WCCLF 2021

II World Congress on Integrated Crop-Livestock-Forestry Systems

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PREFACE

Promoted by the Ministry of Agriculture, Livestock and Food Supply - MAPA; Brazilian Agricultural Research Corporation - Embrapa; ICLF Network Association; State Secretariat for the Environment, Economic Development, Production and Family Agriculture - SEMAGRO; Federation of Agriculture and Livestock of Mato Grosso do Sul - Famasul; and FB Eventos, the II World Congress on Integrated Crop-Livestock-Forestry Systems (WCCLF 2021) took place on the 4th and 5th May 2021 in a 100% digital format.

The objective of the Congress was to provide a forum for discussion, theoretical insights and practical applications related to technology as well as economic and environmental aspects of mixed agricultural systems that combine integrated production of crops, animals and trees in the same area, having an efficient use of inputs, all being essential for food security in the future.

ICLF is a production strategy that integrates crop, livestock, and forestry farming in the same area, in a consortium, rotated or in succession, so that there is interaction among components, generating mutual benefits.

For two days, we discussed issues related to challenges and opportunities for ICLF systems around the World; solutions and demands from Agribusiness Companies; scenarios and trends of ICLF in the World; current hot topics in ICLF; solutions and demands for ICLF from the farmer's view; Public Policies for Supporting ICLF; and innovation on ICLF systems.

The integrated agricultural production systems can be implemented combining two or three components, according to the particularities of each farm and region. They can also be adopted in small, medium, and large farms, in different biomes, using different crops, livestock and trees species. Among the many benefits of ICLF are increasing total yields of a given area, diversification of income sources, better use of inputs, improvement of soil chemical, physical and biological qualities, along with improvement of animal welfare as well as jobs and income generation. In addition, ICLF systems reduce pressure to clear new areas, it helps to recover degraded low yielding areas while mitigating greenhouse gas emissions, increasing carbon sequestration in soil and biomass. These benefits corroborate with three of the Sustainable Development Goals - SDGs:

- SDG 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture;
- SDG 13 - Take urgent action to combat climate change and its impacts; and
- SDG 15 Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

These Proceedings report 166 scientific contributions approved by the scientific committee of the WCCLF 2021 and 18 papers from speakers that also contributed to this publication.

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GYPSUM AND LIME EFFECTS ON TEAK GROWTH AND SOIL CHEMICAL ATTRIBUTES IN SILVOPASTORAL SYSTEM

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ABSTRACT

A field experiment was conducted to determine the effects of limestone and gypsum application on the soil chemical properties and growth of teak in a silvopastoral system, in the Amazon biome, Brazil. The factors studied were liming; gypsum; liming + gypsum (3000 kg ha^{-1} each) and control (no amends). Growth and soil data were evaluated at the age of eigth years. Teak height growth followed a sigmoidal pattern. Teak height and yield were increased with the combined application of lime and gypsum. The basal area and yield were the smallest with gypsum application. The leaf nutrient content was not improved with the separate application of gypsum and lime. However, the combined application of lime and gypsum increased the macronutrient contents i.e. calcium, nitrogen, phosphrus and potasium. Liming increased the values of soil pH, the sum of base (SB), base saturation (V%), Cation Exchange Capacity (CEC), and organic matter (OM). The results obtained in the present study indicate that the combined application of gypsum and lime together improves the teak productivity in the silvopastoral system.

Key words: *Tectona grandis*; Livestock-Forest Integration; calcium sulfate

INTRODUCTION

Brazil is the second largest producer of beef globally with the largest herd (about 214.7 million heads of cattle). It is the world's largest cattle exporter totalled 1.9 million tonnes in 2019 (ABIEC, 2018; IBGE, 2019). Most of Brazil's beef cattle herds are located in the central-west and northern regions of the country. Mato Grosso state plays an important role in the economic development of the country, because of the largest cattle herd, being 14.8% of the total (TEIXEIRA; HESPANHOL, 2014; IBGE, 2019), that is largely based on grass production. The increase in degraded pasture mostly due to overgrazing, low indexes of production and low soil fertility has been a great challenge for livestock farming (ABADIAS et al., 2020; PACIULLO et al., 2014).

Integrated production systems, such as silvopastoral systems are important to improve the quality of the available forage, and also to obtain higher yield and profit per hectare. The adoption of silvopastoral system - that is constituted by forest components, pasture, and animals - decrease environmental impacts inherent to conventional cattle raising systems by favoring animal well-being, soil and water conservation, mitigation of greenhouse gases and carbon sequestration. It also diversifies farm production, reduces dependence on external inputs, and enhances sustainable land use (CABRAL et al., 2017; CORRÊA et al., 2015; DENIZ et al., 2018; NAIR, 2014).

Teak as a tree component in silvopastoral systems establishment is an option that is highly appreciated by producers. It present easy cutting and lamination and its wood has high market value (CABRAL et al., 2017). One of the biggest challenges to increase teak productivity in silvopastoral systems in

Mato Grosso is related to low levels of soil nutrients, such as calcium, magnesium and mainly phosphorus, and high levels of iron and aluminium.

The use of lime can raise soil pH and reduce aluminum saturation in surface layers. Gypsum ($CaSO_4 2H_2O$) has been used with lime, as an alternative to reduce the toxicity of Al in depth, in addition to increase the levels of Ca and S. Surface application of lime + gypsum is an effective strategy to increase the vertical movement of exchangeable bases in the rooting zone at greater depth (FAGERIA; NASCENTE, 2014; GABRIEL et al., 2018). Thus, this research aims to assess the effect of lime and gypsum application on the growth of teak and soil chemical attributes in a silvopastoral system with marandu palisade grass pastures, in the Amazon biome, Brazil.

MATERIAL AND METHODS

The study was carried out at Bacaeri Farm, Alta Floresta, Mato Grosso (56° 52' 44" W and 09° 58' 17" S, and elevation of 230 m). The region's climate, according to Köppen, is Am, with a well-defined rainy season (October to April), and precipitation averaging 2,000 mm year^{-1} (Souza et al., 2013). The soil is red-dystrophic Argisol and Red-Yellow Latosol with medium to the clayey texture of low fertility and high acidity (SANTOS et al., 2011). The chemical soil characteristics in the experimental area, before the establishment of the system indicated that fertilization correction was required.

In February 2012 teak (*Tectona grandis* L. F.) clonal seedlings were established with a spacing of 3 m x 20 m in an area with marandu palisade grass (*Urochloa brizantha* cv. Marandu). Cattle (average of 325 kg) was introduced at 12 months after planting (2 animal units per hectare). Lime and gypsum (0 and 3000 kg ha^{-1}) were applied 30 days after teak was planted, both distributed in 4 m x 45 m plots along the planting line, with 15 trees. The treatments consisted of control; 3000 kg ha^{-1} of lime; 3000 kg ha^{-1} of gypsum and 3000 kg ha^{-1} each of lime and gypsum.

The total height (*ht*) and the diameter at 1.3 m in height (*dbh*) of the 15 teak plants per plot were measured at 5 (except for dbh), 77 and 95 months of age. Chapman and Richards model was adjusted to assess the growth trend for total height over ages in each treatment. The equations were compared by model identity tests (Regazzi; Silva, 2010). To estimate the volume with teak bark (Vcc) the volumetric equation: $vcc = (\pi * dbh^2/40000) * ht * ff$..

The mean annual increment in volume (MAIv) per tree were calculated by dividing the the individual volume at the age of 8 years by the number of years.

Soil samples were collected at 95 months after planting at five depths (0–5, 5–15, 15–30, 30–40 and 40–60 cm) from different points. Leaf samples were collected in each plot in the lower third of the crown for the first three trees, at 77 months of age.

RESULTS AND DISCUSSIONS

The growth in height followed the Chapman-Richards model ($Y=\beta_0(1-e^{-\beta_{1I}})\beta_2 + \varepsilon$). All parameters of the model were significant ($p < 0.05$). The adjusted equations, after being compared using model identity tests, were grouped when required ($p>0.05$). The tree height for the treaments with gypsum, lime + gypsum, and control has similar growth pattern ($p>0.05$) Thus, it was represented by a single equation: with a correlation coefficient of 0.9898 and a residual standard error of 1.0630. The height growth with the application of lime was represented by the equation, with a correlation coefficient of 0.9983 and a residual standard error of 0.3948 m. The sigmoidal teak growth (height, *dbh* and yield) was observed by other authors from monoculture (SILVA et al., 2014) and silvopastoral system (MARIA et al., 2019) with high increments in height up to 3 years of age. This behavior indicates adaptation of the species to the region.

Teak exhibited different growth responses to the treatments (Table 1). The combined application of lime and gypsum produced higher height growth than the control. The application of gypsum and lime alone showed very small height growth. The application of gypsum and lime presentend *dbh* 5% greater than for the control. The teak individual volume with the application of gypsum were 14% greater than for the control. However, there was lower yield and basal area.

The yield and basal area with the application fo gypsum were 10% lower than for the control. This was due to the smaller tree number in the gypsum treatment (75% survival). Basal area and yield both depends on the population density. The combined application of lime and gypsum increased in 3% the yield of teak trees. The MAIv per tree (0.047 to 0.053 m^3 $year^{-1}$) exhibted little variation among treatments (Table 1).

The growth values of height, diameter and volume obtained in this study were higher than for those found by Silva et al. (2014): 16.1 m, 15.7cm and 0.1454 m^3 at 8 years in a homogeneous stand in Alta Floresta, MT. The mean values of height, diameter and individual volume were higher than those reported by Maria et al. (2019) and Pachas et al. (2019) in larger spacings (167 trees ha^{-1} at 4.4 years, and 159 trees ha^{-1} at 9,3 years old, respectively). The volume was higher than that estimated by Pachas et al. (2019) at 9.3 years old (47.0 m^3 ha^{-1}) in northern Lao PDR. Probably, this difference is related to the use of clonal seedlings, edaphoclimatic conditions, and the application of gypsum (MEDEIROS et al., 2018; MARIA et al., 2019; PACHAS et al., 2019).

Table 1. Dendometric variables and productivity of teak at 8 years of age and leaves nutrient content in a silvopastoral system with application of gypsum and lime, in Alta Floresta, MT.

Treatment	***ht***	**dbh**	**vcc**	**MAIv**	**BA**	**Yield**
	m	**cm**	**m^3**	**m^3 $year^{-1}$**	**m^2 ha^{-1}**	**m^3 ha^{-1}**
Control	16.94±0,76	26.64±1.06	0.37±0.03	0.047	9.19	62.27
Gypsum	16.98±1.52	28.01±1.34	0.42±0.04	0.053	8.23	55.78
Lime + Gypsum	17.34±0.89	26.52±1.32	0.38±0.04	0.048	9.23	63.92
Lime	15.38±0.49	28.08±1.35	0.38±0.04	0.048	10.34	63.62
			Nutrient leaf content			
Macronutrient (dag kg^{-1})	N	P	K	Ca	Mg	S
Control	1.96	0.17	0.99	1.27	0.15	0.10
Gypsum	2.24	0.17	1.01	1.03	0.16	0.10
Lime + Gypsum	2.24	0.18	1.15	1.89	0.16	0.07
Lime	1.82	0.17	1.00	1.44	0.15	0.08
Micronutrient (mg kg^{-1})	B	Cu	Fe	Mn	Zn	-
Control	27.88	18.76	183.70	116.55	16.87	-
Gypsum	20.37	17.72	129.11	127.76	18.07	-
Lime + Gypsum	13.49	9.87	113.04	149.35	39.70	-
Lime	18.93	9.54	83.94	132.87	19.21	-

±: standard deviation; **vcc:** individual volume and **BA:** basal area.

The application of lime in the soil (Table 1) improved the leaves content of N, P, K, Ca, Mg, Mn and Zn. An increase in foliar Ca and Mg after liming – especially if containing both Ca and Mg – may be expected (BAKKER et al., 1999). However, the leaf content of Ca, Mg and K were lower (41; 50 and

10%, respectively) than the values reported by Behling (2009) in a 7.5 years old teak stand in high soil fertility with high productivity. Zhou et al. (2016) reported positively and significant correlation of MAI with foliar mineral element concentrations of N, P, K, Ca, Mg, S, Zn, Fe, B, Cu. They also reported that the relationship between foliar Ca and N and productivity of teak plantation is linear. They reported that foliar content Ca, at the age of 5–8-years was 5.63 to 13.55%, higher values than the findings values of this study (Table 1).

Soil liming increased soil pH, exchangeable Ca content, base saturation, and organic matter (OM) mainly in the upper layers (<30 cm) (Table 2). The application of gypsum alone promoted the greatest S-SO_4 availability especially in the soil layers deeper than 15 cm compared to the control.

Table 2. Soil chemical properties of teak stands in silvopastoral system with application of gypsum and lime.

Soil chemical properties	**Treatment**											
	C	**G**	**L**	**L+G**	**C**	**G**	**L**	**L+G**	**C**	**G**	**L**	**L+G**
	Depth (cm)											
	----------- 0 – 05 -----------				*----------- 05 – 15 -----------*				*----------- 15 – 30 -----------*			
P (mg dm^{-3})	2.7	1.6	2.3	1.1	1.9	1.4	2.1	1.8	1.5	0.5	0.8	1.4
K (mg dm^{-3})	60	61.6	90.4	111.3	38	51.8	95.9	75.5	46.8	34.1	70	68
Ca ($cmol_c$ dm^{-3})	2.74	2.07	2.85	2.32	2.23	2.56	2.93	2.2	2.32	1.31	3	2.13
Mg ($cmol_c$ dm^{-3})	0.71	0.54	0.73	0.6	0.58	0.64	0.61	0.51	0.51	0.32	0.53	0.52
S (mg dm^{-3})	3.6	4.7	4.5	4.4	3.2	4.1	4.1	4.1	4.3	8.1	5.6	4.4
Al ($cmol_c$ dm^{-3})	0.17	0.15	0.09	0.11	0.12	0.18	0	0.1	0.1	0	0	0
Zn (mg dm^{-3})	2.1	1.9	1.9	1.7	1.2	1.5	1.1	1.1	0.4	0.5	0.7	0.4
Fe (mg dm^{-3})	12.1	16.7	21.9	12.7	14	13.7	21.2	17.4	19.2	15.4	18.6	21.9
Mn (mg dm^{-3})	108.5	129.3	107.7	93.3	104.2	79	79.8	98.9	61.1	57.7	47.1	67.2
Cu (mg dm^{-3})	0.9	1.9	1.8	1	1.2	1.4	1.9	1.4	1.5	2.4	1.7	1.7
B (mg dm^{-3})	0.15	0.14	0.14	0.11	0.13	0.13	0.12	0.1	0.11	0.08	0.1	0.09
pH_H_2O	5.6	5.7	5.9	5.7	5.7	5.7	6	5.8	5.8	5.8	6.1	6.1
H+Al ($cmol_c$ dm^{-3})	3.7	3.9	2.8	2.8	3.2	3.7	2.5	2.5	2.6	3.1	2.2	2.5
SB (cmolc dm^{-3})	3.6	2.8	3.8	3.2	2.9	3.3	3.8	2.9	2.9	1.7	3.7	2.8
ETC ($cmol_c$ dm^{-3})	7.3	6.7	6.6	6	6.1	7	6.3	5.4	5.5	4.8	5.9	5.3
OM (dag kg^{-1})	3.37	2.92	2.92	2.63	2.59	2.53	2.79	2.15	1.86	1.63	2.08	1.68
Base saturation (%)	49.3	41.3	57.7	53.3	47.7	47.6	60.2	53.7	53.6	35.8	62.9	53.2
m (%)	4.5	5.1	2.3	3.3	4	5.1	0	3.3	3.3	0	0	0
	----------- 30 – 40 -----------				*----------- 40 – 60 -----------*							
P (mg dm^{-3})	0.7	0.8	1.7	1.7	0.4	1.1	0.4	1	-	-	-	-
K (mg dm^{-3})	43.2	27.1	32.5	37.6	22.4	19.5	30.6	20.5	-	-	-	-
Ca ($cmol_c$ dm^{-3})	1.96	1.44	2.59	1.92	1.86	1.51	2.2	1.33	-	-	-	-

Mg (cmol$_c$ dm^{-3})	0.49	0.24	0.51	0.54	0.55	0.28	0.45	0.38	-	-	-	-
S (mg dm^{-3})	7.1	22.2	17	8	14.6	61.6	37.4	12.9	-	-	-	-
Al (cmol$_c$ dm^{-3})	0.16	0.1	0	0.17	0	0.08	0	0	-	-	-	-
Zn (mg dm^{-3})	0.2	0.3	0.4	0.4	0.2	0.3	0.3	1	-	-	-	-
Fe (mg dm^{-3})	7.4	14.5	13.5	13.7	7.3	11	12	18	-	-	-	-
Mn (mg dm^{-3})	36.1	47.9	44.6	51.7	34.7	31.1	39.5	49.6	-	-	-	-
Cu (mg dm^{-3})	1.4	2.4	2.5	1.8	1.9	2	2.5	3.3	-	-	-	-
B (mg dm^{-3})	0.09	0.08	0.09	0.1	0.1	0.08	0.06	0.1	-	-	-	-
pH_H_2O	5.9	5.6	5.9	5.8	5.9	5.6	5.7	5.5	-	-	-	-
H+Al (cmol$_c$ dm^{-3})	2.8	2.3	2.3	2.2	2.9	2.2	2.5	2.5	-	-	-	-
SB (cmolc dm^{-3})	2.6	1.8	3.2	2.6	2.5	1.8	2.7	1.8	-	-	-	-
ETC (cmol$_c$ dm^{-3})	5.4	4.1	5.5	4.8	5.4	4	5.2	4.3	-	-	-	-
OM (dag kg^{-1})	1.6	1.42	1.6	1.44	1.21	1.18	1.51	1.38	-	-	-	-
Base saturation (%)	47.4	42.7	57.8	53.3	45.7	46	52.5	40.9	-	-	-	-
m (%)	5.9	5.4	0	6.2	0	4.2	0	0	-	-	-	-

C: control, **L:** lime, **G:** gypsum.

The surface application of lime alone, or associated with gypsum, increased soil Ca and Mg levels along the soil profile, and K levels up to 30 cm depth, which influenced the base saturation. As a result of the improved soil chemical properties due to lime and gypsum application, the yield of teak increased (Table 1). Zhou et al. (2016) reported significant correlation betweem MAI and base saturation at a depth of 0-20 cm. They also reported a significant correlation between the MAI and soil pH, available P, exchangeable Ca, Mg, Zn and Cu, and a negative correlation between the MAI and total exchangeable acidity, and Al and Mo concentration. According to Zech and Dreschsel (1991), teak growth decreases with increasing soil acidity. Thus, the highest tree height and individual volume were mainly due to the increased availability of Ca, Mg and K in the soil. Crusciol et al. (2019) reported that simultaneous application of lime and gypsum increased peanut, white oat, and corn crops yield and had positive economic results.

CONCLUSIONS

Surface liming reduced the exchangeable acidity and Al concentration even after 95 months. Gypsum application increased S levels through the soil profile. Lime + gypsum increased teak heigth and volume in silvopastoral system.

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