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BIOMASS PRODUCTION OF TAQUARA BAMBOO IRRIGATED AND FERTILIZED WITH POTASSIUM AND ZINC

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ABSTRACT: One of the most efficient and effective alternatives according to specialists is bioenergy, obtained through biomass; however, are rare the scientific works that quantify the biomass of the several bamboo species in Brazilian territory. The objective of this work was to assess biomass production, absolute growth rate, and relative growth rate of Taquara plants (*Bambusa tuldoides*) irrigated and fertilized with potassium and zinc. The experimental design was randomized block, in a split-split-plot arrangement (2 × 2 × 4) with three replications, with two potassium rates in the plots (0 and 80 kg ha^{-1}), two zinc sulphate rates in the subplots (0 and 5 kg ha^{-1}), and four evaluation times in the sub-subplots (60, 90, 120 and 150 days after sprouting). Stem fresh weight, stem dry weight, stem water weight, stem dry weight to fresh weight ratio, absolute growth rate, and relative growth rate of the plants were also evaluated. The potassium e zinc fertilization increased the biomass production and growth rate of Taquara plants (*Bambusa tuldoides*).

Keywords: *Bambusa tuldoides*, growth rate, nutrient, bioenergy.

PRODUÇÃO DE BIOMASSA DO BAMBU TAQUARA IRRIGADO E ADUBADO COM POTÁSSIO E ZINCO

RESUMO: Uma das alternativas mais eficientes e eficazes, segundo especialistas, é a bioenergia, obtida através da biomassa; no entanto, são raros os trabalhos científicos que quantificam a biomassa das diversas espécies de bambu em território brasileiro. O objetivo deste trabalho foi avaliar a produção de biomassa, a taxa de crescimento absoluto e a taxa de crescimento relativa do bambu Taquara (*Bambusa tuldoides*) irrigado e adubado com potássio e zinco. O delineamento experimental utilizado foi em blocos ao acaso, analisado em esquema de parcelas sub-subdividas 2 × 2 × 4, com três repetições, e as parcelas foram compostas por duas doses de potássio (0 e 80 kg ha^{-1}), as subparcelas duas doses zinco (0 e 5 kg ha^{-1}) e 4 épocas de avaliações (60, 90, 120 e 150 dias após a brotação). As variáveis avaliadas foram massa fresca (MF), massa seca (MS), massa de água (MA), razão massa seca/massa fresca (MS/MF), taxa de crescimento absoluto (TCA) e taxa de crescimento relativo (TCR). A adubação com potássio e zinco incrementa a produção de biomassa e a taxa de crescimento do bambu Taquara (*Bambusa tuldoides*).

Palavras-chave: *Bambusa tuldoides*, taxa de crescimento, nutriente, bioenergia.

1 INTRODUCTION

Bamboos are distributed in areas of Asia, Australia, Africa and America; Brazil has a great diversity of bamboo, around 250 species can be found, of which about 160 are considered to be endemic (Guerreiro; Lizarazu, 2010; Generoso *et al*., 2016).

Bamboo has unique rhizomal growth feature by which stems (individual bamboo) in the clump (cluster of stems) are interconnected and reproduce asexually to produce new stems every year, this characteristic distinguishes

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bamboo from most other woody plants (Kumari; Bhardwaj, 2017).

One of the most efficient and effective alternatives according to specialists is bioenergy, obtained through biomass; among the diversity of biomass sources, the bamboo is considered a useful energy source, as well as its peculiar growth characteristic and accelerated biomass production, where its usage is described as an excellent exploration strategy (Inbar, 2013; Melo *et al*., 2015).

The maximization of biomass production is a result of satisfactory conditions of the environment and of management, which are relevant for a successful production system, hence the relevance of the knowledge of its components to understand the influence of management strategies (fertilization, irrigation, and others) (Lopes *et al*., 2013).

The potassium fertilization is highlighted as essential for being one of the mineral nutrients most absorbed by plants, in addition to the fact to promote the stimulation of growth and consequently, increases in production of biomass (Cantarella, 2007; Morais *et al*., 2016); already with zinc fertilization the plant biomass tends to decrease with increasing soil Zn levels, whereas plant growth at lower levels of soil Zn. However, are rare the scientific works that quantify the biomass of the several bamboo species in Brazilian territory (Vasconcellos, 2006).

The objective of this work was to assess biomass production, absolute growth rate, and relative growth rate of Taquara plants (*Bambusa tuldoides*) irrigated and fertilized with potassium and zinc.

2 MATERIAL AND METHODS

The experiment was conducted under field conditions, at the North Star farm, in Gurupi – TO, Brazil (11°53’24.4”S 49°06’47.1”W). The climate of the region is classified as B1wA’a’, according to Köppen and Geiger (1928). The region presents mean annual temperature of 27°C, mean annual precipitation of 1600 mm.

The soil of the experimental area was classified as Red Latosol (Oxisol) (Embrapa, 2013). Undisturbed soil samples were collected form the 0.0-0.2 and 0.2-0.4 m layers for physical and chemical characterization (Table 1).

Table 1. Physical-chemical characteristics of a Red Latosol (Oxisol) soil collected from the 0.0-0.2 and 0.2-0.4 m layer.

Layer[1]	**Ca^{2+}**	**Mg^{2+}**	**Ca+Mg**	**Al**	**H+Al**	**K^+**	**S**	**P**	**pH**
m			**$cmol_c\ dm^{-3}$**				**$mg\ dm^{-3}$**		**$CaCl_2$**
0.0-0.2	5.6	0.9	6.5	0.0	3.1	133	7.5	3.6	5.8
0.2-0.4	2.8	0.5	3.3	0.0	2.9	142	9.1	1.7	5.8
Layer			Micronutrients						
	Na^+	Fe	Mn	Cu	Zn	B	CEC	SB	V%
m			$mg\ dm^{-3}$				$cmol_c\ dm^{-3}$		%
0.0-0.2	4.0	19.9	37.0	1.5	1.7	0.6	9.9	6.8	69
0.2-0.4	3.0	20.2	22.8	1.9	0.9	0.5	6.5	3.6	56
Layer		Texture				Relationship between bases			
	Clay	Silt	Sand	OM	Ca/Mg	Ca/K	Mg/K	Ca/CTC	Mg/CTC
m		%		$g\ dm^{-3}$	-	-	-	-	-
0.0-0.2	42	10	48	31.4	6.3	16.4	2.6	0.56	0.09
0.2-0.4	52	7	41	22.4	5.8	7.7	1.3	0.43	0.07

[1]Determination methods: P, K, Na, Cu, Fe, Mn. And Zn: Mehlich 1; Ca, Mg, and Al: KCl 1 N; S: Ca $(H_2PO_4)_2$ in HOAc; OM: calorimetry; B: $BaCl_2$. Cation exchange capacity (CEC); Sum of bases (SB); Saturation by bases (V%); Organic Matter (OM).
Source: Author (2023)

The experimental design was randomized block, in a split-split-plot arrangement (2 × 2 × 4) with three replications, with two potassium rates in the plots (0 and 80 kg ha^{-1}), two zinc rates in the subplots (0 and 5 kg ha^{-1}), and four evaluation times in the sub-subplots (60, 90, 120 and 150 days after sprouting).

Potassium and zinc fertilizations were applied according to the treatments, by using as sources, potassium chloride (K_2O) and zinc sulphate, respectively. The soil of all treatments was fertilized with nitrogen (80 kg ha^{-1}; urea), phosphorus (80 kg ha^{-1}; triple superphosphate), and micronutrients, except zinc, as recommended by Pereira and Beraldo (2010). The spacing between the seedlings was 5 m × 5 m. The plants were irrigated using drip irrigation with a drip pipe network in the soil surface along the planting furrows, that showed the following characteristics: maximum working pressure of 1.5 bar; nominal thickness (mm) of 0.40mm; spacing between emitters of 100 cm; internal diameter of 16.1 mm and external diameter of 16.9 mm.

Stem fresh weight, stem dry weight, stem water weight, stem dry weight to fresh weight ratio, absolute growth rate, and relative growth rate of the plants were also evaluated. Leaves and stems of each plant were separated, packed in numbered paper bags according to each treatment, and dried in a forced-air circulation oven at 65°C for 48 hours to evaluate their dry weights (Lacerda; Freitas; Silva, 2009). The weighing was carried out in a balance with accuracy of 0.01 g.

The data were subjected to analysis of variance by the F test at 5% probability level, and significant means were subjected to regression analysis considering the evaluation periods, and Tukey's test ($p<0.05$) considering the fertilizer rates, using the R program (R Core Team, 2015).

3 RESULTS AND DISCUSSION

The K fertilization of 80 kg ha^{-1} increased the stem fresh weight (SFW) of Taquara plants in 11.68, 9.41, 7.30 and 9.85% at 60, 90, 120 and 150 DAS, without Zn fertilization; and in 19.33, 17.73, 7.96 and 5.97% at 60, 90, 120 and 150 DAS with Zn fertilization of 5 kg ha^{-1}, respectively (Table 2). According to Piouceau *et al*. (2014), the increase in K fertilization significantly increased fresh biomass (above 20%) of the species of bamboo: *Bambusa vulgaris*, *Bambusa oldhamii*, *Bambusa multiplex*, *Bambusa tuldoides*, *Thyrsostachys siamensis*, *Dendrocalamus strictus* and *Gigantochloa wrayi*.

Table 2. The stem fresh weight (SFW), stem dry weight (SDW) and stem water weight (SWW) of Taquara plants (*Bambusa tuldoides*) irrigated and fertilized with potassium and zinc.

DAS	**Zn kg ha^{-1}**	**K[1] (kg ha^{-1})**					
		SFW (kg)		**SDW (kg)**		**SWW (kg)**	
		0	**80**	**0**	**80**	**0**	**80**
60	0	1.56 Bb	1.77 Ba	0.50 Bb	0.62 Ba	1.06 Aa	1.14 Ba
	5	1.79 Ab	2.22 Aa	0.63 Ab	0.80 Aa	1.16 Ab	1.42 Aa
90	0	2.36 Bb	2.61 Ba	0.80 Bb	0.88 Ba	1.56 Ba	1.72 Ba
	5	2.65 Ab	3.22 Aa	0.87 Ab	0.95 Aa	1.78 Ab	2.27 Aa
120	0	3.26 Bb	3.52 Ba	0.96 Bb	1.06 Ba	2.30 Bb	2.52 Aa
	5	3.54 Ab	3.85 Aa	1.02 Ab	1.27 Aa	2.53 Aa	2.58 Aa
150	0	4.09 Bb	4.53 Ba	1.15 Bb	1.31 Ba	2.94 Bb	3.22 Ba
	5	4.58 Ab	4.87 Aa	1.35 Ab	1.43 Aa	3.23 Ab	3.44 Aa

[1]Means followed by different letters, lowercase in the row and uppercase in the column, differ by Tukey test ($p < 0.05$).
Source: Author (2023)

Stem fresh weight presented increases of 12.83, 10.76, 7.92 and 10.81% at 60, 90, 120 and 150 DAS, respectively, due to the zinc rate of 5 kg ha^{-1}, without K fertilization; and differences of 20.39, 18.96, 8.57 and 6.97% at 60, 90, 120 and 150 DAS, respectively, with K fertilization of 80 kg ha^{-1}.

The K fertilization of 80 kg ha^{-1} increased the stem dry weight (SDW) of Taquara plants in 19.27, 9.17, 9.87 and 12.58%

at 60, 90, 120 and 150 DAS, without Zn fertilization; and in 20.82, 8.43, 19.71 and 5.74% at 60, 90, 120 and 150 DAS with Zn fertilization of 5 kg ha^{-1}, respectively (Table 2). According to Chen et al. (2015) the plants with K fertilization produce much more biomass, increased so the biomass of plants by 21.58%.

Stem dry weight presented increases of 20.55, 7.28, 5.74 and 15.21% at 60, 90, 120 and 150 DAS, respectively, due to the zinc rate of 5 kg ha^{-1}, without K fertilization; and differences of 22.07, 6.53, 16.03 and 8.57% at 60, 90, 120 and 150 DAS, respectively, with K fertilization of 80 kg ha^{-1}.

The biomass production and nutrient distribution in growing Bamboo (*Bambusa bambos* (L.) Voss) from two days old to maturity, showed a linear increase in the total biomass for all components with the percentage contribution of stem maximum followed by branches, and leaves (Shanmughavel; Francis, 1996).

The K fertilization of 80 kg ha^{-1} increased the stem water weight of Taquara plants in 8.67 and 8.74% at 120 and 150 DAS, without Zn fertilization; and in 18.50, 21.60 and 6.06% at 60, 90 and 150 DAS with Zn fertilization of 5 kg ha^{-1}, respectively (Table 2). The K fertilization increases dry matter production greatly, improves the retention of water in the plant tissues, also is related to lower water losses by the plant (Lindhauer, 1985; Taiz; Zeiger, 2013).

Stem water weight presented increases of 12.46, 8.80 and 8.97% at 90, 120 and 150 DAS, respectively, due to the zinc rate of 5 kg ha^{-1}, without K fertilization; and differences of 19.44, 24.13 and 6.30% at 60, 90 and 150 DAS, respectively, with K fertilization of 80 kg ha^{-1}. Various levels of Zn and K fertilization significantly influenced the water retention ability and biomass of the plant, with increments above 15% (Ghasemi *et al*., 2010; Sá *et al*., 2014).

The stem dry weight to fresh weight ratio (SDW/SFW) of Taquara plants fertilized with 0 and 80 kg ha^{-1} of K, with the absence of zinc fertilization, presented no differences at 90, 120 and 150 DAS, whereas with 5 kg ha^{-1} of Zn presented no differences at 150 DAS (Table 3).

Table 3. The stem dry weight to fresh weight ratio (SDW/SFW), absolute growth rate (AGR) and relative growth rate (RGR) of Taquara plants (*Bambusa tuldoides*) irrigated and fertilized with potassium and zinc.

DAS	Zn kg ha^{-1}	K[1] (kg ha^{-1})					
		SDW/SFW		AGR (kg dia^{-1})		RGR (kg kg^{-1} dia^{-1})	
		0	80	0	80	0	80
60	0	0.32 Bb	0.35 Aa	0.0063 Bb	0.0087 Aa	0.0269 Bb	0.0305 Ba
	5	0.35 Aa	0.29 Bb	0.0089 Aa	0.0049 Bb	0.0307 Ab	0.0346 Aa
90	0	0.34 Aa	0.34 Aa	0.0093 Aa	0.0087 Ba	0.0156 Aa	0.0116 Ab
	5	0.33 Ab	0.36 Aa	0.0112 Aa	0.0117 Aa	0.0105 Ba	0.0056 Bb
120	0	0.29 Aa	0.30 Ba	0.0067 Aa	0.0083 Ba	0.0059 Aa	0.0062 Ba
	5	0.29 Ab	0.33 Aa	0.0078 Ab	0.0107 Aa	0.0054 Ab	0.0098 Aa
150	0	0.28 Aa	0.29 Aa	0.0052 Aa	0.0060 Aa	0.0060 Ba	0.0070 Aa
	5	0.30 Aa	0.29 Aa	0.0051 Aa	0.0056 Aa	0.0095 Aa	0.0042 Bb

[1]Means followed by different letters, lowercase in the row and uppercase in the column, differ by Tukey test ($p < 0.05$).
Source: Author (2023)

The K fertilization of 80 kg ha^{-1} increased the SDW/SFW of Taquara plants in 8.67% at 60 DAS, without Zn fertilization; and in 8.33 and 12.12% at 90 and 120 DAS with Zn fertilization of 5 kg ha^{-1}, respectively.

Oliveira *et al.* (2008) observed that the fertilization whit N and K provided the increase in the production of the total biomass of the bamboo plant (*Bambusa vulgaris*); the highest total dry weight biomass was achieved by the dose of 120 e 100 kg ha^{-1} of N and K.

The SDW/SFW presented increases of 8.82% at 60 DAS, due to the zinc rate of 5 kg ha^{-1}, without K fertilization; and differences of

8.31% at 120 DAS, with K fertilization of 80 kg ha^{-1} (Table 3). Bukvić *et al*. (2003) found differences of 7.93% in production and biomass ratio on zinc fertilization treatments.

The K fertilization of 80 kg ha^{-1} increased the absolute growth rate of Taquara plants in 27.59% at 60 DAS, without Zn fertilization; and in 27.10% at 120 DAS with Zn fertilization of 5 kg ha^{-1}, respectively (Table 3).

The bamboo is famous for their rapid growth and fast biomass accumulation, however, the plant growth was constrained by the most limiting nutrient, the different spatial distribution patterns suggested that fertilizers with different N:P:K ratios should be applied to maintain and improve the stand productivity (Tang *et al*., 2016).

Absolute growth rate presented increases of 29.21% at 60 DAS, due to the zinc rate of 5 kg ha^{-1}, without K fertilization; and differences of 25.64 and 22.43% at 90 and 120 DAS, respectively, with K fertilization of 80 kg ha^{-1}. Romualdo (2008) noted that the growth rate, of the plants with Zn fertilization, is higher when compared to the plants with the absence of zinc fertilization, indicating differences above 11%.

The K fertilization of 80 kg ha^{-1} increased the relative growth rate of Taquara plants in 11.72% at 60 DAS, without Zn fertilization; and in 11.25 and 44.98% at 60 and 120 DAS with Zn fertilization of 5 kg ha^{-1}, respectively (Table 3). Alvarez, Crusciol and Nascente (2012) and Oliveira et al. (2014) observed the highest relative growth rate levels, as well as the highest productivity, in the plants with K and Zn fertilization, showing differences of 50% at 120 days in the growth.

Relative growth rate presented increases of 12.45 and 37.35% at 60 and 150 DAS, respectively, due to the zinc rate of 5 kg ha^{-1}, without K fertilization; and differences of 11.99 and 36.45% at 60 and 120 DAS, respectively, with K fertilization of 80 kg ha^{-1}. Tavares *et al*. (2015) similarly, noted that the relative growth rate responded significantly, the zinc fertilization, mainly in the last evaluation periods.

4 CONCLUSIONS

The K fertilization of 80 kg ha^{-1} increased the stem dry weight of Taquara plants in values greater than 6% at 150 DAS, with and without Zn fertilization (0 and 5 kg ha^{-1}), consequently the potassium e zinc fertilization increased the biomass production of Taquara plants (*Bambusa tuldoides*) irrigated.

The K fertilization of 80 kg ha^{-1} increased the absolute growth rate and relative growth rate of Taquara plants in approximately 27% and 45% at 120 DAS with Zn fertilization of 5 kg ha^{-1}, respectively.

The Taquara plants irrigated and fertilized with potassium and zinc showed a significant increase in the stem fresh weight and stem dry weight to fresh weight ratio.

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