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Water storage in *Eucalyptus urophylla* progenies

Armazenamento de água em progênies de Eucalyptus urophylla

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Abstract

Eucalypts are the most planted hardwoods in the world with around 30 million ha; one of which is *E. urophylla*, which is also one of the most planted species in Brazil. The objective of this work was to study water storage in the stem of progenies and verify the influence of precipitation on soil and wood humidity, as well as planting density (spacing between trees) on the humidity and productivity of the progenies. To this end, 21 progenies were evaluated in three replications (one progeny per block) in a progeny test. The results show that the productivity and humidity of the progenies did not depend on rainfall or soil humidity. Planting density did not influence productivity of wood or soil humidity.

Keywords: Hydraulic conductance; Pearson's correlation; Soil humidity; Wood anatomy, Water storage in the stem.

Resumo

O eucalipto é a folhosa mais plantada no mundo com cerca de 30 milhões de ha, sendo uma delas o *E. urophylla*, que também é uma das mais plantadas no Brasil. O objetivo deste trabalho foi estudar o armazenamento de água no fuste de progênies e verificar a influência das precipitações na umidade do solo e da madeira, bem como a densidade de plantio (espaçamento entre árvores) na umidade e produtividade das progênies. Para tal, foram avaliadas 21 progênies em três repetições (uma progênie por bloco) em um teste de progênies. Os resultados mostram que a produtividade e umidade das progênies não dependem das precipitações nem da umidade do solo. A densidade de plantio não influenciou a produtividade nem a umidade da madeira ou solo.

Palavras-chave: Condutância hidráulica; Correlação de Pearson; Umidade do solo; Anatomia da madeira; Armazenamento de água no fuste.

INTRODUCTION

Eucalyptus is the most planted hardwood genus in the world, with approximately 30 million hectares, 90% of which are concentrated in nine species, being *E. urophylla* one of them, as it presents good productivity in any type of soil or climate, is easy to propagate by seeds or cuttings, produces well in the second rotation and is suitable for wide array of uses. In Brazil, 7.62 million hectares were planted with eucalypts in 2019, with *E. urophylla* being one of the most planted species (Indústria Brasileira de Árvores, 2020; Payn et al., 2015; Scanavaca Júnior & Garcia, 2021). In Brazil, *E. urophylla* does not adapt to the semi-arid region, where the precipitation is less than 800 mm; while the provenances introduced in Brazil are adapted to areas with more than 1000 mm of annual precipitation. The provenance which might adapt to the semi-arid region is from Wetar Island or *E. wetarensis* (Reclassification of provenance,

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Pryor et al., 1995), but there are other *Eucalyptus* species more suitable for such a climate, like *E. camaldulensis*, *E. brassiana*, etc.

The stems of the eucalypts have four basic functions: 1) transport of water and nutrients (xylem and phloem); 2) mechanical support of the crown (cellulose, hemicelluloses, and lignin; 3) storage of water (in the 65% fibers, 17% vessels and 18% parenchyma); 4) prevention of pest and disease attacks (mainly through the extractives, which are 5%). The composition and proportion of these constituents varies with the species and age of the plant due to genetic and environmental influences. The percentage of extractives and lignin increases with age, while the proportion of holocellulose decreases; the proportion of vessels and parenchyma (rays) increases, while fibers decrease with age. The wall thickness and length of fibers, vessels and rays increase from the pith to the bark in the radial direction. As the tree grows from the outside in, new layers of cells are added to the tree. The youngest tissues follow the apical growth of the tree, so that the cells formed first go from the base to the top of the tree, that is, the oldest and thinnest vessels are at the apex of the tree, while the newer ones, with larger diameters and lengths, are at the base; in the same way the radii and fibers are arranged so that their diameters increase from the top to the base of the tree. In this way, the narrowest vessels, with the smallest diameter of the lumens, are in the highest parts of the trees, being able to withstand greater tensions in water transport.

According to the stress-cohesion theory, xylem water is constantly under stress, moving from the roots to the leaves of trees. This tension can overcome the cohesive forces that bind the water molecules, resulting in the formation of air bubbles which, when expanding form, a void, breaking the cohesion forces, which will cause cavitation, interrupting the rise of water through this channel and hence the rate of photosynthesis. The storage of water in the stem is important to maintain the plant's water balance. The removal of water from the stem during the day and the replenishment of these reserves at night is a dynamic process. The water stored in the cellular cavities of the stem can supply six to 28% of the tree's daily water requirements (Hao et al., 2013; Zweifel et al., 2007).

There are three mechanisms by which the water stored in the stem of trees can be released for the physiological processes of the plant: (1) capillary storage where water is stored mainly in the lumen of dead fibers (heartwood or pith); this water moves between the cells without energy cost; (2) elastic storage, water is located in the symplast of living cells, like the radial parenchyma cells, located in the sapwood, this water moves with energy expenditure; and (3) cavitation release, this water comes from the phloem to restore the connectivity of the cavitation water columns, with energy expenditure (Knipfer et al., 2019).

The objective of this study was to verify the adaptive strategies of water deficit in *E. urophylla*, which lead to adaptation to diverse climatic environments. The following hypotheses were raised: 1) soil and wood humidity accompany the precipitations; 2) larger diameter progenies have a higher percentage of water in the wood; 3) lower planting densities have a higher percentage of water in the soil; 4) soil humidity is the main factor that determines progeny productivity.

MATERIAL AND METHODS

Genetic material, climatological data and experiment layout

This material is part of the Basic Population Cooperative Program (PCPN), created by the Institute for Forestry Research and Studies (IPEF) in 2008, whose objective was to install populations with a broad genetic base and to recombine them. For *E. urophylla*, 167 progenies were used. This test was installed in several bioclimatic regions of Brazil, with Anhembi, SP being one of these locations.

The material was installed in Anhembi (22º40 'S; 48º10' W and 455 m above sea level), on flat ground. The experiment was installed in a Dystrophic Yellow Latosol, containing 5 to 8% of clay, 2 to 3% of silt and 89 to 93% of sand. Soil field capacity lies between 5 and 13%. The pH varies from 4.6 to 5.8 depending on the depth; it is deficient in macro and micronutrients.

The climate, according to Köppen's classification, is Cwa, with hot, rainy summers and moderately cold, dry winters. The occurrence of frosts is rare. The average annual temperature is 23°C, and the average temperature of the coldest and hottest months is 17.1°C and 23.7°C, respectively. The minimum and maximum temperatures are, respectively, 5°C and 34°C. Mean annual precipitation is 1,100 mm and the annual water deficit is 20 mm (Empresa Brasileira de Pesquisa Agropecuária, 2018; Universidade de São Paulo, 2020).

The experiment was installed in December 2009, in randomized complete blocks with 167 progenies, four replications, linear plots with six plants per plot, in a spacing of 3 m x 2 m. In a progeny test, 21 progenies were selected with three replications, one per block. The selection was made with the expectation of thinning at the end of the experiment to evaluate the physical and mechanical properties of the wood; therefore, the selection went from the bottom and the best tree in the plot was not selected. Meteorological data were provided by ESALQ.

Soil humidity

The experiment was evaluated every three months for 18 months (04/26/17 to 11/21/18), spanning six climatic seasons. Soil samples were taken in open areas, intermediate areas and closed areas within the experiment, at depths from 0 to 10 and 20 to 30 cm, with two replications per block, to measure the percentage of soil moisture in each season of the year, using an increment borer with a capacity of 100 grams. At one station, soil samples were not collected because it rained in torrents, making collection impossible on the assessment days.

The areas were classified as open, intermediate, or closed depending on planting density. Areas that suffered the highest percentage of thinning and had the lowest planting density within the experiment and were classified as open areas. Closed areas were those that did not undergo any thinning and presented the original planting density of the experiment (3 m x 2 m spacing). Intermediate areas had intermediate tree densities between these two extremes.

To measure tree moisture, wood fillets were extracted using a motorized borer with a power HP and an increment borer with 20 mm diameter and 20 cm length. The trees were drilled until reaching the pith, the heights varied from 130 to 170 cm above the ground. After the extraction of the wood fillet, the holes were covered with wooden coins of the same diameter as the borer to reduce or avoid the risk of attack by pests or diseases.

The fillets were identified and stored in a plastic bag and packed in Styrofoam. On the same day, the fillets were divided into several segments of approximately two centimeters in length, properly identified and weighed on a digital scale with a precision of 0.01 g.

After weighing, the fillets were placed in an oven at 103 °C ± 2 °C until constant weight. After stabilization of the weights, the fillets were weighed again to calculate the moisture. Due to their indistinct color and weight, the first segment (closest to the center of the tree) was considered medulla. The last segment, closer to the bark was sapwood. The remaining segments of the central part were considered heartwood. Heartwood moisture was considered as being the arithmetic mean of the segments of these central threads.

The moisture of each segment of wood, as well as the soil samples were calculated using the Equation $[(WW - DW) / DW] * 100$. Where: WW is the wet weight of the sample (g); and DW is the dry weight of the sample (g).

Basic density (Bb)

The basic density was determined after the sixth evaluation (15/01/2019), when the trees were cut. A 2 cm x 2 cm x 3 cm cube was removed from the heartwood of tree. The wooden cubes were saturated to a constant weight. After saturation, the samples were measured with a 0.01 mm precision caliper. After these procedures, the wooden cubes were placed in an oven at 103 °C ± 2 °C until constant weight. After weight stabilization, the wooden cubes were weighed on a scale with a precision of 0.01 g. Basic density is the ratio between dry mass and saturated volume (kg m^{-3}).

Diameter at breast height (DBH) (cm)

The DBH was measured at approximately 1.30 m from the ground, in all plots, using a dendrometric caliper with a precision of 1 cm; except for one season when it rained, making the operation impossible.

Statistical analysis

Statistical analyses were performed using SAS 9.3 statistical package using Proc Glimmix procedure and Pearson correlation using Proc Corr. Data normality was tested using Proc Univariate. The level of significance was set at 5% probability.

RESULTS AND DISCUSSION

Table 1 - Maximum and minimum temperature and accumulated precipitation by season in 2017 and 2018 in Anhembi.

Season	Temperature (°C)		Precipitation
	Maximum	Minimum	accumulated (mm)
Summer	35.66	17.27	535.74*
Autumn	31.24	10.51	420.64
Winter	32.58	8.21	144.73
Spring	35.96	13.26	584.47
Summer	35.36	17.19	516.33
Autumn	32.23	8.03	50.94*
Winter	33.77	6.10	22.32**
Spring	35.45	13.22	43.02
Mean	34.03	11.72	289.77
Standard Deviation	1.83	4.21	246.78
Variation Coefficient	1.72	9.82	81.41

* Soil moisture, DBH and wood moisture were not evaluated. ** Soil moisture and DBH were not evaluated.

Climatological data

Climatic data for Anhembi were provided by ESALQ/USP. Data from 2017 and 2018 were used. Temperatures varied little, but precipitation varied considerably according to the coefficient of variation (CV) and standard deviation (SD) (Table 1). There was no correlation between precipitation and wood humidity (0.2333 p = 0.6564), soil humidity (0 10 cm: -0.4822 p = 0.4107; and 20 to 30 cm: -0.4956 p = 0.3959) or DBH (-0.5703 p = 0.3154).

Table 2 - Average soil moisture in the five seasons by area opening and depth.

Depth	Closed area	Intermediate area	Open area
		Autumn (26/04/17)	
0 a 10	7.32	8.93	7.75
20 a 30	8.04	8.60	8.02
		Winter (16/08/17)	
0 a 10	11.94	10.22	9.03
20 a 30	11.11	10.56	9.88
		Spring (24/11/17)	
0 a 10	62.19	63.26	69.82
20 a 30	63.72	69.92	73.48
		Summer (26/02/18)	
0 a 10	65.84	69.25	64.67
20 a 30	68.85	69.32	73.47
		Spring (21/11/18)	
0 a 10	66.29	64.70	60.04
20 a 30	69.09	69.09	69.75

Soil humidity

Data were statistically analyzed related to planting density or gap size (opening by thinning or death of progenies).

There were no statistical differences between soil humidity related to planting density or depth at any time of year. The soil has a sandy texture whose field capacity (FC) is between 5 and 13%. In all seasons, the 20 to 30 cm depth layer was slightly wetter than the top layer, except in the intermediate area in autumn and in the closed area in winter (Table 2). After water drainage, the deeper layers become wetter than the upper layers (Empresa Brasileira de Pesquisa Agropecuária, 2018; Melo Neto et al., 2017). Assuming FC was 5%, all samples were above this level; but if we consider 13% FC, all autumn and winter evaluations were below FC. At a FC of 13% water would still be percolating, thus, the lower layer should have a higher percentage of humidity than the upper layer, in the same soil profile. If the FC were 5%, the water would have already stopped its movement and the humidity percentages should be close, but the humidity could be higher in any layer, due to the variability of the soil (higher clay content, smaller pore diameters, etc.), as found in the present study.

Magalhães et al. (2018), working on Dystrophic Yellow Latosol, in a livestock and forest cropping system at three spacings, did not find statistical differences for soil humidity related to spacing. Melo Neto et al. (2017) working with *E. urophylla* x *grandis* related to spacing had the same result and so did Liu et al. (2017) when considering age.

In this study, in the dry seasons (autumn and winter), soil humidity was around 10%. In the rainy seasons (spring and summer), the humidity was above 60%. Somehow the trees compensated for the difference in soil humidity and presented a stem with low humidity fluctuations. There are several mechanisms used by eucalyptus species to maintain humidity in the wood and, consequently, productivity; among these stand out the deepening of the root system; more efficient use of water; reduction of photosynthesis rate, etc. (Bourne et al., 2017; Zhang et al., 2016).

Soil water availability did not affect wood humidity at any time. The maximum amplitude, from one season to another in the six measurements, was 8.66% in stem humidity (Tables 4 to 9). This was much smaller than the range of soil humidity, which was 10 times wetter in the rainy seasons (7.32% in autumn and 73.48% in spring) (Table 2).

Table 3 - Correlation of soil moisture with wood moisture, Diameter at Chest Height (DCH) and Basic density (Bd).

Variables	t value	Probability t	Variables	t value	Probability t
	Soil 1a	**0 a 10cm**		**Soil 3b**	**20 a 30cm**
Pith1	0.1296	0.3115	Pith3	0.0784	0.5412
Heartwood1	0.0819	0.5234	Heartwood3	0.1457	0.2546
Sapwood1	0.0038	0.9764	Sapwood3	0.2103	0.0981
Average1	0.0939	0.4641	Average3	0.1752	0.1696
DBH1	- 0.0590	0.6458	DBH3	- 0.1851	0.1464
Bb	- 0.0200	0.8763	Bb	- 0.1716	0.1788
	Soil 1b	**20 a 30cm**		**Soil 4a**	**0 a 10cm**
Pith1	0.1037	0.4186	Pith4	- 0.0753	0.5575
Heartwood1	0.0637	0.6199	Heartwood4	0.0022	0.9864
Sapwood1	- 0.0354	0.7829	Sapwood4	- 0.0309	0.8103
Average1	0.0581	0.6513	Average4	- 0.0541	0.6737
DBH1	- 0.0428	0.7391	DBH4	0.0414	0.7474
Bb	0.0278	0.8289	Bb	0.0721	0.5747

Table 3 – Continued...

Variables	t value	Probability t	Variables	t value	Probability t
	Soil 2a	**0 a 10cm**		**Soil 4b**	**20 a 30cm**
Pith2	- 0.1252	0.3282	Pith4	0.0651	0.6121
Heartwood2	- 0.1516	0.2357	Heartwood4	0.0231	0.8574
Sapwood2	- 0.1338	0.2959	Sapwood4	- 0.0007	0.9959
Average2	- 0.1651	0.1960	Average4	0.0439	0.7325
DBH2	0.1111	0.3859	DBH4	- 0.1629	0.2022
Bb	0.1786	0.1613	Bb	- 0.2415	0.0565
	Soil 2b	**20 a 30cm**		**Soil 6a**	**0 a 10cm**
Pith2	- 0.1285	0.3156	Pith6	- 0.2619	0.0381*
Heartwood2	- 0.1559	0.2225	Heartwood6	- 0.3292	0.0084**
Sapwood2	- 0.1181	0.3566	Sapwood6	0.3055	0.0149*
Average2	- 0.1631	0.2015	Average6	- 0.3721	0.0027**
DBH2	0.1031	0.4212	DBH6	0.0860	0.5029
Bb	0.2022	0.1120	Bb	0.2298	0.0700
	Soil 3a	**0 a 10cm**		**Soil 6b**	**20 a 30cm**
Pith3	0.0868	0.4989	Pith6	0.1256	0.3280
Heartwood3	0.1452	0.2562	Heartwood6	0.1820	0.1534
Sapwood3	0.2111	0.0968	Sapwood6	0.2515	0.0468*
Average3	0.1801	0.1579	Average6	0.2281	0.0722
DBH3	- 0.1886	0.1388	DBH6	- 0.0606	0.6369
Bb	- 0.2362	0.0623	Bb	- 0.1738	0.1733

Soil 1ª = camada de 0 a 10 cm; b = camada de 20 a 30 cm; índice 1 = Primeira avaliação, 2 = segunda avalição, etc.; DBH = Diameter breast height; Bb = Basic density.

There was a correlation between soil humidity and wood humidity in the sixth evaluation (spring, 11/21/18), the season with one of the lowest rainfalls during the experiment evaluation (43.02 mm) (Table 1). The soil was moist and the progenies removed water from the soil for immediate consumption in the photosynthesis process, with the sapwood showing a positive correlation with soil humidity at both depths, while the other compartments showed a negative correlation, that is, the soil water was insufficient for the photosynthesis rates used by the trees, so that complementation with water from the heartwood and pith was necessary; therefore the correlations were positive for the sapwood and negative for the heartwood and pith. The fact that there was no correlation between the humidity content of wood and soil in the other evaluations means that the progenies were getting water from deeper layers, that is, they did not depend on precipitation (Table 3).

Natural wood moisture

Six wood humidity assessments were carried out, one in each season, three in 2017 and three in 2018. The normality tests showed that the data came from a normally distributed population, therefore, they were analyzed as being parametric.

Table 4 - Natural wood moisture per progeny and Tukey test at 5% probability, average of three trees, on 04/26/2017 (Autumn).

Progeny	Pith	Heartwood	Sapwood	Average
32	139.02	134.21 abcde	128.54	133.92
33	127.99	121.53 bcdef	88.82	112.78
51	156.80	160.23 a	102.07	139.70
52	146.77	156.69 ab	120.19	141.22
53	114.66	142.17 abcd	115.78	124.21
54	124.76	118.12 cdef	102.71	115.20
59	150.60	142.30 abcd	120.82	137.90
75	146.39	130.63 abcdef	88.67	121.90
82	115.61	133.38 abcdef	101.06	116.68
85	106.18	106.13 def	105.77	106.03
88	155.44	143.81 abc	122.69	140.65
91	107.44	138.93 abcde	121.93	122.77
92	143.74	146.96 abc	121.09	137.27
94	122.99	119.41 cdef	108.51	116.97
101	118.33	128.14 abcdef	115.30	120.59
108	126.85	122.80 bcdef	89.78	113.14
125	100.83	103.22 ef	126.75	110.27
133	133.32	141.99 abcd	106.24	127.18
137	133.24	137.12 abcde	93.98	121.45
138	101.99	97.85 f	76.17	92.01
142	127.55	118.19 cdef	96.80	114.18
Mean	128.59	130.66	107.32	122.19
Standard deviation	23.36	22.29	24.18	18.92

Means followed by the same letter do not differ by the Tukey test at 5%.

Table 5 - Natural wood moisture per progeny and Tukey test at 5% probability, average of three trees, on 08/16/2017 (winter).

Progeny	Pith	Heartwood	Sapwood	Average
32	135.14	136.61	124.09 ab	131.95 abcd
33	120.25	123.49	99.68 abc	114.47 bcd
51	163.86	157.85	103.17 abc	141.63 ab
52	156.52	146.39	114.49 abc	139.13 ab
53	146.52	139.48	102.66 abc	129.55 abcd
54	134.76	128.93	82.77 c	115.48 abcd
59	141.95	146.03	129.35 a	139.11 ab
75	131.97	126.21	98.53 abc	118.91 abcd
82	144.72	143.93	105.95 abc	131.53 abcd
85	112.32	104.96	86.66 c	101.31 d
88	146.38	142.24	93.68 bc	127.44 abcd
91	141.83	139.95	125.01 ab	135.60 ab
92	157.47	157.98	126.20 ab	147.22 a
94	120.78	121.14	97.51 abc	113.14 bcd
101	128.76	138.97	104.09 abc	123.94 abcd
108	129.08	118.17	83.91 c	110.38 bcd
125	106.50	102.54	101.42 abc	103.48 cd
133	146.36	149.24	106.88 abc	134.16 abc
137	148.34	136.55	98.65 abc	127.84 abcd
138	101.24	105.12	96.26 abc	100.87 d
142	140.34	121.98	104.43 abc	122.25 abcd
Mean	135.96	132.75	104.07	124.26
Standard deviation	24.41	24.55	18.84	18.77

Means followed by the same letter do not differ by the Tukey test at 5%.

Table 6 - Natural wood moisture per progeny and Tukey test at 5% probability, average of three trees, on 11/24/2017 (Spring).

Progeny	Pith	Heartwood	Sapwood	Average
32	141.20	132.66 abcde	114.40	129.42 abcd
33	116.71	115.05 cde	99.07	110.28 bcde
51	147.08	157.62 a	101.17	135.29 ab
52	153.87	142.38 abc	103.03	133.10 abc
53	104.39	153.24 ab	116.54	124.72 abcde
54	110.82	123.59 abcde	79.91	104.77 cde
59	134.41	139.87 abcd	114.54	129.61 abcd
75	140.20	128.69 abcde	89.86	119.58 abcde
82	125.06	135.35 abcde	99.49	119.97 abcde
85	107.46	101.80 e	95.80	101.69 de
88	155.71	151.98 ab	88.12	131.93 abcd
91	111.53	141.64 abc	107.52	120.23 abcde
92	161.65	151.99 ab	113.02	142.22 a
94	137.06	120.54 bcde	96.62	118.07 abcde
101	125.17	138.77 abcd	112.76	125.57 abcde
108	121.18	126.67 abcde	90.36	112.73 abcde
125	113.12	105.34 de	91.44	103.30 cde
133	144.92	144.40 abc	93.33	127.55 abcd
137	147.53	139.74 abcd	94.76	127.34 abcd
138	94.71	101.66 e	90.50	95.62 e
142	136.15	128.69 abcde	102.46	122.43 abcde
Mean	129.30	132.46	99.75	120.74
Standard deviation	29.85	21.89	17.16	17.38

Means followed by the same letter do not differ by the Tukey test at 5%.

Table 7 - Natural wood moisture per progeny and Tukey test at 5% probability, average of three trees, on 02/26/2018 (Summer).

Progeny	Pith	Heartwood	Sapwood	Average
32	144.76	129.97 abcde	111.51	128.75
33	121.53	119.29 bcde	102.14	114.32
51	137.62	152.21 ab	94.85	128.23
52	114.93	142.85 abc	107.38	121.72
53	145.74	132.61 abcde	89.8	122.72
54	105.24	118.24 bcde	74.73	99.41
59	128.58	136.46 abcd	71.78	112.28
75	130.29	122.71 abcde	81.33	111.44
82	136.52	135.78 abcd	70.97	114.43
85	106.35	105.88 de	89.06	100.43
88	143.70	131.09 abcde	102.46	125.75
91	118.79	139.18 abcd	119.09	125.68
92	147.46	153.25 a	116.16	138.96
94	119.71	115.31 cde	93.47	109.50
101	117.90	124.99 abcde	103.61	115.50
108	82.49	119.23 bcde	88.06	96.60
125	99.11	106.04 de	86.46	97.20
133	149.00	127.63 abcde	88.8	121.81
137	144.52	132.63 abcde	90.85	122.67
138	101.14	101.64 e	87.57	96.78
142	136.64	112.01 cde	110.17	119.61
Mean	125.33	126.62	94.30	115.42
Standard deviation	28.44	19.72	23.57	17.40

Means followed by the same letter do not differ by the Tukey test at 5%.

Table 8 - Natural wood moisture per progeny, average of three trees, on 06/21/2018 (Winter).

Progeny	Pith	Heartwood	Sapwood	Average
32	149.33	132.4	115.11	132.30
33	110.37	124.14	95.96	110.16
51	83.94	82.80	59.03	75.28
52	130.06	131.21	107.68	122.98
53	104.47	133.92	114.62	117.67
54	154.57	151.48	115.61	140.55
59	125.77	129.83	97.33	117.65
75	121.59	116.18	93.74	110.50
82	131.11	132.29	102.51	121.97
85	126.26	127.25	98.13	117.21
88	128.27	137.52	109.95	125.25
91	140.81	134.23	140.31	138.45
92	138.57	144.13	109.29	130.66
94	124.39	119.68	85.41	109.83
101	119.03	108.72	104.48	110.74
108	118.45	121.79	80.88	107.04
125	119.62	116.03	89.83	108.49
133	120.46	114.15	84.53	106.38
137	128.82	126.03	83.51	112.79
138	109.28	114.01	76.55	99.95
142	135.60	135.20	97.13	122.64
Mean	126.80	125.38	99.18	116.12
Standard deviation	34.00	25.93	27.69	25.34

Table 9 - Natural wood moisture per progeny and Tukey test at 5% probability, average of three trees, on 11/21/2018 (Spring).

Progeny	Pith	Heartwood	Sapwood	Average
32	124.04	134.13	137.98 a	132.05
33	119.13	109.20	99.72 bcde	109.35
51	115.29	128.43	104.18 abcde	115.96
52	115.30	131.40	118.40 abc	121.70
53	129.81	125.10	93.05 bcde	115.99
54	160.99	147.00	118.59 abc	142.19
59	140.55	129.33	97.48 bcde	122.45
75	84.86	111.66	92.36 bcde	96.30
82	135.55	125.05	93.96 bcde	118.19
85	132.61	126.68	96.90 bcde	118.73
88	131.85	112.55	81.44 cde	108.61
91	109.72	130.05	112.54 abcd	117.44
92	130.13	134.06	125.02 ab	129.74
94	115.13	110.77	90.13 bcde	105.34
101	115.06	114.33	103.50 abcde	110.96
108	128.34	124.76	81.12 cde	111.40
125	124.36	119.65	93.08 bcde	112.36
133	116.44	111.16	66.80 e	98.14
137	108.64	108.98	75.48 de	97.70
138	113.34	124.87	81.22 cde	106.48
142	127.93	118.92	91.92 bcde	112.92
Mean	122.81	122.77	97.85	114.48
Standard deviation	30.08	20.86	22.98	19.49

Means followed by the same letter do not differ by the Tukey test at 5%.

In the first evaluation (autumn), there were statistical differences between progenies in the heartwood. Progeny 51 was the wettest and 138 the driest. Heartwood was wetter than the pith which, in turn, was wetter than the sapwood. Variations within progenies were similar according to standard deviation (Table 4). In the second evaluation, there was a statistical difference in sapwood between the progenies and in the mean. The sapwood was the driest and least variable compartment within the progenies (Table 5). In the third evaluation, there was a statistical difference in the heartwood and in the mean. Heartwood was the most humid compartment and sapwood the driest. The variability within progenies was also lower in the sapwood (Table 6). In the fourth evaluation, there was a statistical difference in the heartwood, which was the wettest compartment and with less variability (Table 7). In the fifth evaluation there was no statistical difference between the compartments (Table 8) and in the sixth evaluation there was a statistical difference in the sapwood, which was the least humid compartment (Table 9).

Table 10 - Correlation of wood moisture with Diameter at Breast Height (DBH) and Basic density (Bd) (kgm^{-3}) per season.

Variable	Coefficient r	Probability r
	Average1	
DBH1	0.3024	0.0153
Bb	-0.1175	0.3989
	Total2	
DBH2	0.2662	0.0350
Bb	-0.1791	0.1601
	Total3	
DBH3	0.0532	0.6787
Bb	-0.1588	0.2138
	Total4	
DBH4	0.1176	0.359
Bb	-0.1546	0.2264
	Total5	
DBH5	.	.
Bb	-0.0562	0.6618
	Total6	
DBH6	0.0568	0.6582
Bb	-0.1540	0.2282

There is no correlation of wood humidity with DBH or basic density, but in the drier seasons (autumn and winter) there were weak correlations between DBH and wood humidity, probably reflecting the consumption of elastic water (Table 10).

The volume of water in elastic storage is small because eucalypt species have only 18% rays. In eucalypts, the contraction and expansion of the xylem and phloem are diametrically opposite. When the phloem contracts during the day, the radius increases. In xylem, variation is low (base: 37.6 μm and upper stem: 38.5 μm) compared to phloem (base: 212.1 μm; upper stem: 225.4 μm). Non-functional carbohydrates are stored in the rays. As wood humidity decreases, water and carbohydrates are extracted from the phloem into the sapwood rays. As water enters the vessels, carbohydrates accumulate in the rays, increasing the osmotic potential of the rays, which will result in an influx of water, hence the expansion of the sapwood. Once wood moisture is restored, usually at night, carbohydrates and water are drawn back into the phloem (Barrichelo & Brito, 1976; Knipfer et al., 2019; Pfautsch et al., 2015; Pratt & Jacobsen, 2017; Zeppel et al., 2019).

Basic density is negatively related to wood humidity, as the higher the basic density, the greater the amount of mass in the same volume of wood and, consequently, less space for free water to be stored (Table 10).

The humidity in wood suffers considerable environmental influence as it is an ecological adaptation to climatic conditions. Anisohydric species, such as *E. urophylla*, suffer less fluctuations in water supply in the dry season or the rainy season than isohydric species because they store water in the stem (Knipfer et al., 2019; Pfautsch et al., 2015; Yi et al., 2017).

Ananías et al. (2014), studying with *E. nitens* at 17 years of age, found higher natural wood moisture in the pith (180%) than in the heartwood (147%) and sapwood (146%). Similar results were found by Hillis (1978) with other eucalypts species. The wood's natural humidity can vary in different parts of the stem, but the variation between the different seasons of the year is negligible (Kollmann & Côté Junior, 1984).

CONCLUSION

The storage of water in the stem of *E. urophylla* allows it to maintain the same growth rate at any time of the year, regardless of rainfall. There is no correlation between the diameter of the progenies with wood or soil humidity. There was no correlation between soil humidity and planting density or gap size.

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