evidence of the history of leaf emergence (Sharpe & Mehltreter 2010). Therefore, tree fern

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age can be estimated by measuring the increase in caudex height and assessing leaf emergence rates (Tanner 1983; Schmitt & Windisch 2006b; Sharpe & Mehltreter 2010). In the Neotropics, studies including phenological data, caudex growth rates and age estimates for Cyatheaceae, restricted to a few species and sites, were conducted by Mehltreter & García-Franco (2008), in Mexico; by Conant (1976), Seiler (1981), Tanner (1983) and Bittner & Breckle (1995), in Central America; by Ortega (1984), Arens & Baracaldo (2000) and Arens (2001), in South America; and by Schmitt & Windisch (2001; 2003; 2006a; 2006b; 2007, 2012) and Lehn & Leuchtenberg (2008), in southern Brazil.

Cyathea corcovadensis (Raddi) Domin forms caudices as tall as 5 m and has persistent petiole bases. The leaves are up to 3 m long, the petiole is tuberculate or muricate, and the lamina is bipinnate. Secondary veins are bifurcate or (more often) forked, and sori are distributed medially on the pinnulae (Fernandes 2003). In Brazil, the species occurs in northeastern region (in the states of Pernambuco, Bahia and Alagoas), southeastern region (in the states of Minas Gerais, Espírito Santo, São Paulo and Rio de Janeiro) and southern region (in the states of Paraná, Santa Catarina and Rio Grande do Sul), as reported by Windisch & Santiago (2013). Specifically in the state of Rio Grande do Sul, where it is found only in the northern coastal plain (Lorscheitter *et al*. 1999), it is listed as a threatened species and classified as endangered (SEMA 2012). In the present study, we analyze the vegetative phenology (leaf emergence, expansion and senescence) and reproductive phenology (leaf fertility) of *C. corcovadensis* in a subtropical forest in southern Brazil. In addition, we evaluate the relationships between climatic variables and caudex height. We also determine caudex growth rates and estimate plant ages, using two different approaches.

Material and methods

Study area

Between August 2008 and July 2011, field work was conducted in a 5-ha fragment of dense rain forest (29°24'59.23"S; 49°54'51.09"W) in the municipality of Três Cachoeiras, in the state of Rio Grande do Sul, which is in southern Brazil. The soil is classified as organic; it is poorly drained and contains organic material in different stages of decomposition (Streck *et al*. 2002). The climate of Rio Grande do Sul is humid throughout the year (Buriol *et al*. 2007). According to the Köppen classification system, the climate of the region under study is type Cfa (humid subtropical), with average temperatures that exceed 22°C in the warmest month. The proximity to the ocean is a factor in temperature regulation, is responsible for temperature stability in the region (Moreno 1961).

According to data related to the period of August 2008 to July 2009 (the first year of the three-year study period), obtained from the 8th District of the Brazilian National Institute of Meteorology, the average monthly temperature was highest in March (23.6°C) and lowest in July (12.7°C). During that same period, total monthly rainfall was highest in January and lowest in December (200.9 mm and 25.0 mm, respectively); and the mean monthly photoperiod ranged from 10 h and 9 min in June to 14 h and 1 min in December (Fig. 1). Over the three years evaluated, the mean annual temperature ranged from 18.9°C to 20.4°C and annual rainfall ranged from 1342 mm to 1998 mm (Fig. 1).

Individual tagging

In July 2008, a field trip was taken to identify the *Cyathea corcovadensis* plants in the fragment under study. In August of the same year, 30 individuals were tagged with numbered plastic tags fixed to the caudex with nylon thread. Plants growing near the perimeter of the fragment were excluded, as were those that had a branched caudex, with two crowns.

Monthly monitoring

To determine production and senescence rates, we counted the croziers, mature leaves (fully expanded green pinnae), fertile leaves, and senescent leaves (all pinnae

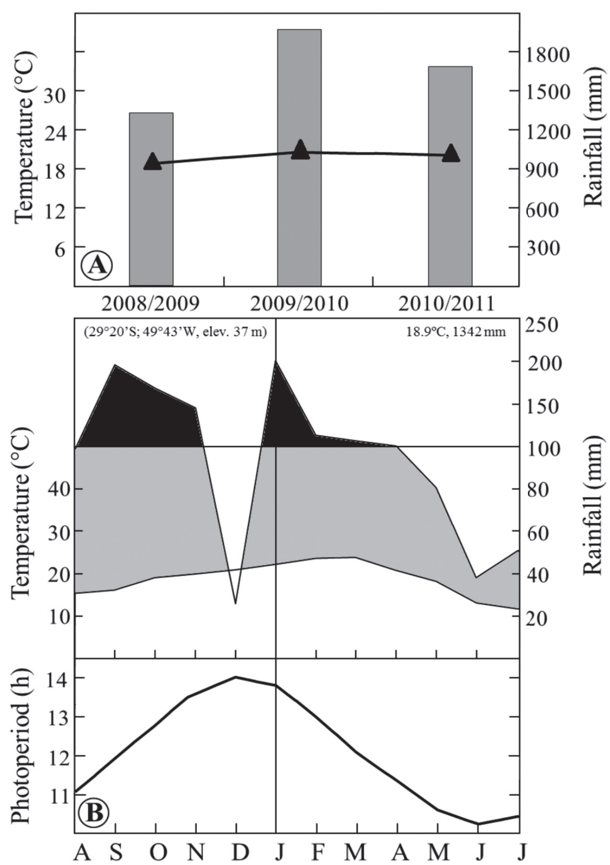

Figure 1. Climatic conditions during the study period: (A) annual rainfall and mean temperature for the study period as a whole (from August 2008 to July 2011); and (B) monthly means for temperature, rainfall and photoperiod during the first year of the study (from August 2008 to July 2009), as well as the geographic location, elevation, mean annual temperature and annual rainfall.

dried or only the petiole bases remaining) of all plants on a monthly basis for the first year of the study period (August 2008 to July 2009). To determine leaf growth rates, we marked young croziers with plastic rings and checked their development monthly until they were fully expanded.

Annual monitoring

To calculate the annual growth rates, we measured plant height, defined as the distance from the ground to the top of the caudex, in August 2008 and again at 12, 24, and 36 months. The number of mature leaves was recorded annually.

Age estimation

To estimate the age of *Cyathea corcovadensis* individuals, we used two separate approaches, as described by Schmitt & Windisch (2006b). The first approach was based on the relationship between the total length of the caudex and the average annual increase in height during the study period as a whole. The second was based on the relationship between the total number of leaves (determined by counting scars or petiole remains along the whole caudex) and the average annual leaf production during the first year of the study.

Statistical analysis

We used the Statistical Package for the Social Sciences, version 17.0 (SPSS Inc., Chicago, IL, USA) and Spearman's rank correlation test to determine the relationship between number of leaves and caudex height, as well as to determine whether phenological events correlated with temperature, photoperiod and rainfall. The reference values that qualify the correlations were adopted according to David (1971). The synchrony of the population phenophases was measured using the synchrony index (Z) according to a method adapted by Pedroni *et al.* (2002) from Augspurger (1983). Synchrony is perfect when Z=1, indicating that all individuals in the population are simultaneously in the same phenophase, whereas a Z of 0 indicates that there is no synchrony in the population. We drew comparisons among the three years evaluated, in terms of the mean annual caudex growth rates and mean number of mature leaves in a single month (August) of each year, using the nonparametric Kruskal Wallis test, with a 5% significance level.

Results

Monthly monitoring

Between August 2008 and July 2009, individuals with emerging croziers were proportionally most common in November (66.67%) and March (46.67%), at monthly means of 1.17±1.34 and 0.83±1.26 new leaves plant^{-1}, respectively. In those two months, ≥ 33.33% of all individuals in the population produced leaves (Fig. 2), at a synchrony rate (Z=0.53) close to the annual rate (Z=0.48). However, there was no leaf emergence in June or July (Fig. 2). Together, the plants produced a mean of 4.33±2.32 leaves year^{-1} and a strong correlation was found between annual leaf production and plant height (r=0.67; p<0.001; n = 30). For instance, individuals that were 0.09 m and 5.10 m tall produced two and nine leaves per year, respectively. The mean monthly number of new leaves was quite strongly correlated with temperature and photoperiod during the month of occurrence, as well as with those during the previous month (Tab. 1).

The tagged *Cyathea corcovadensis* croziers (n = 36) expanded most rapidly in the first and second months after emergence (4.13±1.53 cm day^{-1} [n = 36] and 2.69±1.49 cm day^{-1} [n = 14], respectively). The maximum crozier expansion rate in the first month was 10.14 cm day^{-1}. From the end of the second month onward, two of those same leaves continued to increase in length, although at a slower rate (1.62±1.50 cm day^{-1}). The mean total length of expanded leaves was 177.40±68.15 cm (range, 58-290 cm). The height of individuals was strongly correlated with the total leaf length (r=0.54; p=0.001; n = 36) and the length of the leaf blade (r=0.60; p<0.001; n = 36).

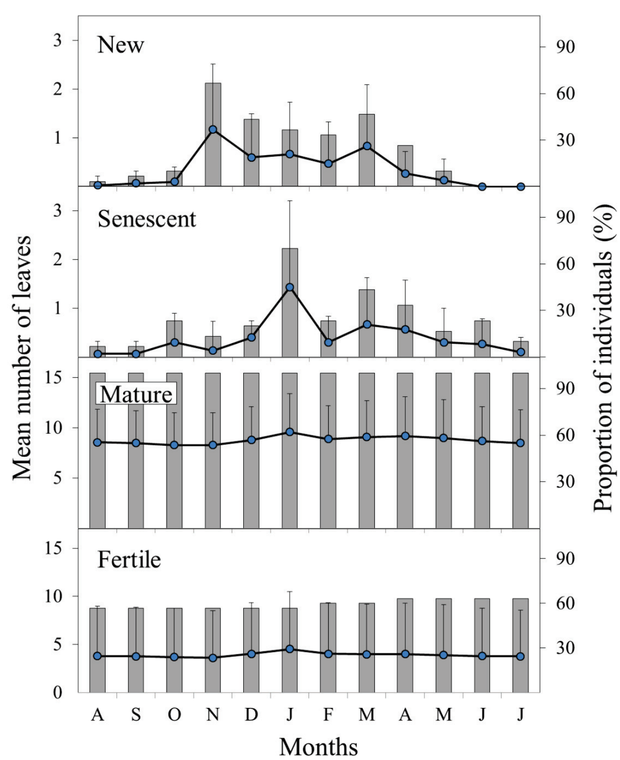

Figure 2. Leaf production by *Cyathea corcovadensis* in a subtropical forest in southern Brazil during the first year of the study (from August 2008 to July 2009) with the monthly means and standard deviations, for the numbers of new, senescent, mature and fertile leaves per plant.
Columns indicate the proportion (%) of individuals in each phenophase and bars show standard deviation of mean number of leaves during each month.

Table 1. Spearman rank correlations between phenological events of *Cyathea corcovadensis* and climatic factors, in the month of occurrence and in the previous month, from August 2008 to July 2009, in a subtropical forest in southern Brazil.

Climatic factor	Month	Phenological events		
		New leaves	Senescent leaves	Fertile leaves
Photoperiod	0	0.79	0.47*	0.34*
	1	0.86	0.80	0.65
Temperature	0	0.86	0.79	0.63
	1	0.67	0.80	0.73
Precipitation	0	0.37*	0.11*	−0.10*
	1	0.46*	0.18*	−0.07*

0 – month of occurrence; 1 – previous month.
*Not significant.

During the first year of the study period, the minimum and maximum number of fully-expanded (mature) leaves per sporophyte ranged from three to 19. As can be seen in Fig. 2, the mean monthly number of mature leaves was highest in January (9.63±3.78 leaves plant^{-1}) and lowest in November (8.30±3.15 leaves plant^{-1}), representing a marked difference that did not occur again over the course of the first year of the study.

Plants with senescent leaves were found in all months of the first year, and the lowest mean (0.07±0.25 leaves plant^{-1}) was found in August and September. From the summer (January) to the beginning of autumn (April) of 2009, leaf senescence was found in ≥ 23.33% of the individuals in the population (Fig. 2) and the monthly synchrony rate was higher than the annual synchrony rate (Z=0.45 vs. Z=0.30). As can be seen in Fig. 2, the mean rate of leaf senescence was highest in January (1.43±1.77 leaves plant^{-1}). The overall mean rate of leaf senescence was 4.6±3.24 leaves year^{-1}, and a strong correlation was found between plant height and leaf senescence (r=0.66; p<0.001; n = 30). Individuals that were 0.09 m and 5.10 m tall presented two and 12 senescent leaves per year, respectively. The mean number of senescent leaves per month was strongly correlated with temperature in the month of occurrence and in the previous month, as well as with photoperiod in the previous month (Tab. 1).

Of the 30 plants monitored, 19 (63.3%) had fertile leaves. The fertile individuals were those with caudices between 10 cm and 5.10 m in height. As shown in Fig. 2, the mean monthly number of fertile leaves was highest in the summer month of January (4.53±5.97 leaves plant^{-1}) and lowest in the spring month of October (3.70±5.06 leaves plant^{-1}). The mean monthly number of fertile leaves was strongly correlated with temperature in the month of occurrence and in the previous month, as well as with photoperiod in the previous month (Tab. 1). Height was very strongly correlated with the mean annual number of fertile leaves (r=0.715; p<0.001; n = 30). During the first year of the study, the mean annual number of fertile leaves among the population as a whole was 3.91±5.19 leaves plant^{-1} (ranging from 0 to 15.58 leaves plant^{-1} in plants with a height of 0.08 and 4.66 m, respectively).

Annual monitoring

Although mean annual caudex growth rates increased gradually over the course of the study period (Tab. 2), there were no statistical differences among the three years (H=2.74; p=0.254; df=2). Plant height also increased over the course of the study, reaching 46 cm year^{-1} in 2011. The number of leaves remained relatively stable (Tab. 2), without significant differences between any of the years (H=0.286; p=0.963; df=3).

Plant age estimates

When we estimated the age of hypothetical plants with a 4 m caudex using the first approach (dividing total caudex length by the mean annual growth rate), we found it to be 60.3 years. In reality, the mean plant height was 1.22±0.87 m, and there were 62±33.65 petiole remains caudex^{-1} (n = 18; we excluded 12 individuals because the petiole remains could not be counted). A very strong correlation was found between the total number of petiole remains or leaf scars and plant height (r=0.93; p<0.001; n = 18) and, proportionally, a 4-m tall plant would have 203 petiole remains or leaf scars. When we estimated the age of a plant with that height, using to the second approach (calculating the ratio of total number of petiole remains or leaf scars on the caudex to mean annual leaf emergence), we found it to be only 46.9 years.

Discussion

In the present study, *Cyathea corcovadensis* showed continuous and irregular leaf senescence, which is characteristic of a nonseasonal pattern. The pattern was not clearly defined for leaf emergence, because, in the winter (especially in June and July), no emergent leaves were observed on any of the plants monitored. Leaf senescence and emergence in this population of *C. corcovadensis* was continuous throughout the year due to the heterogeneity of individual patterns, which contributed to the fact that no plant showed total leaf abscission. This more continuous pattern of leaf emergence and senescence, albeit irregular, has also been reported for *C. delgadii* Sternb. (Schmitt & Windisch 2007) and *C. atrovirens* (Schmitt & Windisch 2012) in Rio Grande do Sul, probably because of the similar weather patterns.

The vegetative and reproductive events of *Cyathea corcovadensis* are partially explained by two climatic variables: photoperiod and temperature. It is likely that the variation of approximately 3.5 h in the photoperiod over the course of a year in the coastal region of Rio Grande do Sul, together with the direct effects of changes in temperature, triggers

Table 2. Minimum, maximum and mean numbers of mature leaves in the month of August in each of the years evaluated, together with annual caudex growth rates, of *Cyathea corcovadensis* in a subtropical forest in southern Brazil.

Variable	Period	Minimum	Maximum	Mean±SD	H	*p*
Mature leaves	August 2008	4	17	8.97±3.42	0.286	0.963
	August 2009	3	14	8.53±3.27		
	August 2010	3	16	8.72±3.22		
	August 2011	2	18	8.67±3.92		
Annual growth rate*	2008-2009	0	20	4.67±3.78	2.74	0.254
	2009-2010	0	20	7.00±5.28		
	2010-2011	0	46	8.23±9.83		

SD – standard deviation; H – Kruskal-Wallis statistic.
*August to August.

predictable physiological responses in several species (Marchioretto *et al.* 2007), as was observed for *C. corcovadensis* in the present study, as well as and for *C. atrovirens* and *Dicksonia sellowiana* in the studies conducted by Schmitt *et al.* (2009) and Schmitt & Windisch (2012), respectively. In a study of 16 fern species in a subtropical broadleaf forest in northeastern Taiwan, Lee *et al.* (2009) reported that leaf senescence, spore maturation and spore release all presented significant positive correlations with temperature but not with precipitation, which is in agreement with our findings for *C. corcovadensis*. A delay between environmental stimulus and phenological response has previously been reported (Marques & Oliveira 2004), which might also explain our finding that the *C. corcovadensis* phenophases were correlated with the photoperiod and temperature in the month prior to the field observations.

The *Cyathea corcovadensis* individuals evaluated presented the highest mean numbers of emergent leaves in November (in the spring), when temperatures are higher and the days are longer, as well as in March (at the end of the summer), when the highest monthly mean temperature was recorded. The fact that the mean number of emergent leaves correlated positively with photoperiod and temperature might indicate that those climatic factors optimized photosynthesis rates in *C. corcovadensis*. Volkova *et al.* (2011) found that low temperatures appeared to be the most limiting factor for photosynthesis in *C. australis* Domin and *Dicksonia antarctica* Labill. under field conditions in a wet sclerophyll forest of southeastern Australia. According to Sato (1982), low temperatures have a restrictive effect on fern leaf expansion and spore production.

In subtropical regions, where the rainfall varies over year, but there is no defined dry season or water limitation, rainfall might be expected to be a poor predictor of phenophases for *Cyathea corcovadensis* in comparison with photoperiod and temperature. Lee *et al.* (2009b) monitored the phenophases of *C. hancockii* Copel., *C. metteniana* (Hance) C.Chr. and *C. podophylla* (Hook.) Copel. in a subtropical rainforest in northern Taiwan. The authors found that none of the phenophases correlated with precipitation, as was found for *C. corcovadensis* in the present study. Other factors have also been found to be triggers of physiological processes (Rivera & Borchert 2001) in subtropical regions.

We found that the phenology of *Cyathea corcovadensis* was also attributable to a biotic factor, specifically a morphological factor, because taller plants produced leaves that were larger, as well as producing greater numbers of emergent, senescent and fertile leaves. This association with height indicates that the size and age of the caudex affect leaf renewal, senescence and fertility, and that more well-developed caudices support a greater number of larger leaves. The same trend in leaf emergence in taller *C. corcovadensis* plants was also reported by Schmitt & Windisch (2003; 2007) for *Alsophila setosa* and *C. delgadii*, as well as by Tanner (1983) for *C. pubescens*. Taller plants capture more light in the understory, which increases their productivity and leaf development rate (Schmitt & Windisch 2007). In El Salvador, Seiler (1981) found no association between leaf emergence and height in *A. salvinii* Hook., which grows in fully illuminated areas. According to Schmitt & Windisch (2007), the fact that the tallest *C. delgadii* plants are more exposed to desiccation might be attributable to their higher numbers of senescent leaves. The tendency to greater fertility among taller plants might favor the dispersion of spores through the wind, which was also found for *C. lasiosora* (Mett. ex Kuhn) Domin by Young & Leon (1989), in Peru; for *A. setosa* and *C. delgadii* by Schmitt & Windisch (2005; 2007), as well as for *Dicksonia sellowiana* by Schmitt *et al.* (2009), in southern Brazil.

The high proportion of fertile individuals observed in the present study indicates that *Cyathea corcovadensis* has the potential to increase the size of its population. This is uncommon among tree ferns, as reported by Nagano & Suzuki (2007) in *C. spinulosa* Wall. ex Hook. (33%) from Japan; by Mehltreter & García-Franco (2008) in *Alsophila firma* (Baker) D.S. Conant (25%) from Mexico; and by Schmitt & Windisch (2006b) in *A. setosa* (8.88%), Schmitt & Windisch (2007) in *C. delgadii* (9.75%) and Schmitt *et al.* (2009) in *Dicksonia sellowiana* (38%) from southern Brazil.

In the population studied here, the plants produced new fertile and sterile leaves every year. The mean monthly number of mature and fertile leaves of *Cyathea corcovadensis* varied slightly during the first year of observation because leaf emergence overlapped with senescence. The mean annual number of mature leaves was equivalent among the three years evaluated. Therefore, tree ferns seem able to maintain a relatively stable number of leaves over a long period of time, as observed for *Dicksonia sellowiana* (Schmitt *et al.* 2009) and *C. atrovirens* (Schmitt & Windisch 2012).

In the *Cyathea corcovadensis* population evaluated here, the annual rates of leaf production and senescence were

Table 3. Annual rates of caudex growth, leaf production and leaf senescence, as well as leaf expansion rates, for tree ferns in southern Brazil and in other neotropical regions.

Species	Reference(s)	Annual caudex growth (cm year^{-1})	Annual leaf production (leaves per plant^{-1})	Annual leaf senescence (leaves per plant^{-1})	Leaf expansion (cm day^{-1})	Location
Cyathea caracasana	Arens 2001	16.80	5.09	-	-	Colombia
Cyathea pubescens	Tanner 1983; Shreve 1914	6.66	8.0	-	4.94	Jamaica
Cyathea corcovadensis	This study	6.63*	4.33	4.6	10.14	Brazil
Alsophila setosa	Schmitt & Windisch 2006a	6.32	5.51	4.33	7.48	Brazil
Cyathea delgadii	Schmitt & Windisch 2007	4.65	5.75	4.92	6.71	Brazil
Dicksonia sellowiana	Schmitt *et al.* 2009	4.78*	10.86	10.54	3.45	Brazil
Cyathea atrovirens	Schmitt & Windisch 2012	1.73**	8.6	8.76	5.18	Brazil

*Three-year mean; **Five-year mean.

similar to those recorded for other tree ferns. The highest leaf expansion rate recorded in the present study was higher than those recorded for other neotropical tree ferns (Tab. 3). The different expansion rates in the different months of leaf development observed in the present study seems to constitute a pattern among tree ferns in southern Brazil (Schmitt & Windisch 2012). The increased length of rachises during the phase in which the croziers are rapidly unfurling is due almost entirely to the elongation of parenchymatous cells, rather than to the increased numbers of these cells by mitosis. However, cell elongation is not responsible for leaf unfurling. This is a result of a greater elongation of the adaxial and abaxial faces of the leaf (Voeller 1966).

Under the canopy of the forest studied here, where climatic conditions during the study period varied little from year to year, *Cyathea corcovadensis* presented slow and relatively constant growth. The mean annual height increases were all within the range of values recorded for other tree ferns in southern Brazil, as well as in Jamaica and Colombia (Tab. 3).

The mean age of *Cyathea corcovadensis* individuals estimated according to total height and mean annual growth was approximately 13 years greater than that estimated according to the number of total remains of petioles or scars on the caudex and mean annual leaf production. Given that height is a poor predictor of the time required for caudex growth (Tanner 1983), the second method probably resulted in a more realistic estimate of the mean age of plants with a height of 4 m (46.9 years). Schmitt & Windisch (2006b) used the former method and found that the estimated age of 4-m tall *Alsophila setosa* plants was practically twice that previously reported for the secondary forest under study (63 years vs. 36 years). Differential growth over a lifetime might be associated with less realistic estimations. *Cyathea muricata* Willd. grows slowly when young and more rapidly as it ages (Prugnolle *et al.* 2000). In contrast, when Schmitt & Windisch (2006b) estimated the age of *A. setosa* in the same forest by dividing the number of leaf scars on the caudex by the number of leaves produced annually, they obtained a more reasonable estimate of 32 years. According to those authors, neither estimate takes the entire life cycle of the plant into account, because a number of factors remain unknown: the time needed to establish the sporophyte from the spore; the growth up to the stage where a caudex with noticeable scars is formed and preserved throughout the life of the plant; and the vegetative or sexual reproductive origin of the plants. On the basis of the annual caudex growth rate, Schmitt *et al.* (2009) estimated an age of 52 years for 2.5-m tall *Dicksonia sellowiana* tree ferns.

Another difficulty in estimating age is that caudex leaf scars may be densely covered by an adventitious root mantle, which, for example, can obscure the lower 1-4 m of the caudex in *Alsophila firma* (Mehltreter & García-Franco 2008), or by epiphytes (Schmitt & Windisch 2006). In the present study, 40% of the plants had epiphytes covering large areas of their caudices, and it was therefore not possible to count the number of leaf scars. As previously mentioned, the site at which we monitored *Cyathea corcovadensis* was within a fragment of a dense rain forest, the vegetation type with the greatest epiphyte richness in southern Brazil (Roderjan *et al.* 2002).

The results of this three-year study show that, in the *Cyathea corcovadensis* population evaluated, caudex growth rates and the number of the leaves in the crown remained stable across the years. In order to maintain this current dynamics of the population, it is necessary to maintain the conservation of the fragment in the studied region. Given the high proportion of fertile individuals observed, this could facilitate the occupation of other habitats by *C. corcovadensis* in the future, thus decreasing the risk of extinction of the species in Rio Grande do Sul.

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References

Aide, T.M. 1993. Patterns of leaf development and herbivory in a tropical understory community. **Ecology 74**(2): 455-466.

Arens, N.C. & Baracaldo, P.S. 1998. Distribution of tree ferns (Cyatheaceae) across a successional mosaic in an Andean cloud forest, Nariño, Colombia. **American Fern Journal 88**(2): 60-71.

Arens, N.C. 2001. Variation in performance of the tree fern *Cyathea caracasana* (Cyatheaceae) across a successional mosaic in Andean cloud forest. **American Journal of Botany 88**(3): 545-551.

Augspurger, C.K. 1983. Offspring recruitment around tropical trees: changes in cohort distance with time. **Oikos 40**(2): 189-196.

Bittner, J. & Breckle, S.W. 1995. The growth rate and age of tree fern trunks in relation to habitats. **American Fern Journal 85**(2): 37-42.

Borchert, R. 1983. Phenology and control of flowering in tropical trees. **Biotropica 15**(2):81-89.

Buriol, G.A.; Estefanel, V.; Chagas, A.C. & Eberhardt, D. 2007. Clima e vegetação natural do Rio Grande do Sul segundo o diagrama climático de Walter e Lieth. **Ciência Florestal 17**(2): 91-100.

Chiou, W.L.; Lin, J.C. & Wang, J. 2001. Phenology of *Cibotium taiwanense* (Dicksoniaceae). **Taiwan Journal for Science 16**(4): 209-215.

Churchill, H; Tryon R. & Barrington. 1998. Development of the sorus in tree ferns: Dicksoniaceae. **Canadian Journal of Botany 76**(7): 1245-1252.

Conant, D.S. 1976. **Ecogeographic and systematic studies in American Cyatheaceae.** Cambridge: Harvard University. Tese de Doutorado.

Condack, J.P.S. 2013. **Dicksoniaceae in Lista de Espécies da Flora do Brasil**. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB90945 (access 15/07/2013).

Davis, J.A. 1971. **Elementary survey analysis**. Englewood. Prentice-Hall.

Fernandes, I. 2003. Taxonomia dos representantes de Cyatheaceae do nordeste oriental do Brasil. **Pesquisas Botânica 53**(1): 7-53.

Lee, P.H.; Lin, T.T. & Chiou, W.M. 2009. Phenology of 16 species of ferns in a subtropical forest of northeastern Taiwan. **Journal of Plant Research 122**: 61-42.

Lee, P.H.; Chiou, W.M. & Huang, Y.M. 2009b. Phenology of three *Cyathea* (Cyatheaceae) ferns in northern Taiwan. **Taiwan Journal Forest Science 24** (4): 233-42.

Lehn, C.R. & Leuchtenberger, C. 2008. Resistência ao fogo em uma população de *Cyathea atrovirens* (Langsd. & Fisch.) Domin (Cyatheaceae) no Estado do Rio Grande do Sul, Brasil. **Biotemas 21**(3): 15-21.

Lorscheitter, M.L.; Ashraf, A.R.; Windisch, P.G. & Mosbrugger, V. 1999. Sonder-Abdruck aus Palaeontographica Beiträge zur Naturgeschichte der Vorzeit. PartII. **Pteridophyte spores of Rio Grande do Sul flora, Brazil.** Stuttgart, E. schweizerbart'sche Verlagsbuchhandlung.

Marchioretto, M.S.; Mauhs, J. & Budke, J.C. 2007. Fenologia de espécies arbóreas zoocóricas em uma floresta psamófila no sul do Brasil. **Acta Botanica Brasilica 21**(1): 193-201.

Marques, M.C.M. & Oliveira, P.E.A.M. 2004. Fenologia de espécies do dossel e do sub-bosque de duas florestas de restinga da Ilha do Mel, sul do Brasil. **Revista Brasileira de Botânica 27**(4): 713-723.

Mehltreter, K. & García-Franco, J.G. 2008. Leaf phenology and trunk growth of the deciduous tree fern *Alsophila firma* (Baker) D. S. Conant in a Lower montane Mexican forest. **American Fern Journal 98**(1): 1-13.

Mehltreter, K. 2008. Phenology and habitat specificity of tropical ferns. Pp. 201-221, In: **Biology and Evolution of Fern and Lycophytes.** Cambridge, Cambridge University Press.

Moreno, J.A. 1961. **Clima do Rio Grande do Sul**. Porto Alegre: Secretaria da Agricultura.

Nagano, T. & Suzuki. E. 2007. Leaf demography and growth pattern of the tree fern *Cyathea spinulosa* in Yakushima Island. **Tropics 16**(1): 47-57.

Ortega, F. 1984. Notas sobre la autecologia de *Sphaeropteris sanilis* (Kl) Tryon (Cyatheaceae) em el Parque Nacional El Ávila - Venezuela. **Pittieria 12**: 31-53.

Pedroni, F.; Sanchez, M. & Santos, F.A.M. 2002. Fenologia de copaíba *Copaifera langsdorffii* Desf. - Leguminosae, Caesalpinioideae) em uma floresta semidecídua no sudeste do Brasil. **Revista Brasileira de Botânica 25**(2): 183-194.

Prugnolle, F.; Rousteau, A. & Belin-Depoux, M. 2000. Occupation spatiale de *Cyathea muricata* Willd. (Cyatheaceae) en foret dense humide guadeloupéenne. I—A l'échelle de l'individu. **Acta Botanica Gallica 147**(2): 361-374.

Rivera, G. & Borchert, R. 2001. Induction of flowering in tropical trees by a 30-min reduction in photoperiod: evidence from field observations and herbarium collections. **Tree Physiology 21**(4):201-212.

Roderjan, C.V.; Galvão, F.; Kuniyoshi Y.S. & Hatschbach, G.G. 2002. As unidades fitogeográficas do estado do Paraná, Brasil. **Ciência e Ambiente 24**: 75-92.

Sato, T. 1982. Phenology and wintering capacity of sporophytes and gametophytes of ferns native to Northern Japan. **Oecologia 55**(1): 53-61.

Schmitt, J.L. & Windisch, P.G. 2001. Prejuízos causados pela geada no desenvolvimento de *Alsophila setosa* Kaulf. (Pteridophyta, Cyatheaceae). **Revista de estudos / Universidade Feevale 24**(1): 79-88.

Schmitt, J.L. & Windisch, P.G. 2003. Relação entre comprimento do estípite, produção de frondes e tamanho do cáudice, em *Alsophila setosa* Kaulf. (Pteridophyta, Cyatheaceae). **Pesquisas Botânica 53**(1): 55-63.

Schmitt, J.L. & Windisch, P.G. 2005. Aspectos ecológicos de *Alsophila setosa* Kaulf. (Cyatheaceae, Pteridophyta) no sul do Brasil. **Acta Botanica Brasilica 19**(4): 861-867.

Schmitt, J.L. & Windisch, P.G. 2006a. Phenological aspects of frond production in *Alsophila setosa* Kaulf. (Cyatheaceae: Pteridophyta) in southern Brazil. **Fern Gazette 17**(5): 263-270.

Schmitt, J.L. & Windisch, P.G. 2006b. Growth rates and age estimates of *Alsophila setosa* Kaulf. in southern Brazil. **American Fern Journal 96**(4): 103-111.

Schmitt, J.L. & Windisch, P.G. 2007. Estrutura populacional e desenvolvimento da fase esporofitica de *Cyathea delgadii* Sternb. (Cyatheaceae, Monilophyta) no sul do Brasil. **Acta Botanica Brasilica 21**(3): 731-740.

Schmitt, J.L. & Windisch, P.G. 2012. Caudex growth and phenology of *Cyathea atrovirens* (Langsd. & Fisch.) Domin (Cyatheaceae) in secondary forest, southern Brazil. **Brazilian Journal of Biology 72**(2): 397-405.

Schmitt, J.L.; Schneider, P.H. & Windisch, P.G. 2009. Crescimento do cáudice e fenologia de *Dicksonia sellowiana* Hook. (Dicksoniaceae) no sul do Brasil. **Acta Botanica Brasilica 23**(1): 289-291.

Seiler, R.L. 1981. Leaf turnover rates and natural history of the Central American tree fern *Alsophila salvinii*. **American Fern Journal** 71(3): 75-81.

SEMA - Secretaria do Meio Ambiente . **Espécies da flora ameaçadas de extinção do Rio Grande do Sul.** Decreto n 42.099, publicado em 1/01/2003 Secretaria do Meio Ambiente, Porto Alegre. Available at:http://www.sema.rs.gov.br/sema/html/pdf/especies-ameacadas.pdf. (access 05/07/2012)

Sharpe, J.M. & Mehltreter, K. 2010. Ecological insights from fern population dynamics, Pp. 61-110. In: **Fern Ecology Cambridge Publisher**. Cambridge, Cambridge University Press.

Streck, E.V.; Kämpf, N.; Dalmolin, R.S.D.; Klamt, E.; Nascimento, P.C. & Schneider, P. 2002. **Solos do Rio Grande do Sul.** Porto Alegre, EMATER/ UFRGS.

Tanner, E.V.J. 1983. Leaf demography and growth of tree-fern *Cyathea pubescens* Mett. Ex Kuhn in Jamaica. **Botanical Journal of the Linnean Society 87**(3): 213-227.

Tryon, R. & Tryon, A. 1982. **Ferns and allied plants with special reference to Tropical America.** New York: Springer Verlag.

Van Schaik, C.P.; Terborgh, J.W. & Wright, S.J. 1993. The phenology of tropical forest: adaptive significance and consequences for primary consumers. **Annual Review of ecology and Systematics 24**(1): 353-377.

Voeller, B. 1966. Crozier Uncoiling of Ferns. **The Rockefeller University Review 4**:14-19.

Volkova, L; Bennett, L.T. & Tausz, M. 2011. Diurnal and seasonal variations in photosynthetic and morphological traits of the tree ferns *Dicksonia antarctica* (Dicksoniaceae) and *Cyathea australis* (Cyatheaceae) in wet sclerophyll forest of Australia. **Environmental and Experimental Botany 70**(1): 11-19.

Windisch, P.G. & Santiago, A.C.P. 2013. **Cyatheaceae in Lista de Espécies da Flora do Brasil**. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB90850 (access 15/07/2013).

Young, K.R. & León, B. 1989. Pteridophyte species diversity the Central Peruvian Amazon: importance of edaphic specialization. **Brittonia 41**(4): 388-395.