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Effect of chemical or organic fertilizers in mining remnant substrate on forage production and marandu grass morphogenesis

Efeito de fertilizantes químicos ou orgânicos em substrato remanescente de mineração na produção de forragem e morfogênese do capim marandu

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ABSTRACT: Mining drives economic development, but it frequently alters the fertility of remaining soil or substrates. Increasing organic matter in these substrates has been a critical factor for the successful recovery and establishment of plants. In this study, the development of 'Marandu' *Urochloa brizantha* in a Cambisol substrate, a remnant of bauxite mining, was assessed in the municipality of Poços de Caldas-MG, in response to chemical and organic fertilizers derived from vermicomposting of residues from the production of shimeji mushrooms. An experiment was conducted in a greenhouse, where six treatments, namely: conventional fertilizers (FertConv; FertConv + micro and Cal) and exclusively with the use of vermicompost (20, 40 and 60 t ha^{-1}) were evaluated in a completely randomized design in four replications. Fertilization with vermicompost resulted in significant increases in nutrients. Stem and leaf elongation rates, leaf appearance rate, phyllochron, tiller density and dry matter were influenced by both organic and conventional fertilization. However, the greatest benefits were observed with the application of vermicompost. After 90 days of growth, using conventional fertilization, there were no significant increases in the mentioned variables. The use of vermicompost is effective in improving the fertility conditions of the post-mining substrate, with significant impacts on the development of 'Marandu' grass, a fact that can contribute to the recovery of areas impacted by mining. Chemical fertilization based only on chemical fertilizers did not result in increases in TAlC, TAlF, TApF, DPP and DM until 90 days of initial growth of 'Marandu' grass.

KEYWORDS: Degraded areas, cambisol, vermicompost, shimeji mushroom residue, pasture.

RESUMO: A mineração impulsiona o desenvolvimento econômico mas muitas vezes afeta a fertilidade dos solos ou substratos remanescentes. Aumentar a matéria orgânica nesses substratos é crucial para o sucesso da recuperação e estabelecimento de plantas. Neste estudo, investigou-se o desenvolvimento da *Urochloa brizantha* cv. Marandu em substrato de Cambissolo remanescente da mineração de bauxita em - Poços de Caldas-MG, em resposta a fertilizantes químicos e orgânico derivado da vermicompostagem de resíduos da produção de cogumelos shimeji. Conduziu-se um experimento em casa de vegetação, com seis tratamentos: adubações convencionais (FertConv; FertConv + micro e Cal) e exclusivamente com o uso de vermicomposto (20, 40 e 60 t ha^{-1}), em delineamento inteiramente casualizado com quatro repetições. A adubação com vermicomposto resultou em aumentos significativos de nutrientes. As taxas de crescimento de colmos e folhas, taxa de aparecimento foliar, filocrono, densidade de perfilhos e massa seca foram influenciadas tanto pela adubação orgânica quanto pela convencional, sendo os maiores benefícios observados com o vermicomposto. Após 90 dias de crescimento , não foram encontrados aumentos significativos nas variáveis mencionadas com adubação convencional. O uso de vermicomposto é eficaz para melhorar as condições de fertilidade do substrato pós-mineração, impactando positivamente o desenvolvimento do capim marandu e contribuindo para a recuperação de áreas afetadas pela mineração. A adubação química exclusiva não resultou em aumentos em TAlC, TAlF, TApF, DPP e MS até 90 dias de crescimento inicial do capim Marandu.

PALAVRAS-CHAVE: áreas degradadas, cambissolo, vermicomposto, resíduo de cogumelos shimeji, pastagem.

INTRODUCTION

Mining is one of the most impactful human activities on natural resources: in addition to suppressing the vegetation cover, commonly in highly threatened native ecosystems, it removes the soil surface layer and most of the nutrients and organic matter with it (Brady; Noskke, 2010), compromising

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the dynamics of biological activities, even natural hydrological processes (Longo; Ribeiro;Melo, 2005), intensely affecting its quality and, consequently, the establishment of plants in post-mining areas.

In altered areas that have undergone activities such as mining, what is observed is the prevalence of a remnant that is no longer considered soil itself, but rather a mineral matrix, with poor physical structure, little or no organic matter and a limited amount of nutrients. essential for plants, which makes revegetation of the area difficult and delays its recovery (Longo, Ribeiro; Melo, 2011).

Griffith (1980) reported that the only way to mitigate mining impacts on the soil is through the reestablishment of a perennial vegetation cover over the mined site in the short term, since succession is slow, while erosion is immediate and accelerated, making recovery even more difficult.

The municipality of Poços de Caldas is located on a geological formation rich in bauxite, a natural aluminum source. Therefore, mining represents an important economic activity, fundamental to the economic structure of the region. Consequently, in contracts signed between mining companies and landowners, it is common to provide that, after mining has been carried out, the area will be returned to the owner with eucalyptus cover or pastures, normally with forages of the genus *Urochloa*.

In Brazil, the genus *Urochloa* is the most representative among forage crops in the seed market, and the species *Urochloa brizantha* ('Marandu') is the one that has shown greater adaptation and prominence in zootechnical parameters (Valle *et al*., 2009; Dutra, 2021). This grass has cespitose growth, is resistant to the attack of pasture leafhoppers, shows high seed production and leaf biomass, as well as deep roots and tolerance to aluminum and manganese in the soil (Ourives *et al*., 2010; Silva and Ferrari, 2012; Lima *et al*., 2019), characteristics that can favor its use in areas destined for mining activities and enable greater environmental recovery, combined with the benefits in income diversification by enhancing livestock activity, consequently contributing to the economic, social and environmental sustainability of the entire sector.

According to Lopes *et al.* (2014), the knowledge of the ideal soil and climate conditions for cultivation, associated with fertilization management and the characteristics of forage growth, are of great importance for the selection of ideal conditions in which the plant expresses its maximum productive potential. Therefore, understanding the morphogenic behavior of grasses subjected to specific production conditions precedes the adoption of adjustments in pasture management (Meneses *et al*., 2018), in order to provide forage plants with better conditions to achieve greater efficiency in their morphophysiological processes and, as a consequence, greater growth and production.

Regarding soil fertility, the restriction in organic matter is one of the main problems in the recovery of areas degraded by mining (Longo *et al.,* 2011). Its replacement with the use of organic compounds can increase the supply of available nutrients, bring physical restructuring and improvements in biological activities in the soil, thus resulting in greater yield in these areas. Furthermore, the use of organic waste as a fertilizer is an efficient sustainability mechanism, as it reduces incorrect disposal, generates income for producers and reduces dependence on chemical fertilizers.

Studies have indicated advantages of using various organic residues in soil fertility and plant establishment in post-mining areas (Dey *et al.,* 2019). Amaral *et al*. (2012) evaluated the development of 'Marandu' *Urochloa brizantha* in areas degraded by quartzite mining, as a function of combinations of chemical and organic fertilization with doses ranging from 0 to 10 t ha^{-1} of farmyard manure. They found that the dry matter production of shoots, roots and total, in addition to nutritional status, were influenced by the interaction between fertilizations, with emphasis on doses of 37 kg N, 37 kg P_2O_5, 30 kg K_2O and 2.6 t farmyard manure. Orrico Junior *et al*. (2018) studied higher levels of organic fertilizer in a dystrophic oxisol of low fertility, on the forage plants 'Paiaguas' and 'Piatã' *Urochloa brizantha*, and concluded that high doses of chicken manure, 19.39 to 28.78 t ha^{-1}, were necessary for cultivars to achieve greater forage accumulation and increases in morphogenic and structural parameters.

There is a wide range of recommended doses for traditional organic fertilizers. However, there is little information regarding those coming from specific preparations such as vermicomposting. Therefore, the objective of this research was to evaluate the morphogenic and productive development of 'Marandu' *Urochloa brizantha*, grown in substrate remaining from mining activity in the municipality of Poços de Caldas, in response to the use of both chemical and organic fertilizers from waste vermicomposting from the production of shimeji mushrooms.

MATERIAL AND METHODS

An area representative of bauxite mining activity in the Poços de Caldas region was initially identified which, according to the Soil Map of the State of Minas Gerais (UFV *et al*., 2010), originally represented a soil classified as an inceptisol. Samples from the 0-20 cm layer of the remaining substrate were collected for an initial diagnosis and, subsequently, the following chemical composition was verified: pH 5.57; 1.60 mg dm^{-3} P; 27.23 mg dm^{-3} K; 0 cmolc dm^{-3} Al; 1.57 cmolc dm^3 Ca, 0.24 cmolc dm^3 Mg, 3.22 cmolc.dm^3 H, 5.10 cmolc.dm^3 CTC, 36.53 % V, 3.54 dag dm^3 MO, 2.43 mg dm^3 Zn, 109.07 mg.dm^3 Fe, 49.33 mg.dm^3 Mn, 0.10 mg.dm^3 Cu, 0.20 mg.dm^3 B.

An experiment was conducted under controlled greenhouse conditions and, for this purpose, a sample of the remaining mining substrate was collected in the 0-20 cm layer, subjected to sieving (2-mm mesh) for homogenization and disposal of coarse material and 4.5-kg plastic pots were then filled for the cultivation of plants in sequence.

When filling the pots, soil acidity was corrected, seeking to increase the base saturation level to 60%. Application was carried out 30 days before sowing. During this period, the vessels were maintained with a water depth equivalent to 60% of the TPV (total pore volume) occupied with water, according to the methodology of Bomfim-Silva *et al.* (2011) and monitored by frequent weighing. This moisture was also maintained throughout the experiment, based on the same procedure.

An organic fertilizer was previously obtained through vermicomposting, using 450 kg of Shimeji mushroom residue and 4.5 kg of earthworms (1% mass). 'Caipira' earthworms were used, collected in the Cuniculture sector of Federal Institute of Southern Minas Campus Inconfidentes. The residue was placed in a pit (8m x, 0.5 m x 0.40 m), located in the vermicomposting sector of Federal Institute of Southern Minas Campus Inconfidentes. The worms were evenly distributed in the residue, and the entire production process lasted six months. During this period, composting was monitored by irrigation and, at the end, the compost was sieved and a sample was taken for chemical analysis, where the following results were obtained based on dry matter: 1.55 % N, 0.35% P, 0.27% K, 5.45% Ca, 0.84% Mg, 0.25% S, 210 mg kg^{-1} Zn, 2369 mg kg^{-1} Fe, 613 mg kg^{-1} Mn, 52 mg kg^{-1} Cu, 31.8 mg kg^{-1} B, with 36,84% moisture and a C:N ratio of 9.5%.

Subsequently, the experiment was designed and conducted according to a completely randomized design, and six treatments were defined as: FertConv + micro - Conventional fertilization, following the doses described by Lopes *et al.* (2014) plus application of micronutrients at 1.8% B, 9% Zn, 1.00% Fe, 0.8% Cu and 2.1% Mn via nutrient solution; FertConv – According to Lopes *et al.* (2014), without the application of micronutrients; Lime – Only lime application and treatments with vermicompost doses obtained from residues from the production of shimeji mushrooms. Vermicompost doses were defined to eliminate the need for P_2O_5 used in sowing. Thus, doses above and below that were set, defined as: Org 20 – referring to 20 t ha^{-1}; Org 40 – 40 t ha^{-1} and Org 60 – 60 t ha^{-1}; in four replications. Sowing was carried out using 1.5 grams of commercial seeds of the species 'Marandu' *U. brizantha* per pot, with 36% crop value.

Potassium (potassium chloride), phosphate (simple superphosphate) and micronutrient (nutrient solution) fertilizations were planned based on both the results of the initial chemical analysis of the soil and applications carried out by Lopes *et al*. (2014). For the first growth cycle and exclusively with chemical fertilization treatments, an initial dose of phosphorus (125 mg P_2O_5 dm^{-3}) was applied at once, at sowing. At this moment, micronutrients were supplied via nutrient solution to comprise treatment FertConv + micro. Nitrogen and potassium cover applications were carried out in plots. The first half of the nitrogen dose (120 mg N dm^{-3}) was applied 45 days after planting (DAP) and the second, 15 days after the first. The first potassium fertilizer (120 mg K_2O dm^{-3}) was applied right at the start of the experiment (sowing). The second application (120 mg K_2O dm^{-3}) was carried out together with the first nitrogen dose.

Plants were thinned 25 DAP, with 2 plants kept in the central position of the pot, for subsequent conduction and collection of morphogenic parameters. Each of the plants received identification with a ring of a different color. The selected plants were those that showed the best development during that period. The marked plants were evaluated every 7 days, starting on the 15th day after emergence; 45 DAP, a soil sample was taken for chemical characterization, after applying the treatments. The first shoot was cut 3 months after sowing.

For the second growth cycle (after the first cut), in treatments without vermicompost application, cover fertilization was carried out using conventional fertilizer formulated NPK 19-04-19, with doses corresponding to 240, 50 and 240 kg ha^{-1} in NPK, applied in two plots: the first was carried out one week after shoot cutting and the second, 25 days after the first. The second cut was carried out 75 days after the first; at which time the roots were also collected.

The characteristics evaluated in both growth periods were: shoot dry matter (DM, g pot^{-1}); leaf elongation rate (TAlF, mm leaf^{-1} day^{-1}); stem elongation rate (TAlC, mm stem^{-1} day^{-1}); number of living leaves (NFV, number of expanded leaves), leaf appearance rate (TApF, expanded leaves day^{-1}); based on this variable, the phyllochron (PHYLO, number of days for a leaf to appear) was calculated according to the methodology proposed by Chapman & Lemaire (1993). The tiller population density (DDP, tiller pot^{-1}) was estimated according to Costa (2021). Subsequently, based on Reis (2020), the ideal rest period (PD, days) was estimated. At the end of the second cut, root dry matter (RDM, g pot^{-1}) was obtained, as well as the total shoot dry matter (SDM, g pot^{-1}), by adding cuts 1 and 2.

All data were analyzed for normality and then subjected to analysis of variance – ANOVA; the Scott Knott test ($p \leq 0.05$) was used to compare treatment means.

RESULTS AND DISCUSSIONS

Regarding soil nutrient content, 60 t ha^{-1} of vermicompost provided the highest values for P, Ca, Mg, Zn and pH. Cu presented higher concentration in treatment FertConv + micro. For B content, increased values were verified in treatments FertConv and FertConv+micro (Table 1).

According to Dey *et al.* (2019), N mineralization from organic fertilizers is frequently reported. However, information on the availability of other nutrients is still limited. This information would contribute to a more efficient calibration of

Table 1. Nutrient contents in the substrate remaining from the mining activity in Poços de Caldas/MG 45 days after sowing in response to fertilization with both conventional fertilizers and vermicompost.

Fertilizers applied	Nutrients analyzed									
	K	P	Ca	Mg	Zn	Fe	Mn	Cu	pH	B
	mg.dm³	mg.dm³	cmol. dm³	cmol. dm³	mg.dm³	mg.dm³	mg.dm³	mg.dm³	-	mg.dm³
FertConv + micro	27.35b	2.84d	3.84a	0.67b	1.10c	20.30b	11.55b	0.12a	6.51e	4.98a
FertConv	31.33b	3.16d	2.94b	0.58b	1.10c	19.58b	11.60b	0.00b	6.65d	5.02a
Cal	24.08b	1.38d	2.22c	0.59b	1.10c	28.23a	16.20b	0.01b	6.70d	1.09b
Org 20	30.73b	6.51c	2.87b	0.73b	2.38b	32.55a	24.43a	0.01b	6.92c	0.07b
Org 40	59.95a	12.72b	3.57a	1.09a	3.88a	16.93b	21.23a	0.05b	7.07b	0.12b
Org 60	52.55a	25.26a	3.94a	1.25a	4.05a	10.20c	13.30b	0.05b	7.25a	0.15b

*Means followed by the same letter do not differ by the Scott & Knott test at 0.05% probability. Fert.Conv= conventional NPK fertilization, Fert + micro= conventional NPK fertilization plus application of micronutrients B, Fe, Cu, Zn, Mn) with waste vermicompost from the production of shimeji mushrooms (Org 20= 20 t ha^{-1}; Org 40= 40 t ha^{-1} and Org 60= 60 t ha^{-1}.

doses to be applied, and thus enable farmers to reduce dependence on chemical fertilizers, assuring greater sustainability in their production systems. The aforementioned authors studied the release dynamics of some macro-and micronutrients from farmyard manure, mushroom compost, poultry manure, vermicompost, biogas slurry and biochar from *Lantana* sp., as a function of time (120 days), and found greater release of Fe and Mn when applying mushroom compost; K, Ca, Mg and S in farmyard manure; P, Zn and Cu in biogas slurry and B in biochar from *Lantana* sp. The average percentages of the totals released were 30.5% P, 71.8% K, 23.1% Ca, 24.4% Mg, 29.3% S, 47.2% Zn, 22.9% Cu, 38.6% Fe, 46.6% Mn and 70.9% B.

There was an increase of 889.44 and 799.37% in P concentration when comparing the dose of Org 60 treatment in relation to FertConv+micro and FertConv, respectively. The availability of P in the soil through the decomposition of organic matter tends to vary according to the specific characteristics of each soil (Pavinato; Merlin; Rosolem, 2008). Therefore, this result indicates the potential of vermicompost in fertilizing the studied substrate, which originally had only 1.60 mg.dm^{-3} P. The increase in phosphorus levels with the application of the organic compound reflects the importance of its use in building soil fertility, especially for tropical soils where phosphorus is the most limiting nutrient for biomass yield (Costa; Silva; Ribeiro, 2013). Furthermore, degraded soil tends to have a high fixation rate of this nutrient, limiting the increase in its levels (SILVA et al., 2018); thus, the application of organic matter minimizes phosphorus adsorption and enhances its use from future phosphate fertilizers (Ramos *et al.*, 2010).

For B and Cu, treatment FertConv+micro provided respective increases of 3320 and 80% in relation to Org 60, with superiority expected due to the application of the micronutrient solution at planting for that treatment. The dose of 20 t ha^{-1} led to increases of 160.34% for Zn and 211.52% for Mn compared to treatment FertConv+micro.

Treatments Org 20, Org 40 and Org 60 provided an increase in pH of, respectively, 103.28, 105.52 and 108.21% in relation to the soil with lime application alone. The increase in pH with the application of organic compounds was also reported by other authors such as Rout *et al.* (2012) and Malav, Khan and Gupta (2015).

The concentrations of Mg and K were increased, respectively, by 889.44 and 102.60% with the application of vermicompost, when comparing treatments Org 60 in relation to FertConv+micro. For Ca, there was an equivalence between Org 40, Org 60 and FertConv+micro. The increases in K, Ca and Mg levels provided by vermicompost treatments are most likely due to the richness of these nutrients in the residual matrix, such as that from shimeji mushroom production.

The data indicated a balance between nutrients such as Ca and Mg. This is an important impact of the applied doses of vermicompost, since excess Ca in relation to Mg in the soil solution can harm the absorption of the latter, as well as excess Mg and K also impair calcium absorption (Moore; Overstreet; Jacobson, 1961).

It was emphasized by Medeiros *et al.* (2008) that the interrelationship between calcium and magnesium in plant nutrition is related to their close chemical properties, such as ionic radius, valence, degree of hydration and mobility, causing competition for adsorption sites in the soil and absorption by the roots. Therefore, the imbalance in this relationship can significantly impair the adsorption of Ca, Mg and K (Arantes; Nogueira, 1986), with immediate impacts on plant development (Salvador; Carvalho; Lucchesi, 2011).

There were significant differences ($P<0.05$) by the Scott&Knott test between the treatments studied, for all morphogenic and productive variables in the first cut of 'Marandu' *Urochloa brizantha* (Table 2). For the second

Table 2. Morphogenic characteristics and dry matter accumulation of 'Marandu' *U. brizantha* in response to fertilization with both conventional fertilizers and vermicompost, cultivated in substrate remaining from mining activities in Poços de Caldas/MG.

Cuts	Variables	Fertilizers applied					
		Fert. Conv + micro	Fert. Conv	Lime	Org 20	Org 40	Org 60
1st cut	TAlC* (mm.day^{-1})	2.412c	2.739c	1.608c	3.79b	5.425a	6.160a
	TAlF* (mm.day^{-1})	2.297b	3.260b	1.692b	5.16a	5.725a	7.041a
	TApF* (leaf.day^{-1})	0.099b	0.099b	0.101b	0.11a	0.115a	0.108a
	Phylo* (days)	10.226a	10.194a	9.878a	8.72b	8.770b	9.143b
	NFV* (leaves)	4.250b	4.000b	4.000b	5.00a	4.250b	4.250b
	PD* (days)	43.143a	40.778b	39.514b	43.62a	37.103b	38.596b
	DPP* (tiller plant^{-1})	1.000b	1.000b	1.000b	2.25a	2.750a	3.000a
	MS1* (grass pot^{-1})	0.251c	0.314c	0.091c	0.561c	1.194b	2.290a
	TAlC* (mm day^{-1})	2.986b	1.806b	1.688b	3.819b	5.972a	5.972a
2nd cut	TAlF* (mm day^{-1})	18.056a	16.111a	3.331b	10.417b	21.528a	15.694a
	TApF* (leaf day^{-1})	0.153b	0.139b	0.139b	0.181a	0.181a	0.181a
	Phylo* (days)	6.686a	7.200a	7.200a	5.657b	5.657b	5.657b
	NFV^{NS} (leaves)	3.250a	3.250a	3.000a	3.750a	3.750a	3.750a
	PD^{NS} (days)	21.343a	23.400a	21.600a	20.829a	20.829a	20.829a
	DPP* (tiller plant^{-1})	3.500a	2.250b	1.250b	3.750a	4.250a	4.750a
	DM2 (grass pot^{-1})	5.318c	4.880c	2.453d	7.629b	10.248a	11.850a
	SDM (grass pot^{-1})	5.569d	5.194d	2.543e	8.190c	11.442b	14.140a
	RDM (grass pot^{-1})	1.560b	1.270b	0.700b	9.700a	8.668a	10.005a

*Means followed by the same letter do not differ by the Scott & Knott test at 0.05% probability. Fert.Conv= conventional NPK fertilization, Fert + micro= conventional NPK fertilization plus application of micronutrients B, Fe, Cu, Zn, Mn) with waste vermicompost from the production of shimeji mushrooms (Org 20= 20 t ha^{-1}; Org 40= 40 t ha^{-1} and Org 60= 60 t ha^{-1}.

cut, the treatments did not show significant differences for the number of living leaves and estimation of the ideal rest period (Table 2).

Plant growth results demonstrated some limitations in fertility of the substrate remaining from the mining in question. However, fertilization with the organic fertilizer obtained from the residue of the edible mushroom agroindustry through vermicomposting, demonstrated to be a promising alternative for improving cultivation conditions of 'Marandu' *Urochloa brizantha* in the area in question.

In the first cut, for the variables TAlF and TAlC, there was a clear distinction between the means obtained in organic fertilizer treatments and those obtained in treatments using exclusively chemical fertilization. For TAlF, doses 20, 40 and 60 t ha^{-1} were statistically equal and, for TAlC, doses 40 and 60 were statistically equal and higher than dose 20 (Table 2). The treatments using exclusively chemical fertilization (FertConv and Fertconv + micro) did not differ from each other or from the treatment that received only the application of lime (Lime). When comparing the application of organic compost at 20, 40 and 60 t ha^{-1} with treatment FertConv, there was an increase of 138.37, 198.06 and 224.90% in TAlC and 158.28, 175.61 and 215.95% in TAlF with the use of organic fertilizer.

In the second cut, for TAlF, the comparison of treatments conventional fertilization + micro and conventional fertilization to organic fertilization at 40 and 60 t ha^{-1} stands out. TAlF was higher by 173.33% and 154.67% in treatments Fert Conv+micro and Fert Conv, respectively, compared to Lime. This gain in development for the second cut can be assigned to the effect of cover fertilization applied to plants that received treatments Fert Conv+micro and Fert Conv. For TAlC, the highest compost doses differed from the other treatments, and the 353.90% superiority provided by the dose of 60 t ha^{-1} stands out in comparison to Lime.

The increase in stem and leaf elongation rates is largely responsible for the increase in DM in the two cuts studied. As TAlF increases, there is an increase in the proportion of leaves (Alexandrino *et al.*, 2004) and, consequently, a greater photosynthetically active leaf area, which allows for greater biomass accumulation (Lopes *et al.* 2014).

DM1 was statistically higher at 40 and 60 t ha^{-1}, with an increase of 380.33 and 729.29%, respectively, in relation to FertConv. There were no differences between the other treatments. For DM2, FertConv+micro and FertConv differed from Lime, with an increase of 216.84 and 198.97%, respectively. However, vermicompost doses were statistically lower. The dose of 20 t ha^{-1} differed from the others with a superiority of 143.44 and 156.33% in relation to FertConv+micro and FertConv, respectively. The dose of 60 t ha^{-1} led to an increase of 222.82 and 242.82% in DM in the second cut, respectively, compared to FertConv+micro and FertConv.

It was observed that cover fertilization in treatments with conventional fertilization, allowed a recovery in plant development in these treatments, with important impacts on dry matter production in the second cut, causing DM accumulation in this cycle to contribute with a greater share. expressive in SDM (sum cut 1 + cut 2). However, even without receiving chemical cover fertilization, organic fertilization positively maintained greater expansion dynamics of plant tissues, resulting in greater DM accumulation, also throughout the second growth cycle.

Treatments FertConv+micro and Fert.Conv did not differ for SDM, but both show statistical superiority for Cal. There were significant differences between vermicompost doses, and Org 60 was higher than the other treatments, with respective increases of 253.91 and 272.24% compared to the SDM provided by the FertConv+micro and Fert.Conv.

The superiority of plants fertilized with vermicompost can also be assigned to the greater development of the root system, since root production is the inducer for supporting shoot growth (Gurgel *et al.*, 2020). Plants fertilized with conventional fertilizer did not differ from the treatment with soil acidity correction (Lime), even though it is a treatment recommending doses appropriate to plant development. All vermicompost treatments provided significant increases compared to the others. The highest dose (60 t ha^{-1}) resulted in 641.34, 787.80 and 1,429.29% more RDM, compared to the respective treatments FertConv, FertConv+micro and Lime.

The use of vermicompost led to increases in morphogenic variables considered important for pasture management. The highest TApF, tiller population density and lowest phyllochron stand out in the two cuts studied (Table 2).

The increase in organic matter in the soil can modify soil water relations, provide balance in the metabolism of organic carbon by regulating functional relationships between soil microorganisms and, thus, contribute to a gradual increase in nutrient availability over time (Dhaliwal *et al.* 2019). Furthermore, its influence on cation exchange capacity interferes with the storage and replacement capacity of nutrients for the soil solution (Alleoni; Mello; Rocha, 2009). Humified forms improve the root environment, even in poorer soils, increasing nutrient absorption by plants (Ourives *et al.* 2010), a fact also highlighted by (Garcez; Monteiro, 2000) as a critical factor for persistence, especially of grasses in production systems. In this context, vermicompost caused greater recovery of soil fertility compared to conventional fertilizes, increasing the levels of K, P, Ca and Mg, in addition to higher pH and, consequently, greater shoot and root development.

Silva *et al.* (2018) evaluated fertilization and soil correction methods on the yield of *Urochloa decumbens* and soil chemical attributes, in an area degraded with chemical and organic fertilization with turkey litter. Fertilization with organic fertilizer resulted in increases in the contents of OM, P, Ca, Mg and V% in relation to soils subjected to conventional fertilization or just liming; pH, K and CEC contents were not affected by fertilization management.

Ourives *et al.* (2010) evaluated the effects of applying the organic compound Bokashi on the levels of macro-and micronutrients in the soil and leaves, in addition to the dry matterproduction of 'Marandu' *Urochloa brizantha*. The results demonstrated an increase in phosphorus levels by 4.32 times compared to the treatment without fertilization.

Giostri *et al.* (2014) evaluated the agricultural use of liquid residues from the enzyme industry (LWE) and its impact on soil fertility, growth and mineral nutrition of a native pasture set in an inceptisol. The use of LWE provided improvements in parameters such as acidity and P availability, indicating its action as a corrective agent and nutrient source. There was also an improvement in pasture quality through an increase in the levels of N, K and P in the plants, as well as greater yield.

Tiller population density was lower than expected. In the first cut, only plants fertilized with vermicompost showed tillering, with a maximum of 3 tillers per plant. After cutting, the plants showed higher tiller density in all treatments. However, treatment Lime did not differ from Fert.Conv. Conventional fertilization with the addition of micronutrients did not differ from plants that received vermicompost application.

Costa (2021) evaluated potassium fertilization levels under the morphogenic, structural and productive characteristics of 'Marandu' *Urochloa brizantha* in a sandy and acidic soil. The author found DPP varying from 35.50 to 56.50 tiller $plant^{-1}$. However, they concluded that potassium doses did not alter the morphogenic, structural and productive characteristics of the grass in the studied soil conditions.

Evaluating the tiller population density of 'Marandu' and 'Piatã' *Urochloa brizantha* subjected to fertilization with chicken litter and manure from confined cattle, Cruz *et al.* (2021), found, for Marandu grass, 688 tillers.m² and, for Piatã, 485 tillers.m². They did not find a significant effect of the fertilizers used for the analysis of tiller population density, but they did find a reduction in the cutting interval with the use of chicken litter.

The low DPP found in the research indicates the difficulties in establishing forage crops in the soil after bauxite mining. Moreover, this study was carried out during the coldest season of the year, which tends to cause lower DPP (Fagundes *et al.*, 2005).

The superiority of TAPF in treatments using vermicompost in relation to the others was due to the better root development of plants fertilized with vermicompost, which results in better shoot setting and development.

The reduction in phyllochron in vermicompost treatments is justified by the developmental responses of TAlF and TApF (Martuscello *et al.*, 2006) associated with stem elongation rate (Gomide; Gomide, 2000). Therefore, it can be inferred that plants fertilized with vermicompost will reach their maximum number of live leaves per tiller earlier, enabling more frequent harvests of the forage produced, in order to minimize losses due to leaf senescence, as the balance between elongation rates of the leaf blade and stems are decisive for the dynamics of the phyllochron (Skinner; Nelson, 1995).

In general, in the second cut, there was a reduction in the PD estimate in all treatments (Table 2). The application of vermicompost tends to reduce the adequate rest period of the pasture, that is, plants fertilized with vermicompost demonstrated a more pronounced TAlC, TAlF and TAPF and, consequently, a faster recovery period.

These results highlight the potential of using organic fertilizers originating from the mushroom industry in improving forage cultivation conditions in degraded soils. In this context, it is noteworthy that the successful establishment of 'Marandu' *Urochloa brizantha* in a post-mined area is largely compromised if fertilization management is designed only with liming and/or conventional chemical fertilization.

CONCLUSIONS

The results for improving soil fertility in a Cambisol area remaining from bauxite mining in Poços de Caldas/MG, based on conventional and organic fertilization using vermicompost from the shimeji mushroom industry, are notably different for the growth of 'Marandu' *Urochloa brizantha*.

Conventional fertilization does not result in increases in TAlC, TAlF, TApF, DPP and DM until the first 90 days of initial growth of 'Marandu' *Urochloa brizantha*.

The application of vermicompost from the shimeji mushroom industry leads to increases in K, P, Ca, Mg, Zn and pH in the soil, and the growth of 'Marandu' *Urochloa brizantha* reaches an increase of 729.29% in shoot dry matter accumulation until the first 90 days with a dose of 60 t ha^{-1}, when compared to the application of conventional fertilizer alone. Therefore, it is suggested that, for recommendation purposes, future research expand the studied doses.

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