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Environment

Growth analysis of *Gymnanthes klotzschiana* müll.arg. in different sociological positions and soil water conditions

Análise do crescimento de *Gymnanthes klotzschiana* müll.arg. em diferentes posições sociológicas e condições hídricas do solo

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ABSTRACT

The aim of this study was to determine and correlate climatic data and increment of *Gymnanthes klotzschiana* in different sociological positions and soil water saturation conditions. Samples were collected from 116 trees in a fragment of Alluvial Araucaria Mixed Forest using a Pressler auger (5 mm in diameter). The sampling material was fixed in channels and polished with sandpaper of different weights. The increment data were obtained and correlated with climatic variables and compared with the use of a completely randomized design in a factorial arrangement. Factor 1 considered the three piezometric levels (high, medium and low) and factor 2 the two sociological positions (canopy and understory). The results of the analysis indicated that the increment for *G. klotzschiana* ranged from 1.20 mm.year^{-1} in the understory, at low piezometric level, to 1.99 mm.year^{-1} in the canopy, at high piezometric level. These results were correlated with temperature and precipitation data and a negative correlation was found between growth and the sum of precipitation for trees located at a high piezometric level; and the smallest increment values were registered for the trees that were located in a sociological position of understory and at a high piezometric level.

Keywords: Dendrochronology; water level; sociological position; precipitation; temperature

RESUMO

O objetivo deste estudo foi determinar e correlacionar dados climáticos e incremento de Gymnanthes klotzschiana em diferentes posições sociológicas e condições de saturação hídrica do solo. As amostras foram coletadas de 116 árvores em um fragmento de Floresta Ombrófila Mista Aluvial com a utilização do trado de Pressler (5 mm de diâmetro). O material da amostragem foi fixado em canaletas e polido com lixas de diferentes gramaturas. Os dados de incremento foram obtidos e correlacionados com variáveis climáticas e comparados com a utilização do delineamento inteiramente casualizado em

arranjo fatorial. Como fator 1 foram considerados os três níveis piezométricos (alto, médio e baixo) e o fator 2 as duas posições sociológicas (dossel e sub-bosque). Os resultados da análise indicaram que o incremento para G. klotzschiana variou de 1,20 mm.ano-1 no sub-bosque, em nível piezométrico baixo, para 1,99 mm.ano-1 no dossel, em nível piezométrico alto. Esses resultados foram correlacionados com dados de temperatura e precipitação e constatou–se correlação negativa do crescimento com o somatório da precipitação para as árvores localizadas em nível piezométrico alto; e os menores valores de incremento foram registrados para as árvores que estavam localizadas em posição sociológica de sub-bosque e em nível piezométrico alto.

Palavras-chave: Dendrocronologia; nível piezométrico; posição sociológica; precipitação; *Sebastiania commersoniana*

1 INTRODUCTION

The dynamics of water in the soil is one of the main factors that define the structure and composition of a plant community, as depending on its content, it influences the availability of nutrients and serves as a powerful environmental filter, selecting the most adapted and tolerant species to participate in this type of ecosystem (BALESTRIN et al., 2019; RODRIGUES et al., 2018; ROSSATTO et al., 2012). The Alluvial Araucaria Mixed Forest (AAMF) is an example of this type of ecosystem, composed of a small range of selective and adapted species that develop in highly hydromorphic alluvial soils, subject to flood pulses and that occur along the rivers of the southern Brazilian plateau (KERSTEN; BORGO; GALVÃO, 2015) where *Gymnanthes Klotzschiana* Müll.Arg. (Euphorbiaceae) is found in great abundance, representing 60% of all the abundance of these places, where it plays an important functional role for the ecological balance of this vegetation and the environment that comprises it (GONÇALVES et al., 2018; KERSTEN; BORGO; GALVÃO, 2015; KIERAS; MACHADO; ACCIOLY, 2018).

Gymnanthes klotzschiana, as well as other types of plants considered hydrophilic, have morphoanatomical adaptations such as lenticel hypertrophy, schizogenous parenchyma, respiratory roots and metabolic changes, which allow it to survive during long periods of hypoxia and anoxia caused by flood pulses, however, not prevent them from interfering with their metabolic rate and consequently on growth. (DA ROCHA et al., 2020; KOLB et al., 1998). These

characteristics make this species important for stability and recovery of alluvial environments with high soil water saturation (KIERAS; MACHADO; ACCIOLY, 2018; MELI; BETTINARDI; BRANCALION, 2021). However, there are few studies on its environmental dynamics, including analyzes such as the interactions between the sociological position of the species and soil water saturation.

In this sense, the sociological position is a determining factor in the ecological and physiological processes of plants, as they define the incidence of light that can influence, positively or negatively, the development and establishment of seedlings (COSTA; FINGER; DA CUNHA, 2014)

The dynamics of water in the soil acts in the definition of edaphic and vegetational characteristics in the riparian zone. Soil water saturation can be the main definer of vegetation. When soils reach high levels of water saturation, they do not allow the aerobic metabolism of plants (BALESTRIN et al., 2019).

Therefore, as alluvial formations have unique characteristics due to different environmental factors, determining the growth of *G. klotzschiana* can show relevant results from the chronology of the species on a temporal scale. Combining species growth with vertical water table oscillation data can provide innovative and unique data on the species growth pattern at different levels of soil water saturation.

The aim of the study was to determine and correlate with climatic data the increment of *Gymnanthes klotzschiana* in different sociological positions and soil water saturation conditions.

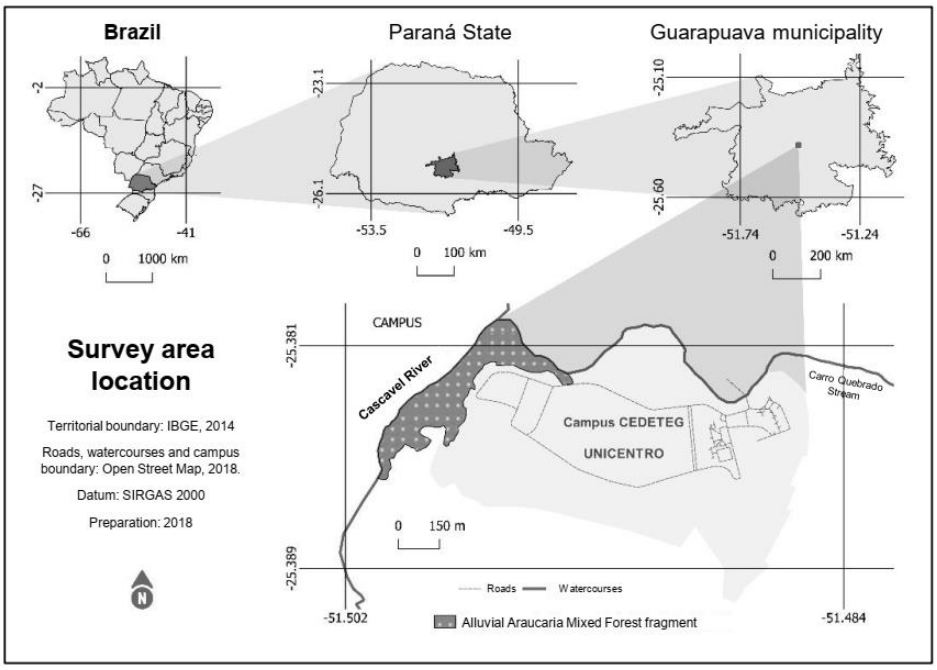
2 MATERIAL AND METHODS

2.1 Area characterization

The study area is located on the CEDETEG campus of the Universidade Estadual do Centro Oeste - UNICENTRO, in the municipality of Guarapuava, State of Paraná, Brazil. The altitude is approximately 1020 meters above sea level and is

located on the third plateau of Paraná. The vegetation of the fragment is of Alluvial Araucaria Mixed Forest with approximately 11.5 ha, located between the geographic coordinates 25º 23' 00" S – 51º 30' 00" W and 25º 22' 47" S – 51º 29' 43" W (Figure 1).

Figure 1 - Location of the study area in the municipality of Guarapuava – PR



Source: Authors (2020)

The area is part of the Cascavel River Hidrographic Basin (CRHB). The forest fragment of the study is bordered in the northern portion by the Carro Quebrado stream and in the western portion by the Cascavelzinho River. According to the Köppen-Geiger Climate classification, the climate is of the *Cfb* type, with an average temperature in the coldest three months between -3°C and 18°C. The climate is always humid with well-distributed rainfall and the average temperature in the warmer months is less than 22°C. The average annual sum of rainfall over the last 29 years (1984-2013) is 1905 mm/year.

The volcanism that occurred in the region gave rise to the vast majority of basaltic rocks that originated the soils: Brown Oxisol, Brown Nitisols,

Hydromorphic, Cambisols and Litholic Neosols. The hydromorphic soils, which are present in the area, are generally soils essentially made up of organic matter, originating from the deposit of plant residues in varying degrees of decomposition: Organosols (EMBRAPA, 2013).

The natural vegetation of the study area is located in a region of moist soils, due to the presence of water bodies around the area that influence the natural distribution of vegetation. The study area is quite altered, mainly due to anthropic processes in the surrounding regions with transport of urban waste with the runoff.

2.2 Measurement of the piezometric level and sociological position of trees

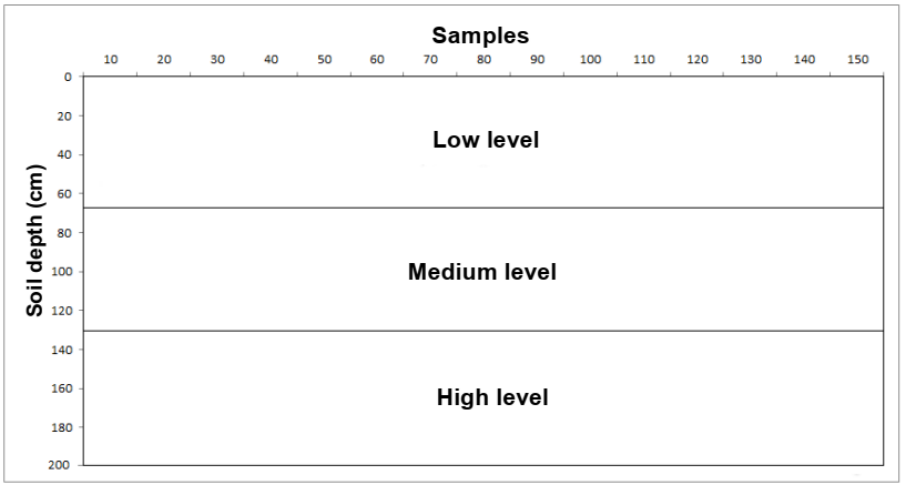
The selection of *G. klotzschiana* trees to be carried out for the augers contemplated individuals located at different piezometric levels and different sociological positions, the choice of the species was due to it being one of the most characteristic species of the physiognomy under study and also because it presents plasticity to colonize environments with different water conditions.

Circumference measurements at breast height (1.30 m) were taken from these trees using a measuring tape. The total height was measured with a 15 meters telescopic ruler. Trees that had the crown exposed directly to the sun were considered canopy trees (CT), while those that had the entire crown shaded were considered understory trees (UT). The dendrochronological samples were taken from the auger, with a Pressler auger, of 116 trees. The collection was random to contemplate different piezometric levels and different sociological positions.

The piezometric classes were created by stratification the water level in the soil through the measurements of piezometers. Based on the annual piezometric data, three classes of soil drainage were established, as shown in Figure 2. As there is no reference, it was decided to parameterize these classes equidistantly. Class 1: High piezometric level (apparent water table at a maximum distance of 66.6 cm from the soil surface – permanently saturated soil); Class 2: Average piezometric

level: (apparent water table distant between 66.66 and 133.33 cm from the soil surface – moderately saturated soil); Class 3: Low piezometric level (water table apparent below 133.33 cm from the surface or absent – well drained soil).

Figure 2 - Determination of piezometric levels sampled in a fragment of the Alluvial Araucaria Mixed Forest in the municipality of Guarapuava – PR



Source: Authors (2020)

From the two sociological positions and the three piezometric levels, six combinations resulted: UTh= understory trees and high piezometric level; UTm= understory trees and mean piezometric level; UTl= understory trees and low piezometric level; CTh= canopy trees and high piezometric level; CTm= canopy trees and mean piezometric level; and CTl= canopy trees and low piezometric level. Dendrochronological collections were randomly performed in different sociological and piezometric positions.

2.3 Collection and preparation of increment rolls

From a total of 116 trees totaled 232 increment rolls. The holes resulting from the collection of samples were filled with “in natura” beeswax in order not to harm the tree's development. The samples taken were stored in plastic tubes and

properly identified. Then, the samples were fixed with white glue in a wooden "roller holder" to promote drying at room temperature for a period of four weeks. Afterwards, they were polished with sandpapers for wood number 100, 180, 220, 320, 400 and 600 to facilitate the reading of the growth rings.

The samples were marked across the wood to identify the boundary of the growth rings. They were then scanned next to a ruler with a flatbed scanner at 1200 dpi (dots per inch) resolution. The images obtained were visualized in the Image tool 2.0 software. The increment measurement was performed with the aid of the distance tool.

2.4 Standardization and correlation of growth data with climatic variables

Statistical verification of the series (initial control of the width of the rings) was performed using *Cofecha* software (HOLMES, 1983). This is unique for dendrochronological analysis and performs a series adjustment to identify samples and segments that have growth measurement problems. The synchronization of the samples was performed with an adjustment of a cubic spline function, which divides each series by the corresponding value of the spline curve. Cofecha provides a chronology called "Master".

The Arstan software enabled the removal of growth trends for each sample by fitting a negative exponential function and applying a cubic spline function. In this software, the master series is standardized to eliminate growth trends and generate a series called standard.

Following the analysis process, the growth data for each year were correlated with the temperature and precipitation indices, using the Assistat 7.7 Beta software. Climatic data were obtained from the meteorological station of the State University of the Center West, approximately 100 meters away from the study area. The period of analysis was from 1984 to 2012.

2.5 Comparison of growth at different piezometric levels

The increment data from the growth analyzes were statistically compared as a function of sociological positions and piezometric levels to verify statistical increment differences in the different combinations. The sample diameter data were subjected to descriptive statistical analysis to assess the standard deviation and coefficient of variation of the samples.

The increment values of *G. klotzschiana* were compared using a completely randomized design in a factorial arrangement (3x2) with 6 replications. The repetitions comprised the mean annual increment of 6 trees for each treatment over a 20-year period (1992-2012). Factor 1 was considered the three piezometric levels (high, medium and low) and factor 2 the two sociological positions (canopy and understory). Thus, treatments were generated as a function of combinations between piezometer levels and sociological positions. Thus, the Bartlett test was performed to verify the homogeneity of variances. Then, the analysis of variance (ANOVA) was performed and the Duncan test was applied with a 95% confidence probability.

3 RESULTS AND DISCUSSION

3.1 Dendrochronological analysis

Only 48 samples, out of a total of 116, were viable for analyzing the reading of the growth rings. The loss of 68 samples was mainly due to the detection of the limits of the growth rings, the presence of false rings, the difficulty of reading and damage to the samples during sanding. Other authors have also encountered the same difficulty with the preparation of samples of this species (COSMO et al., 2010; LONGHI-SANTOS et al., 2019).

With the Cofecha program it was possible to satisfactorily synchronize only 21 trees and 27 series out of a total of 48 trees and 96 series. The intercorrelation

values obtained in the analysis ranged from 0.248 to 0.522 in the different combinations. The time series presented intercorrelation values below the critical value and probably contributed to the loss of correlation.

Intercorrelation is the value derived from the comparison between annual growth series using the Cofecha software. Trees that were in sampling units with lower incidence of water had the highest intercorrelations, while trees in sampling units that were periodically flooded had the lowest values.

For Almeida et al., (2004), species that are located in floodable areas, during periods of flooding, show little growth or even do not increase and form distinct growth rings on the stem. This phenomenon can define low values of time series located in plots with high water influence. The smallest intercorrelations of trees located in flooded areas can also be related to the frequency and duration of flooding. These can influence the normal growth cycle of the plant and generate different responses in growth rings such as the presence of false rings (COSMO et al., 2010).

Understory trees with low piezometric level had an intercorrelation of 0.522 and canopy and low piezometric level trees had a value of 0.45 (Table 1). For species that grow in places that allow the delineation of the summer and spring periods, when the demarcations of the growth rings are clear, intercorrelation values above 0.5 are considered desirable.

Table 1 - Results obtained in the evaluation of the different data synchronies in the different combinations of *Gymnanthes klotzschiana* individuals sampled in a fragment of the Alluvial Araucaria Mixed Forest in the municipality of Guarapuava –PR

Parameters	Timelines					
	UTh*	**UTm***	**UTl***	**CTh***	**CTm***	**CTl***
	6	10	8	6	8	9
Number of Series	1970	1981	1991	1964	1966	1977
	2012	2012	2012	2012	2012	2012
Period Considered	180	223	148	229	262	224
Number of Rings	0.303	0.288	0.522	0.301	0.248	0.450
Intercorrelation (r)	0.32	0.358	0.372	0.325	0.325	0.327

Where: UTh= understory trees and high piezometric level; UTm= understory trees and mean piezometric level; UTl= understory trees and low piezometric level; CTh= canopy trees and high piezometric level; CTm= canopy trees and mean piezometric level; CTl= canopy trees and low piezometric level.
Source: Authors (2020)

In a fragment of Alluvial Araucaria Mixed Forest in the municipality of Araucária – PR , the intercorrelation values between the series for individuals of *G. klotzschiana* was 0.442 for canopy trees and 0.497 for understory trees (LONGHI-SANTOS et al., 2019). Values above 0.30 indicate high sensitivity to environmental changes. In the present work, the mean sensitivity values were always above 0.32, that is, high sensitivity. For the same species, Longhi-Santos et al. (2019) obtained a mean value of 0.387 and Kanieski et al. (2017) obtained a value greater than 0.39.

Regarding the age of the trees analyzed in the research, it was found that the oldest entered in the year 1964 and the youngest in the year 2002. The age of the individuals analyzed ranged from 10 to 48 years. These results are similar to those found by Longhi-Santos et al. (2019), which ranged from 16 to 43 years, while those found by Kanieski et al. (2017) were from 25 to 48 years.

3.2 Correlation of *Gymnanthes klotzschiana* growth with climatic variables

When comparing the data from the Arstan-standardized growth series with the climatic variables, it was found that the significant correlations were with the precipitation data. The other variables minimum, average and maximum temperature did not present significant correlations at 95 and 99% probability. With 99% confidence probability, the understory trees located at high piezometric level, presented a correlation value of (–) 0.59 with the total precipitation. With 95% confidence probability, canopy trees, at high and low piezometric levels, presented correlation values of (–) 0.45 and (-) 0.40, respectively, with the sum of rainfall. These negative correlations of increment and precipitation indicate that the increase in rainfall negatively influences the annual growth of the species (Table 2).

Table 2. Correlations obtained from the growth data of Gymnanthes klotzschiana with precipitation, mean, minimum and maximum temperature in the different combinations in a fragment of the Alluvial Araucaria Mixed Forest in the municipality of Guarapuava –PR

	UTh	**UTm**	**UTl**	**CTh**	**CTm**	**CTl**	**Prec**	**Tmed**	**Tmin**	**Tmax**
UTh	1									
UTm	-0.18	1								
UTl	-0.32	0.03	1							
CTh	0.58**	-0.07	-0.38*	1						
CTm	-0.52**	0.35	0.30	-0.41*	1					
CTl	0.16	-0.03	0.15	0.31	-0.01	1				
Prec	-0.59**	0.15	0.001	-0.45*	0.21	-0.4*	1			
Tmed	-0.27	-0.12	0.20	-0.09	0.06	0.1	-0.07	1		
Tmin	-0.349	0.08	0.24	-0.33	0.19	-0.2	0.27	0.69**	1	
Tmax	-0.06	-0.12	-0.022	0.16	-0.08	-0.22	-0.11	0.67**	0.34	1

Where: UTh= understory trees and high piezometric level; UTm= understory trees and mean piezometric level; UTl= understory trees and low piezometric level; CTh= canopy trees and high piezometric level; CTm= canopy trees and mean piezometric level; CTl= canopy trees and low piezometric level; * significant at the 5% probability level; ** significant at the 1% probability level ($p < 0.01$); Prec: Average of the August-July Rainfall Sum (1984-2012); Tmed: Medium temperature; Tmin: Minimum temperature; Tmax: Maximum temperature (1984-2012).
Source: Authors (2020)

The most favorable period for the growth of *G. klotzschiana* or any tree is the period that extends from the beginning of spring to the end of summer, when the trees present spring growth or initial wood, which is usually the largest ring size in the trunk analysis (Anatro). The analysis of climate data from the last 28 years found that the months of greatest tree growth (spring and summer) are the period where the highest rainfall occurs. During these months, rainfall indices are always above 160 mm and can exceed 200 mm in January and October. Thus, this analysis is important, as it allows us to infer that in this period of better growth favoring, there is high rainfall and greater soil water saturation that may hinder the growth of *Gymnanthes klotzschiana*.

Allied to the high precipitation indices, the location of the study area also directly influenced the growth process of this species. This is an area of floodplain or valley floor that remains saturated for most of the year, due to the anthropization process in the surroundings. Of the rivers that contemplate the Cascavel River basin, the Carro Quebrado Stream, which borders the area, is the one with the highest urbanized area densities. Therefore, this river receives the largest volumes of water, mainly due to surface runoff and the lack of infiltration area. This phenomenon often promotes, during the year, the upwelling of the water table and, eventually, the overflow of the river bed.

Another important factor that contributes to the decrease in the growth *of G. klotzschiana* is the type of soil. In the subunits of the study area, which presented a high piezometric level, the soils are hydromorphic with a large amount of clay. This characteristic and the presence of very shallow rocky substrate make soil drainage difficult and favor the upwelling of the water table.

Several authors found different results when correlating growth with climatic variables. Spathelf et al., (2000) studied the growth of *Ocotea pulchella* Ness et Mart. Ex Ness in the city of Santa Maria – RS. This species from the Alluvial Araucaria Mixed Forest obtained an increase of 4.4 mm.year^{-1}. The authors did not obtain

significant results from the correlation of growth with any climatic variable; however, the results indicate that excess water is the most important variable.

The correlation data between climatic variables and growth for the species of the Alluvial Araucaria Mixed Forest differ from the results found in this research. In the municipality of Araucária – PR, Longhi-Santos et al. (2019) found that an increase in *G. klotzschiana* was positively correlated with an increase in the minimum temperature. In another study, it was found that growth was positively influenced by the average temperature for the species: *Hovenia dulcis, S. commersoniana, Myrrrhinium loranthoides* (KANIESKI et al., 2012) and *Blepharocalyx salicifolius* (KANIESKI et al., 2013). Vantroba et al. (2020) found a correlation between higher growth and higher precipitation averages in the same forest fragment of this study for *Zanthoxylum rhoifolium*.

The divergences in the results are important, as they indicate different growth patterns among individuals of *G. klotzschiana* in fragments of Alluvial Araucaria Mixed Forest. These results corroborate the findings of several authors, when they state that alluvial formations are different from each other, even between areas of relative proximity (LOEBENS et al., 2018).

3.3 Growth of *Gymnanthes Klotzschiana* in different sociological positions and different levels of water saturation

Among the 48 individuals of G. klotzschiana analyzed, the tree with the largest diameter was 18.86 cm, while the one with the smallest diameter was 5 cm. The mean diameter of all trees was 8.93 cm. In the set of all trees, it was found that trees located in the canopy had the highest diameter values, when compared to understory trees. The diameters of the understory trees ranged from 5 to 14.01 cm and the canopy trees ranged from 6.33 to 18.86 cm (Table 3).

Table 3 - Diametric characteristics of individuals of Gymnanthes klotzschiana sampled in a fragment of the Alluvial Araucaria Mixed Forest in the municipality of Guarapuava –PR

SP*	C*	PL*	NS*	DBH with bark sampled trees (cm)				CV%*
				Medium	Minimum	Maximum	S	
	CTh	High	7	12.66	8.47	16.4	2.52	19.89
CANOPY	CTm	Medium	7	13.06	7.96	18.86	3.44	26.35
	CTl	Low	9	8.84	6.33	11.78	1.66	18.79
	UTh	High	6	7.67	5.1	14.01	2.90	37.87
UNDESTORY	UTm	Medium	9	6.24	5.00	7.32	0.79	12.60
	UTl	Low	10	6.71	5.25	8.75	1.10	16.38
Total			48	8,93	5	18.86	3.42	38.27

Where: SP: Sociological position; C: combination; PL: Piezometric level; NS: number of samples collected; S: Standard deviation for diameters; CV%: Coefficient of variation in percentage for diameters.
Source: Authors (2020)

When comparing the diametric data of this research with other works, it was found that the values are similar to those found Alluvial Araucaria Mixed Forest, in the municipality of Araucária - PR. The mean diameter values for understory trees were 5.36 cm, while for canopy trees it was 11.52 cm (LONGHI-SANTOS et al., 2019). For the present research, the mean values for understory trees were 6.87 cm and for canopy trees was 11.52 cm.

Trees located in the understory, at high piezometric level, and canopy trees, at medium piezometric level, presented the highest coefficients of variation of 37.87% and 26.35%, respectively. This greater variation in data is a result of the diametric amplitude between individuals and the small number of samples analyzed.

The statistical analysis data show that there are differences between the increment means for the two factors: the piezometric level and the sociological position. However, the interaction between the two factors was not significant. (Table 4). As the interaction between the two factors was not significant, this indicates that there is independence between the analyzed factors, that is, the

piezometric level does not interfere with the sociological position and the opposite is also valid. The sociological position does not interfere with the piezometric level, which is directly affected by the hydrological regime of the study area. The water level can limit the growth of trees (ALMEIDA et al., 2004), however it does not determine the sociological position of the trees, which are generally determined by a set of factors, such as: competition, edaphic characteristics, climatic characteristics and genetic characteristics of the plant (PRODAN et al., 1997).

Table 4 - Analysis of variance of an experiment in a completely randomized design in a factorial arrangement for the increment of *Gymnanthes klotzschiana* (1992-2012) sampled in a fragment of the Alluvial Araucaria Mixed Forest in the municipality of Guarapuava –PR

FV	GL	SQ	QM	F
Ft1 – Np	2	0.99691	0.49845	18.347 **
Ft2 - Ps	1	0.81000	0.81000	29.815**
Int – Np x Ps	2	0.13385	0.06693	2.463 ns
Residue	30	0.81503	0.02717	
Total	35	2.75579		

Where: Ft1 – Np= Factor 1, piezometric level; Ft2 – Ps= Factor 2 – sociological position; Int – NpxPs= Interaction between piezometric level and sociological position; ** significant at the 1% probability level ($p < 0.01$); * significant at the 5% probability level ($0.01 =< p < 0.05$); ns= not significant ($p >= 0.05$)
Source: Authors (2020)

The analysis of piezometric levels (Factor 1) showed that the high and medium levels differ statistically from the low level, and that there is no statistical difference between the means of increment of *Gymnanthes klotzschiana* between the medium and high levels. It was also verified by the data that the increment in places where the piezometric level is lower presents higher values of growth. The average increment of trees at the low level was 1.68 mm.year^{-1}, while for the medium and high level they were 1.32 and 1.33 mm.year^{-1}, respectively (Table 5).

Table 5 - Increment means for the piezometric level and sociological position factors of the experiment in a completely randomized design in a factorial arrangement for the increment of *Gymnanthes klotzschiana* (1992-2012) sampled in a fragment of the Alluvial Araucaria Mixed Forest in the municipality of Guarapuava – PR

Ft1 – NP*	**Averages**
HIGH	1.33 b
MEDIUM	1.32 b
LOW	1.68 a
Ft2 – PS*	Averages
CANOPY	1.59 a
UNDERSTORY	1.29 b

Where:* Ft1 – Np= Factor 1, piezometric level; Ft2 – Ps= Factor 2 – sociological position; Significant at 95% confidence probability
Source: Authors (2020)

Thus, the lower growth of *G. klotzschiana*, under conditions of high-water saturation, can be explained by the rise in the water table, which eliminates air spaces in the soil and prevents gas exchange with air, as the oxygen available in a few minutes is consumed by roots and microorganisms. Thus, the environment becomes hypoxic or anoxic and can harm the plant's growth (DA ROCHA et al., 2020).

Regarding the sociological position (Factor 2), statistical differences were found between the growth means of *G. klotzschiana* located in the canopy and in the understory. Canopy trees had an average increase of 1.59 mm.year^{-1}, while those in the understory increased by 1.29 mm.year^{-1}. In all the studies that took into account the growth in different sociological positions in the Alluvial Araucaria Mixed Forest, the canopy trees showed the highest growth when compared to understory trees (KANIESKI et al., 2012; KANIESKI et al., 2013; LONGHI-SANTOS et al., 2019; KANIESKI et al., 2017). Light is a determining factor for ecological and physiological processes for plants and can influence plant establishment and development (SMIDERLE et al., 2021)

In a fragment of Alluvial Araucaria Mixed Forest in the municipality of Araucária – PR, the growth of *G. klotzschiana* was evaluated using dendrometric belts. The value found for canopy trees was 1.66 mm.year^{-1} and for understory trees the value was 0.58 mm.year^{-1} (KANIESKI et al., 2012), these results are very similar to those found for this research. In this same area of study, the growth of *S. commersoniana* was evaluated through the complete ANATRO of the trunk. Growth for canopy trees was 3.8 mm.year^{-1} and for canopy trees the value found was 2.8 mm.year^{-1}. When compared with the results of this research, for canopy trees the values found are twice as high and for understory trees the values are four times higher.

Other results found in the municipality of Araucária – PR, in a fragment of Alluvial Araucaria Mixed Forest, were also similar to the results of this research. Canopy trees show an average increase of 2.14 mm.year^{-1} and understory of 0.77 mm.year^{-1} in a chronological period of three years (KANIESKI et al., 2017). The same author compared the growth of *G. klotzschiana* at different levels of water saturation in the soil and found that there were no significant differences in the growth of the species under these conditions. These results differ from those obtained in this research.

Water, sociological position and precipitation influence the growth of *G. klotzschiana*. However, these phenomena cannot be considered as exclusive factors in determining the increment of the species. Since the characteristics of the species, the interaction with the environment, the pedological, topographic and competition factors (WALTHERT; MEIER, 2017) also involve the ecological dynamics of the Alluvial Araucaria Mixed Forest.

4 CONCLUSION

The potential of *G. klotzschiana* for dendrochronological studies was confirmed by the presence of annual growth rings. Trees located in the canopy had

higher increment values than understory trees. Furthermore, it was found that, under high soil water saturation conditions, the growth of *G. klotzschiana* is lower when compared to trees located in areas with better soil drainage. The growth of *G. klotzschiana* in places with high piezometric level was negatively correlated with rainfall.

The data resulting from the research can contribute to other forestry studies, especially for the Alluvial Araucaria Mixed Forest. The growth of *G. klotzschiana* at different levels of water saturation, in addition to providing new information, allows us to infer that the species can be recommended for projects to recover vegetation areas, as it has the capacity to grow in flooded areas. Recovery and conservation projects for these environments must take into account the soil water dynamics, since this factor is decisive for the growth of *G. klotzschiana* and should also influence the development of other species.

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