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Development of the *Urochloa brizantha* (Hochst. ex A.Rich.) R.D.Webster cv. Xaraés under different teakwood sawdust concentrations

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ABSTRACT: *Tectona grandis* L.f. (Teak) is a highly cultivated forest species in Brazil. Its wood is appreciated worldwide and used for different purposes. When industrially processed, it generates a large amount of sawdust, a waste that has limited reuse and accumulates in the industrial yards. The aim of this study was to evaluate the effect of fresh teakwood sawdust on the development of *Urochloa brizantha* (Hochst. ex A.Rich.) R.D.Webster cv. Xaraés in a nursery. The treatments consisted of concentrations of 0, 5, 10, 20, 33 and 50% of sawdust, arranged in four randomized blocks in split-plots. At 45, 75 and 120 days, plant heigh (h), average tillers diameter (d), number of live (nll) and dead leaves per plant, fresh and dry mass of shoots and roots, and Dickson's quality index (dqi) were measured. Data were subjected to analysis of variance and analyzed by the Tukey test, when the difference was significant at 120 days after planting. Regression was used to model the performance of the variables throughout the experimental period. There was a decrease in h growth, d, nll, fresh and dry mass of shoots and roots and in the dqi of the cv. Xaraés as it increased to concentration of wood sawdust in the substrate. This negative effect can be attributed to the high C/N ratio of sawdust (196/1), which influences the decomposition of organic matter. In addition, the possible Teak allelopathic effects, which are the subject of other studies, should be considered. Unlike the other variables, number of live leaves was not influenced by the treatment with 5% sawdust. Teakwood sawdust has negative effects on the *U. brizantha* cv. Xaraés development.

Desenvolvimento de *Urochloa brizantha* (Hochst. ex A.Rich.) R.D.Webster cv. Xaraés sob diferentes concentrações de serragem de madeira de teca

RESUMO: A *Tectona grandis* L.f. (teca) é uma espécie florestal muito cultivada no Brasil. Sua madeira é apreciada mundialmente e utilizada para diversas finalidades. Quando processada industrialmente, gera grande quantidade de serragem, resíduo que possui reaproveitamento limitado e se acumula nos pátios das industriais. O objetivo deste estudo foi avaliar o efeito da serragem da madeira de teca *in natura* sobre o desenvolvimento de *Urochloa brizantha* (Hochst. ex A.Rich.) R.D.Webster cv. Xaraés em viveiro. Os tratamentos constaram das concentrações de 0, 5, 10, 20, 33 e 50% de serragem, dispostos em quatro blocos casualizados em parcelas subdivididas. Aos 45, 75 e 120 dias foram mensurados a altura de plantas (h), o diâmetro médio de perfilhos (d), o número de folhas vivas (nll) e mortas por planta, a massa fresca e seca da parte aérea e das raízes e o índice de qualidade de Dickson (dqi). Os dados foram submetidos à análise de variância e analisados pelo teste de Tukey, quando a diferença foi significante aos 120 dias após o plantio. Utilizou-se a regressão para modelar o desempenho das variáveis ao longo do período experimental. Constatou-se uma diminuição do crescimento em h, d, nll, massa fresca e seca da parte aérea e das raízes e no dqi da cv. Xaraés à medida que a concentração de serragem de madeira no substrato aumentou. Este efeito negativo pode ser atribuído a alta relação C/N da serragem (196/1), que influencia na decomposição da matéria orgânica. Além disso, deve se considerar os eventuais efeitos alelopático da teca, objeto de outros estudos. Diferente das demais variáveis, número de folhas vivas não foi influenciado pelo tratamento com 5% de serragem. De forma geral, a serragem de madeira de teca gera efeitos negativos sobre o desenvolvimento de *U. brizantha* cv. Xaraés.

Introduction

Teak (*Tectona grandis* L.f. - Lamiaceae) is native from Southeast Asian rainforests (India, Myanmar, Thailand, and Laos), is one of the world's leading forest species, with a planted area of 6.89 million ha in 2015 (Kollert and Kleine, 2017; Midgley et al., 2015). In Brazil, the planted area was about 90,957 ha in 2018 (IBÁ, 2019).

The large-scale production of this species is due to its adaptation in the edaphoclimatic conditions mainly in the Mato Grosso state, allied to the use of more productive genotypes and optimal management regimes. That has increased the extensive cultivation of the species, increasing the productivity rates in the state (Medeiros et al., 2019; Passos et al., 2006; Pelissari et al., 2014).

Teak wood is one of the most valuable in the world. It has high value-added and noble uses, which combined with its beauty, durability and strength, results in great demand in the world market (Keogh, 2013; Kollert and Kleine, 2017; Macedo et al., 2005; Moya et al., 2014).

Estimates are that more than 90% of the teakwood produced in Brazil is destined for export to Southeast Asia mainly, and the remainder processed by regional industries (AREFLORESTA, 2018; Reis and Paludzyszyn-Filho, 2011). Although there are no studies to quantify the residues accumulation from industrial teakwood processing, the enjoyment rate in the wood sawing of leafy species varies from 45 to 55%. Thus, it is estimated that half of the processed teak wood is retained as sawdust (Rocha, 2002).

Teak processing generates a considerable quantity of residues, which is an environmental liability that has limited reuse and accumulates in the yards of industries. It can cause problems for companies and may compromise local and regional ecosystems, generating impacts that are difficult to repair (Valério et al., 2007). A possible destination for the sawdust is the agriculture. In Mato Grosso state this sector occupying an area of 23.02 million ha for animal grazing and is favorable to using new low-cost inputs such as the teak sawdust (Dias et al., 2019; IBGE, 2017).

In central-western Brazil, approximately, 85% of pastures are occupied by grasses species of *Urochloa* P.Beauv. (*Brachiaria* (Trin.) Griseb.) genus (Poaceae) (Orrico-Júnior et al., 2013). Species of this group have high growth rates, broad edaphic adaptability, great dry matter production capacity, and tolerance to pest and disease attack (Castro et al., 1996; Fagioli et al., 2000; Quadros et al., 2012). The species *Urochloa brizantha* (Hochst. ex A.Rich.) R.D.Webster cv. Xaraés, from the Cibitoke region of Burundi, Africa (Tropicos, 2020), is one of the most widely used in the Brazilian Savanna pastures (Oliveira et al., 2007). The Xaraés cultivar, also known as Xaraés grass, has an average height of 1.5 m and regrowth capacity superior to other cultivars of the same genus (Martuscello et al., 2005). Its cultivation is indicated for tropical *Cerrado* regions, with climate and medium fertility soils, factors that made this cultivar one of the most widespread in the state (Alencar et al., 2009; Quadros et al., 2012).

Addiction ofteak wood sawdust in pasture areas and its effects and relationships are still insufficiently understood. Therefore, this study was carried out at the experimental level to evaluate the initial development of *Urochloa brizantha* cv. Xaraés under different percentages of teak sawdust in the substrate.

Material and Methods

The research was carried out in a seedling nursery located in the Cáceres municipality, Mato Grosso state (coordinates 16°07’50” S and 57°41’42” W, and 117 m high). The region's climate is Aw, according to Köppen, characterized by a rainy season from October to April and a dry season from May to September (Alvares et al., 2013). The average annual temperature in the region is 26 ºC and the rainfall is around 1,335 mm year^{-1} (Neves et al., 2011).

The experimental design was split-plot in four randomized blocks with six treatments. The plots were pots with 3 dm^3 of substrate. The treatments were in S0 (control), S5, S10, S20, S33 e S50% of substrate volume composed by teakwood sawdust. The other part of the substrate volume was formed by Red-Yellow Latosol with clayey texture (Santos et al., 2018) collected from the 0-20 cm layer. The chemical characteristics of the soil are shown in Table 1.

The sawdust residue was obtained from local forestry companies and submitted to chemical and physical characteristics analyses (Table 2), according to the official analytical methods for mineral, organic, organomineral and conditioner fertilizers (Brasil, 2017).

The *Urochloa brizantha* cv. Xaraés seeds was sown at 1 cm deep and with a density of 15 kg ha^{-1}, corresponding to 6 seeds per plot (Castañon et al., 2014; Pacheco et al., 2010). The irrigation was made daily and weed control was also performed.

The evaluations occur at 45, 75 and 120 days after sowing. The plant heights (h) and the average tillers diameter (d) at 2 cm above the ground was measured with a graduated ruler and digital caliper, respectively. Furthermore, number of live (nll) and dead leaves(ndl) per plant was counted. The ndl was counted only after 75 days, because there were no dead leaves before that.

Fresh and dry mass of shoots (fsm and sdm) and roots (frm and drm) were evaluated (Pacheco et al., 2010) after 120 days from sowing. The samples for this analysis were collected, washed, weighed, and dried in a forced air oven for 72 hours at 65 °C and then weighed again.

Table 1. Chemical characteristics of the soil used as substrate to grow the *Urochloa brizantha* cv. Xaraés

pH H_2O	P (mg dm^{-3})	K (mg dm^{-3})	Ca^{2+} ($cmol_c$ dm^{-3})	Mg^{2+} ($cmol_c$ dm^{-3})
4.91	2.2	36	1.15	0.35
Al^{3+} ($cmol_c$ dm^{-3})	H + Al ($cmol_c$ dm^{-3})	SB ($cmol_c$ dm^{-3})	t ($cmol_c$ dm^{-3})	T ($cmol_c$ dm^{-3})
0.2	3.8	1.59	1.79	5.39
V (%)	m (%)	MO (dag kg^{-1})	P-Rem (mg L^{-1})	S (mg dm^{-3})
29.5	11.2	0.39	45.9	1.8
B (mg dm^{-3})	Cu (mg dm^{-3})	Mn (mg dm^{-3})	Fe (mg dm^{-3})	Zn (mg dm^{-3})
0.05	0.46	36	35.9	0.46

where: pH in water: 1:2.5. P - K - Fe - Zn -Mn - Cu – Extractor: Mehlich-1. Ca^{2+} - Mg^{2+} - Al^{3+} - Extractor: KCl - 1 mol/L. H + Al – Extractor: Calcium acetate 0.5mol/L - pH 7.0. SB is the sum of exchangeable bases, t is the effective cation exchange capacity, T is the cation exchange capacity at pH 7.0, V is the base saturation index, m is the aluminum saturation index, OM (Organic matter) is C.Org x 1.724 -Walkley-Black, P-rem is the remaining phosphorous, S – Extractor: monocalcium phosphate in acetic acid, B - Extractor: hot water.

Table 2. Results of the chemical and physical analysis of the teak sawdust

Analysis	Results in natural unity	Dry basis results	
		60 - 65ºc	110ºc
Density (g cm^{-3})	0.20	-	-
Moisture loss at 60ºC (%)	10	-	-
Moisture loss between 65ºC - 110ºC (%)	1.3	-	-
Total moisture (%)	11.3	-	-
Total mineral residue (%)	4.1	4.56	4.62
Insoluble mineral residue (%)	2.25	2.5	2.53
Soluble mineral residue (%)	1.85	2.06	2.09
Total organic matter (Conbustion) (%)	84.6	94	95.38
Compostable organic matter (%)	62.14	69.05	70.06
Compost-resistant organic matter (%)	22.46	24.95	25.32
Total carbon (Organic and mineral) (%)	49.07	54.52	55.32
Organic carbon (%)	36.05	40.05	40.64
pH $CaCl_2$ 0.01 m (1:5)	6.13	-	-
Total nitrogen (%)	0.25	0.28	0.28
C/N ratio (C. Total e N. Total)	196/1	-	-
C/N ratio (C. Orgânico e N. Total)	144/1	-	-
Total Phosphorus (P205) (%)	0.38	0.42	0.43
Total Potassium (K2O) (%)	0.09	0.1	0.1
Total Calcium (Ca) (%)	0.16	0.18	0.18
Total Magnesium(Mg) (%)	0.09	0.1	0.1
Total Sulfer (S) (%) (mg Kg^{-1})	0.02	0.02	0.02
Total Zinc (Zn) (mg Kg^{-1})	5.8	6.44	6.54
Total Copper (Cu) (mg Kg^{-1})	2.01	2.23	2.27
Total Manganese (Mn) (mg Kg^{-1})	14.6	16.22	16.46
Total Boron (B) (mg Kg^{-1})	9.92	11.02	11.18
Total Iron (Fe) (mg Kg^{-1})	914.4	1016	1030.89
CEC (Cation exchange capacity) (mmolc kg^{-1})	140	-	-

We also evaluated the Dickson quality Index (dqi) (Dickson et al., 1960), which checks the distribution of the plant biomass and is determined as a function of dry matter production of shoots, roots, and total height and diameter (Equation 1).

$$dqi = \frac{tdm}{\frac{h}{d} + \frac{sdm}{drm}} \quad (1)$$

where: dqi – Dickson quality index; tdm – total dry mass; h – height; d – average tillers diameter; sdm – shoots dry mass; and drm – root dry mass.

Experimental design was split-plot in randomized blocks. We used the analysis of variance for the measurements and, if the results were significant for the interactions of plots (treatments) and subplots (age) ($p<0.05$), we applied the Tukey test (Tukey, 1949) with data collected at 120 days and created a model for the time series.

The variables with measurements only at 120 days and the dqi were submitted to analysis of variance for randomized blocks and, if significant ($p<0.05$), treatment means were discriminated by the Tukey test (Tukey, 1949).

To verify the normality assumptions for the analysis of variance we applied the Lilliefors test (Lilliefors, 1967) (Equation 2) and to evaluate the homoscedasticity hypothesis, we used the Hartley test (Hartley, 1950) (Equation 3).

$$L = \max_x \left| F^*(X) - S_n(X) \right| \quad (2)$$

$$F_{\max} = \frac{SM^2}{Sm^2} \quad (3)$$

where: L – Lilliefors test; $\max_x$ – maximum value of x; $S_n(X)$ – sample cumulative distribution function; $F^*(X)$ – cumulative normal distribution function with $\mu = \bar{x}$, the sample mean and s^2, the sample variance, defined with denominator n-1; F_{max} – Hartley test; SM^2 – highest variance in the group; and Sm^2 – lowest variance in the group.

The linear, exponential, sigmoid, quadratic and yield-density models was tested (Hyams, 2017). The non-linear models were fitted using the iterative Livenberg-Marquardt algorithm and the linear ones with the ordinary least square method.

The best models were chosen based in the residual standard error ($S_{yx\%}$), mean absolute differences (MAD), correlation coefficients ($r_{y\hat{y}\%}$), graphical analyzes of biological realism and relative errors ($RE_{\%}$) (Piñeiro et al., 2008).

Similarities in growth trends over the time series were assessed with the model identity test (Equation 4), which verifies the equivalence of models through comparisons between complete (individual treatments) and reduced (grouped treatments) models (Regazzi and Silva, 2010; Santos et al., 2017).

$$F = \frac{(n - p_c)\left[\sum_i (y_i - \hat{y}_{i.r})^2 - \sum_i (y_i - \hat{y}_{i.c})^2\right]}{(p_c - p_r)\sum_i (y_i - \hat{y}_{i.c})^2}; \quad (4)$$

$$\sim F\left(\alpha; (p_c - p_r)\right) \;\; e \;\; (n - p_1)\, gl$$

where: F – statistic F; $\hat{y}_{I,r}$ – j-th observation of y in the reduced model; $\hat{y}_{I,c}$ – j-th estimated observation of y in the complete model; y_i – observed value for the variable of interest; i is the dataset index, with i=1, 2,..., H; n – $\sum_{i=1}^{H} n_i$; p_c – number of coefficients in the complete model; p_r – number of coefficients in the reduced model; and df – freedom degrees .

Model identity tests were performed in pairs, and with the possibility of equivalence between more than two models, tests with a larger number of models were also performed. The statistical analyses and modeling were done using the software Statistica version 12 (StatSoft, 2014).

Results

During the verification to perform the analysis of variance we found that the fresh shoot mass (fsm), fresh (frm) and dry root mass (drm) and Dickson quality index (dqi) data did not meet the homogeneity and normality assumptions. The dry mass of shoots (sdm) was transformed by several methods (Bianconi et al., 2008; Pino, 2014). However, variances homogeneity was not obtained, which made the analysis unfeasible. Thus, we analyze it through the non-parametric Kruskal and Wallis test (Kruskal and Wallis, 1952), at a significance level of 5 %.

Plots (S) and split-plots (id) interactions were significant ($p<0.05$) for the height (h), average tillers diameter (d) and the number of live leaves per plant (nll) (Table 3). The variables fsm, frm, drm and dqi, was different between treatments (S) ($p <0.05$) (Table 4). The analysis of the interaction between these variables was then performed with the Tukey test (Tukey, 1949) with the data collected at 120 days (Table 5), and models were developed in cases where the differences were significant between the split-plot (id) and plot (S) ($p <0.05$) (Table 6).

Table 3. Analysis of variance of the variables evaluated in the randomized block design

Effect	DF	Mean Square			ndl	
		h	d	nll	DF	MS
Block	3	33.4372*	0.0907*	0.2265^{ns}	3	0.8005^{ns}
S	5	7488.3086*	9.3943*	5.6317*	5	1.7696*
Error (a)	15	49.5832	0.0823	0.2084	15	0.3960
id	2	793.1600*	3.0502*	3.1824*	1	0.1763^{ns}
S*id	10	179.5741*	0.3215*	0.3364*	5	0.3807^{ns}
S/id120	5	3781.2464*	4.6866*	2.8850*	5	-
id/S0	2	1157.8863*	2.4464*	0.6862*	1	-
id/S05	2	352.3015*	1.1864*	0.5307*	1	-
id/S10	2	126.9041*	0.7456*	1.1126*	1	-
id/S20	2	26.6362*	0.1637*	2.0881*	1	-
id/S33	2	21.2347^{ns}	0.0908*	0.1961^{ns}	1	-
id/S50	2	6.0676^{ns}	0.0247^{ns}	0.2506^{ns}	1	-
Error (b)	36	7.9841	0.0206	0.0891	18	0.3014
Total	71	-	-	-	47	-

where: $^{*}p<0.05$; $^{ns}p>0.05$. DF –freedom degrees; h, d, nll and ndl – height, average diameter of tillers, and the number of dead and live leaves per plant, respectively.

Table 4. Analysis of variance of the variables in the randomized block design

Effect	DF	MS fsm	MS frm	MS drm	MS dqi
Block	3	205.7088^{ns}	627.2705^{ns}	95.6121^{ns}	0.2013^{ns}
S	5	4141.777*	6581.8891*	587.5508*	2.7565*
Error	15	104.2245	227.3691	42.6536	0.1113
Total	23	-	-	-	-

where: $^{*}p<0.05$; $^{ns}p>0.05$. DF –freedom degrees; MS –mean square; fsm. frm. msr and dqi –fresh shoot mass, fresh and dry root mass, and the Dickson quality index, respectively.

Treatments with higher teakwood sawdust concentrations (>10%) influenced the plant development (p<0.05), and provided greater reductions in growth variables, as observed on height (h), average diameter of tillers (d), fresh shoot mass (fsm), fresh (frm) and dry root mass (drm) and the Dickson quality index (dqi) at 120 days after sowing (Table 5). In addition, the number of live leaves per plant (nll) was higher in the treatment S05 than in S0, demonstrating that 5% of sawdust generates a higher nll (Table 5). All other treatments caused negative effects and differed statistically (*p<0.05*) from control (S0) for the shoots dry mass (*sdm*) measurements (Figure 1).

Table 5. Development of the *Urochloa brizantha* cv. Xaraés at 120 days after sowing cultivated under different teakwood sawdust concentrations (S0, S05, S10, S20, S33 and S50)

Variable	S0	S05	S10	S20	S33	S50
h (cm)	89.92 a	71.97 b	58.99 c	39.39 d	24.06 e	7.63 f
d (mm)	3.31 a	2.68 b	2.35 b	1.64 c	1.10 d	0.52 d
nll	4.00 ab	4.02 a	3.13 bc	2.73 cd	2.50 cd	1.88 d
fsm (g)	81.77 a	54.53 b	32.97 bc	9.79 cd	3.95 d	1.67 d
frm (g)	102.29 a	83.12 ab	53.91 bc	26.78 cd	8.35 d	3.20 d
msr (g)	29.99 a	23.48 ab	14.52 bc	6.23 c	1.64 c	0.38 c
dqi	2.06 a	1.55 ab	1.05 bc	0.40 cd	0.12 d	0.03 d

where: Means followed by the same letter in the line did not differ by Tukey test at 5% level of significance.

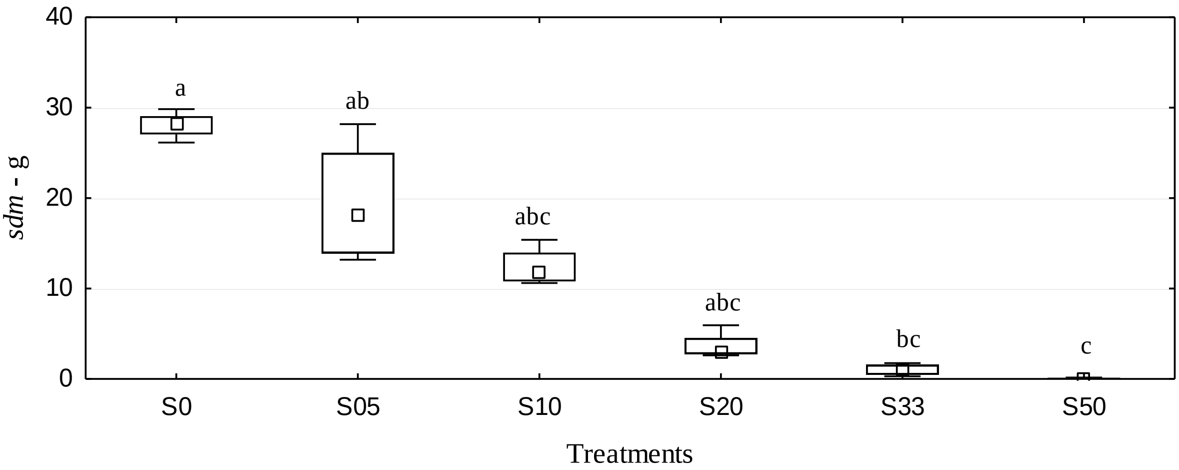

Figure 1. Boxplot to shoot dry mass production (sdm) of *Urochloa brizantha* cv. Xaraés at 120 days after sowing, cultivated under different teakwood sawdust concentrations (S0, S05, S10, S20, S33 and S50). Same letters represent equality between treatments by the Kruskal-Wallis test at 5% level of significance.

The best model for the growth trends of h and d was the modified exponential. For the nll, the second-degree polynomial model provided the best adjustments.

In the models for plant height (h) and average tillers diameter (d) we observed that higher teakwood sawdust concentrations caused poorer values for the statistics Syx% e ryŷ%. The mean absolute differences (MAD)for these two variables and all the statistics for the number of live leaves (nll) did not follow this pattern. Tests of the identity model for h and d all demonstrated thar growth trends differed among themselves (p<0.05). The number of live leaves per plant (nll) for S05 had a growth tendency similar to S0. There was also a similarity between S10 and S20 (Table 6).

Table 6. Parameters of the models for plant height (h), average tillers diameter (d) and number of live leaves per plant (nll) as function of plant age (id) for the *Urochloa brizantha* cv. Xaraés cultivated under different teakwood sawdust concentrations (S0, S05, S10, S20, S33 and S50)

Treatments	Equations	IT**	$S_{yx\%}$	MAD	$r_{y\hat{y}\%}$
S0	$h = 116.696685exp(-34.718641/id)$	a	3.85	5.73	88.01
S05	$h = 86.233275exp(-21.511029/id)$	b	3.67	4.36	82.85
S10	$h = 67.400842exp(-11.692274/id)$	c	4.93	5.52	45.31
S20	$h = 42.276781exp(-3.359771^{*}/id)$	d	6.52	5.33	11.83
S33	$h = \bar{y} = 22.786723$	-	-	-	-
S50	$h = \bar{y} = 7.281766$	-	-	-	-
S0	$d = 4.835865exp(-42.599813/id)$	a	24.03	0.31	84.81
S05	$d = 3.595432exp(-27.703105/id)$	b	24.16	0.27	76.17
S10	$d = 3.075363exp(-26.508196/id)$	c	30.55	0.31	62.66
S20	$d = 1.961657exp(-17.792806/id)$	d	30.75	0.17	59.40
S33	$d = 1.075171exp(-15.290471^{*}/id)$	e	63.05	0.22	26.34
S50	$d = \bar{y} = 0.452595$	-	-	-	-
S0	$nll = 7.193822+(-0.090188id)+0.000530id^2$	a	18.22	0.37	58.77
S05	$nll = 6.893768+(-0.078747id)+0.000457id^2$	a	19.37	0.42	47.73
S10	$nll = 7.111494+(-0.093338id)+0.000501id^2$	b	22.26	0.37	64.31
S20	$nll = 7.832589+(-0.112154id)+0.000581id^2$	b	18.73	0.27	87.87
S33	$nll = \bar{y} = 2.695486$	-	-	-	-
S50	$nll = \bar{y} = 2.172222$	-	-	-	-

where: IT – model identity test; $S_{yx\%}$ – residual standard error; MAD – mean absolute differences; and $r_{y\hat{y}\%}$ – correlation coefficient of the equations. * Coefficient not significant by the t-test (p>0.05). ** Same letters represent equality in growth trend by the model identity test (p>0.05).

All models had biological realism, with estimated growth trends following the patterns of measured data (Figure 2). This effect was less accentuated in treatments with higher wood sawdust concentrations.

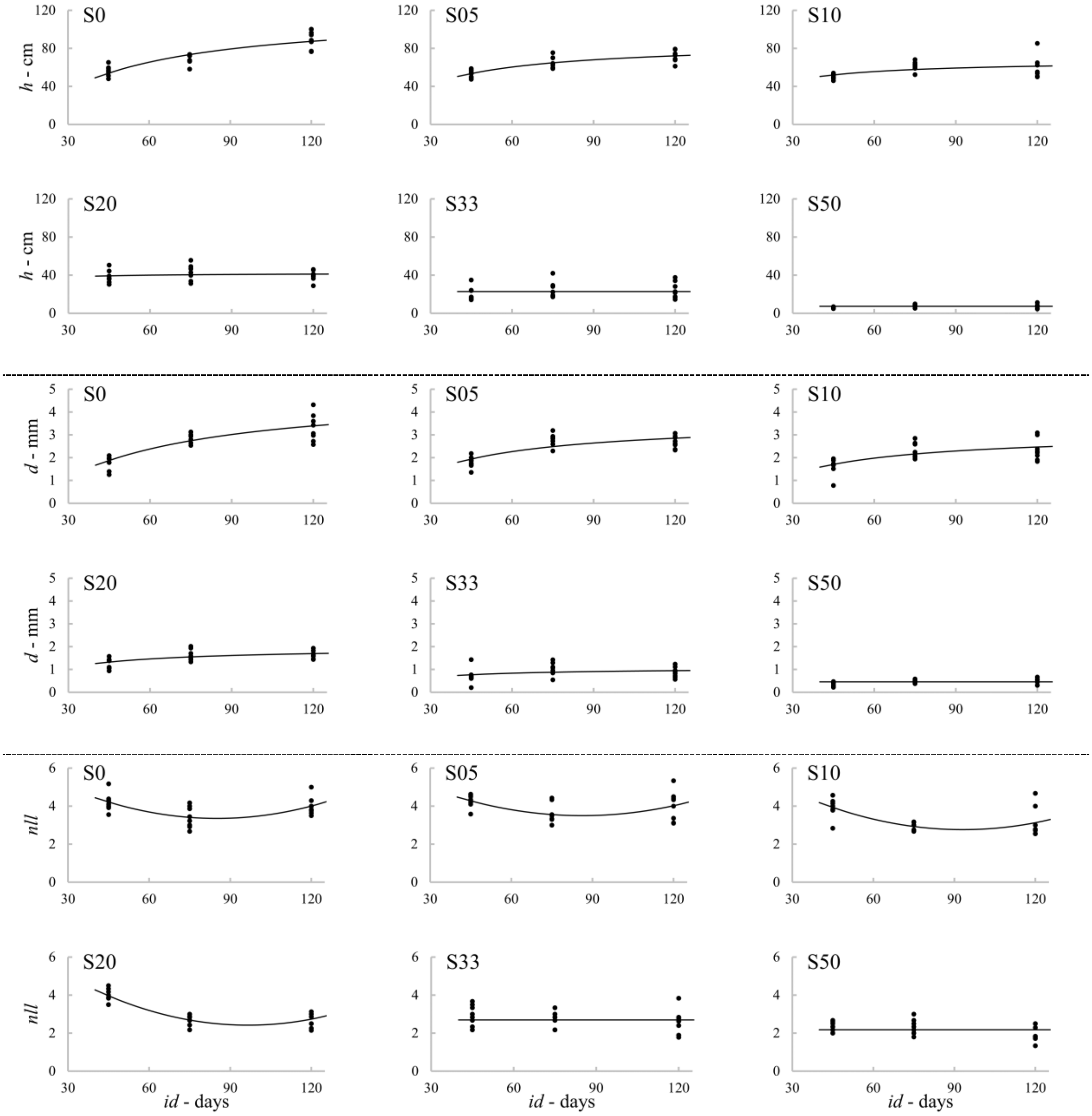

Figure 2. Relationship between observed values (⁝) of plant height (h); average tillers diameter (d) and the number of live leaves per plant (nll) of *Urochloa brizantha* cv. Xaraés, cultivated under different teakwood sawdust concentrations (S0, S05, S10, S20, S33 and S50) and estimated data (—) as a function of age (id).

Treatments S0 and S05 showed similar behavior, as well as treatments S10 and S20 for the number of live leaves per plant (nll). This indicates that there is a relationship between these treatments and a single equation can be used to estimate its live leaves production (Table 7). The combined models presented $S_{yx\%}$, *MAD*, $r_{y\hat{y}\%}$ and the relative errors ($RE_{\%}$) similar to those generated by the complete models (Table 6).

Table 7. Reduced models parameters for the number of live leaves per plant (nll) as a function of age (id) of *Urochloa brizantha* cv. Xaraés, for the combined treatments S0+S05 and S10+S20, and its residual standard error ($S_{yx\%}$), mean absolute differences (MAD) and correlation coefficients ($r_{y\hat{y}\%}$)

S	Equations*	$S_{yx\%}$	MAD	$r_{y\hat{y}\%}$
S0+S05	$nll = 7.043795 + (-0.084467id) + 0.000493id^2$	18.56	0.40	52.81
S10+S20	$nll = 7.472042 + (-0.102746id) + 0.000541id^2$	21.08	0.72	75.05

*All coefficients were significant by the t-test at 5% level of significance ($p<0.05$).

Some treatments presented high relative errors (RE%) (Figure 3), a consequence of the greater data dispersion observed, which hindered the simple and combined equations adjustment for estimating the growth trend, especially, height, diameter, and the number of live leaves.

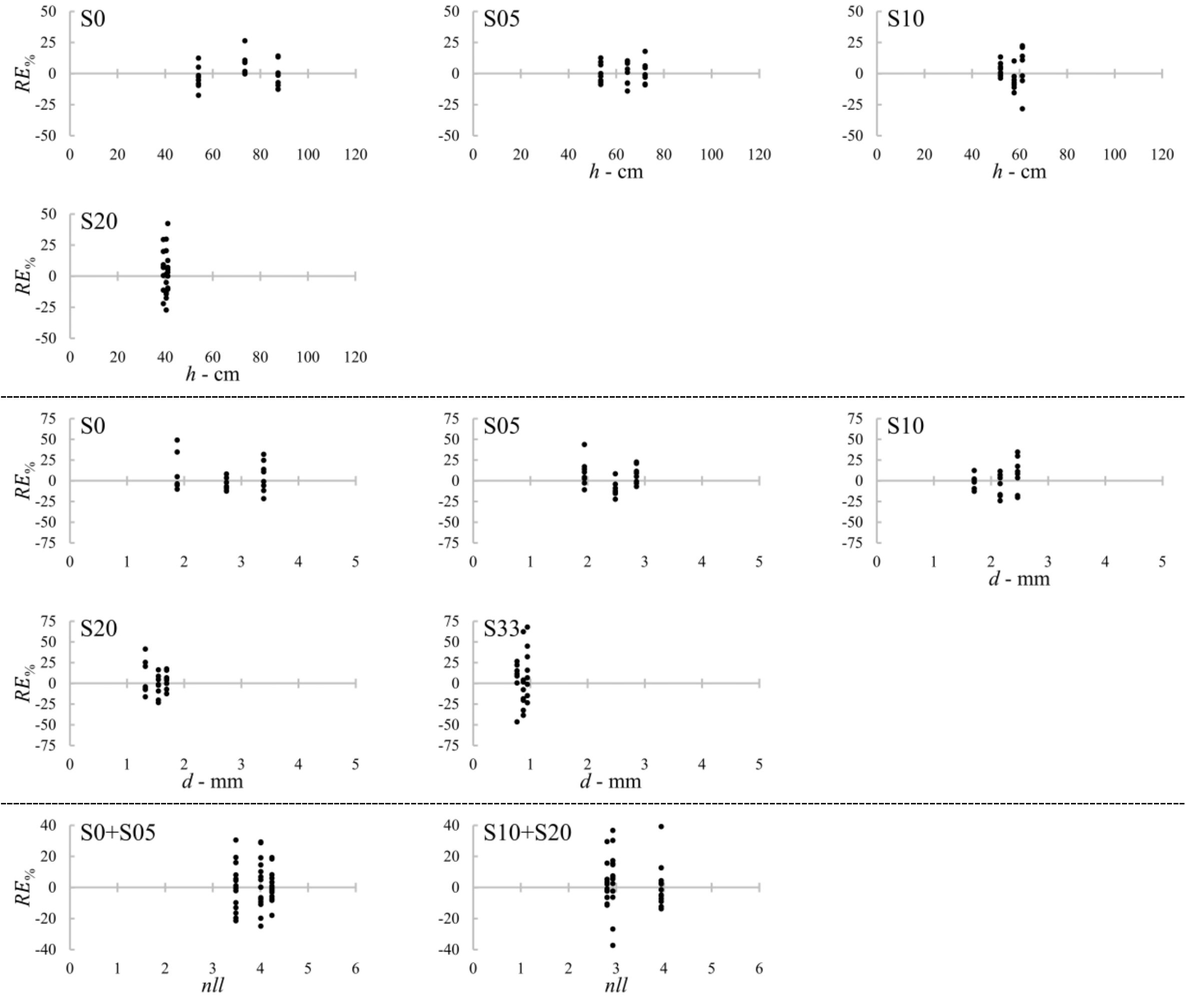

Figure 3. Relative errors (RE%) of complete (a-i) and reduced (combined) (j-k) models for plant height estimates (h) (a-d), average tillers diameter (d) (e-i) and number of live leaves per plant (nll) (j-k) of the *Urochloa brizantha* cv. Xaraés, cultivated under different teakwood sawdust concentrations (S0, S05, S10, S20, S33 and S50).

There was growth reduction, observed in the growth trends of h, d and nll, as the concentration of sawdust added to the treatment increased. Therefore, all concentrations impaired plant development ($p<0.05$). The models S0+S05 and S10+S20 estimated reduction of the number of live leaves before 90 days, for the values were close to 4.5 and 4.2 at 40 days and 3.5 and 2.6 at 90 days, respectively (Figure 4).

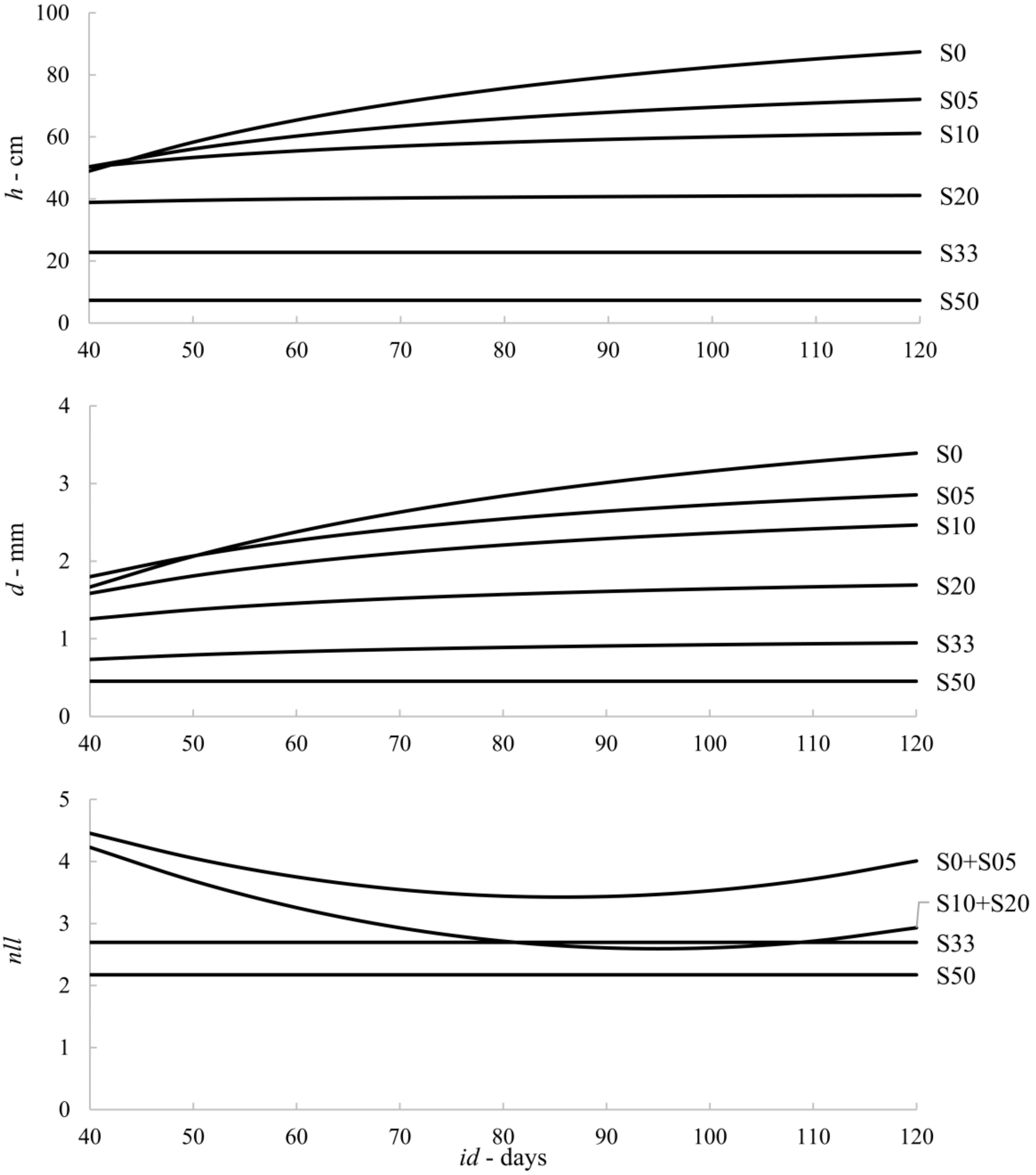

Figure 4. Growth trends for plant height (h), average tillers diameter (d) and number of live leaves per plant (nll) of the *Urochloa brizantha* cv. Xaraés, estimated by complete models (S0, S05, S10, S20, S33 and S50) and reduced models (S0+S05 and S10+S20) of teakwood sawdust concentrations.

Discussion

Statistical evaluations of the data collected at 120 days and the models demonstrate that the addiction of teakwood sawdust in the substrate decreased the height and diameter growth and reduced the number of live leaves per plant, fresh and dry mass of shoots and roots and the Dickson quality index of *Urochloa brizantha* cv. Xaraés. This was verified in the. This result might be due to a large amount of carbon added in these treatments considering that fresh teak sawdust is 49.07% carbon (Table 2). This element can take years or even decades to decompose depending on local conditions and wood density (Piñeiro et al., 2008; Trumbore and Camargo, 2009). According to Vitousek et al. (1994), high concentrations of non-decomposed organic matter may be one of the most limiting factors in the establishment of ecosystems, causing damage to crop development.

That the used teakwood sawdust had a C/N ratio of 196/1, thus, low content of nitrogen (0.25%). Nitrogen is required in large quantities for the development of forage species, its absence is very limiting, affecting plants' morphological characteristics (Bona and Monteiro, 2010; Bonfim-Silva and Monteiro, 2010; Martuscello et al., 2015).

The statistics used in the evaluation of the models for h and d became less precise as the fresh teakwood sawdust concentrations increased. This behavior can be explained by the larger data variance that these treatments showed, affecting the statistics (Campos and Leite, 2017).

The treatment S05 showed the same growth pattern as the control (S0) and superiority at 120 days for the number of live leaves per plant (nll), which is directly related to pasture productivity (Alexandrino et al., 2005). This demonstrates that such concentration does not affect the productivity of live leaves of cultivar Xaraés.

The Dickson quality index (dqi) of the treatments with teakwood sawdust were not equal to the control (S0), demonstrating that its addiction impairs the quality of *U. brizantha* cv. Xaraés plants. A good dqi reflects in plant robustness and distribution of plant biomass (Silva et al., 2012), which are considered important morphological parameters and make this index a good plant quality indicator (Azevedo et al., 2010; Fonseca et al., 2002; Medeiros et al., 2018).

The presence of tannins in the teakwood is a factor that possibly contributes to the negative effects of adding sawdust. These are phenolic compounds that generally have an inhibitory effect on some microorganisms directly responsible for converting organic matter into nutrients that are passively absorbed (Asif, 2011; Guimarães-Beelen et al., 2006; Luo et al., 2016). Therefore, the non-decomposition of organic matter became a very limiting factor to plant development in the treatments with higher sawdust concentration.

Teak allelopathy is another possible cause of the negative effects observed in this study. These effects were previously verified in agricultural crops (Leela, 2017; Leela and Arumugam, 2014; Manimegalai and Manikandan, 2010; Quispe et al., 2010), bushes (Biswas and Das, 2016) and forest species (Ekayanti et al., 2015). Kato-Noguchi (2021) in his work reports that there are several phytotoxic substances involved in theca allelopathy. According to the author, several substances were observed in teak leaves, such as phenolics, benzofurans, quinones, terpens, apocarotenoids, and phenylpropanoids, and some of these substances are released into the soil during litter decomposition, influencing negatively seed germination and plant growth, as occurred in this work.

Another factor that should be considered in future studies is the characteristics of the substrate after its composition, since the mixture results in different physical properties of the materials that gave rise to them, influencing, for example, the density, porosity, water retention, and particle size (Zorzeto et al., 2014).

Teakwood sawdust did not affect the number of live leaves per plant in the treatment S05. However, all the other concentrations undermined the height, tillers diameter, Dickson quality index and production of mass, demonstrating that using fresh sawdust limits the *U. brizantha* cv. Xaraés initial development. We recommend studies about the decomposition and allelopathic effects of the sawdust and tests with other forage species and varieties at the experimental or field level.

Conclusions

As the concentration of teak sawdust in the substrate increases, growth in height and diameter and the number of live leaves, fresh and dry mass of shoots and roots and Dickson quality index of *Urochloa brizantha* cv. Xaraés decreases. Sawdust concentrations up to 5% do not affect the number of live leaves per plant. Fresh teakwood sawdust has negative effects on the development of the cultivar Xaraés and is not recommended as an input for pasture with this forage.

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