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USE OF COMPOST BARN AND MINERAL FERTILIZER IN THE CULTIVATION OF SILAGE CORN

ABSTRACT – The Brazilian savannah soils naturally present high acidity and low nutrient availability, requiring correction and fertilization to obtain high yields. Although mineral fertilization improves soil fertility, organic fertilization can also improve its physical and biological properties. The aim was to evaluate the effects of replacing mineral fertilization with organic fertilization on soil fertility, nutrition, and production of corn (Zea mays L.) for silage. The experiment was carried out at Barreiro Alto farm (Sete Lagoas-MG) under a randomized block design, with four replications and nine treatments; combinations of mineral fertilization (200 to 400 kg ha^{-1} of 30-0-10) and organic fertilization (4 to 8 t ha^{-1} of compost barn) in topdress, in addition to the control (without fertilization). At the end of the cycle, the production, the attributes of soil fertility, the contents, and the accumulation of nutrients in the plants were evaluated. The variables were not significantly influenced by organic and mineral fertilization. On average, the shoot of corn accumulated 254, 33, 213, 53, 36, and 19 kg ha^{-1} of N, P, K, Ca, Mg, and S, in addition to 188, 63, 1263, 952, and 487 g ha^{-1} of B, Cu, Fe, Mn, and Zn, respectively. The average grain yield using mineral fertilizer was 6.7 t ha^{-1}, while 7.1 t ha^{-1} was obtained with applying organic fertilizer. The compost barn provides the same nutrition verified with mineral fertilization to corn grown in soil with good chemical fertility.

Keywords: Brazilian savanna, compost Barn, tropical soils, silage, *Zea mays.*

USO DE COMPOSTO DE ESTÁBULO E FERTILIZANTE MINERAL NO CULTIVO DO MILHO SILAGEM

RESUMO - Os solos do cerrado brasileiro apresentam naturalmente alta acidez e baixa disponibilidade de nutrientes, necessitando de correção e adubação para obtenção de altas produtividades. Embora a fertilização mineral melhore a fertilidade do solo, a fertilização orgânica também pode melhorar as suas propriedades físicas e biológicas. Objetivou-se avaliar os efeitos da substituição da adubação mineral pela adubação orgânica na fertilidade do solo, na nutrição e na produção de milho (*Zea mays* L.) para silagem. O experimento foi conduzido na Fazenda Barreiro Alto (Sete Lagoas-MG) em delineamento em blocos casualizados, com quatro repetições e nove tratamentos; combinações de adubação mineral (200 a 400 kg ha^{-1} de 30-0-10) e adubação orgânica (4 a 8 t ha^{-1} de composto de estábulo) em cobertura, além da testemunha (sem adubação). Ao final do ciclo foram avaliados a produção, os atributos de fertilidade do solo, os teores e o acúmulo de nutrientes nas plantas. As variáveis não foram influenciadas significativamente pela adubação orgânica e mineral. Em média, a parte aérea do milho acumulou 254, 33, 213, 53, 36 e 19 kg ha^{-1} de N, P, K, Ca, Mg e S, além de 188, 63, 1.263, 952, e 487 g ha^{-1} de B, Cu, Fe, Mn e Zn, respectivamente. A produtividade média de grãos com adubação mineral foi de 6,7 t ha^{-1}, enquanto com aplicação de adubo orgânico foi de 7,1 t ha^{-1}. O composto de estábulo proporciona a mesma nutrição verificada com a adubação mineral para o milho cultivado em solo com boa fertilidade química.

Palavras-chave: Cerrado brasileiro, composto de estábulo, solos tropicais, silagem, *Zea mays.*

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Corn (*Zea mays* L.) is an important tropical crop and one of the main cereals cultivated in Brazil with great economic relevance due to its use in the industry and as animal feed and human food (Pedrinho et al., 2010; Fiorini et al., 2020). The Brazilian Cerrado is a central corn producer region; nevertheless, soils in this region usually have low availability of nutrients, high acidity, and a high aluminum (Al) content, which is toxic to plants and jeopardizes crop yield (Bottega et al., 2013). Thus, corn cultivation becomes costly, as inputs account for 70% of total costs, and fertilizers contribute more than 30% (Locatelli et al., 2019). For a grain yield of 10.7 t ha^{-1} and total dry mass of 24 t ha^{-1}, the corn crop requires (kg ha^{-1}) 245 of N, 59 of P, 109 of K, 48 of Ca, 36 of Mg, and 17 of S (Silva et al., 2018) and these nutrients must be supplied during fertilization.

Thus, efficient production systems are needed to attain desirable crop yields, taking into account the actual conditions of the region (Queiroz et al., 2011), and soil fertilization is the action recommended for that purpose (Prior et al., 2015). The growing use of corn in the industry and as human food requires new techniques to increase crop yield (Fiorini et al., 2020) while reducing imported inputs, such as mineral fertilizers.

In this sense, organic fertilization has emerged as a strategic alternative to reduce crop production costs (Locatelli et al., 2019) and improve the soil's physical and biological properties (Hoffmann et al., 2001). Compost barn, produced from wood shavings (eucalyptus wood waste) and cow manure (Chichorro and Batista, 2017), has become an attractive organic fertilizer for dairy farmers since this by-product has the potential to be used to produce silage corn. In compost barn, aerobic decomposition is controlled by the action of microorganisms with the formation of humus with organic matter (OM) stabilization for subsequent use as a crop fertilizer (Cotta et al., 2015; Mota et al., 2019).

However, despite the beneficial effects of compost barn, its use should be contingent on each plant species under specific edaphoclimatic conditions. Therefore, this study aimed to evaluate the effects of using compost barn to replace (partially and totally) mineral fertilization for organic fertilization on soil fertility, plant nutrition, and grain yield of corn cultivated in the Cerrado soil in Minas Gerais State, Brazil.

Materials and methods

The experiment was conducted under field conditions at Fazenda Barreiro Alto, municipality of Sete Lagoas, Minas Gerais State, Brazil (19°28'4" S and 44°14'52" W) between November 2016 and February 2017. During the experimental period, monthly rainfall averaged from 130 to 370 mm, and the mean temperature was 23.4 ºC (Figure 1).

Before the experimental installation, we carried out the soil chemical and physical characterization (layer 0-20 cm) of the experimental site (Table 1), which had been managed in a minimal cultivation system. The site had a history of soil corrective practices, such as liming, gypsum, phosphate, and potash, but there needed to be more information on the doses applied. The experimental site has been cultivated with maize in monoculture since 2011, and before that, it was brachiaria pasture.

The experiment consisted of combinations

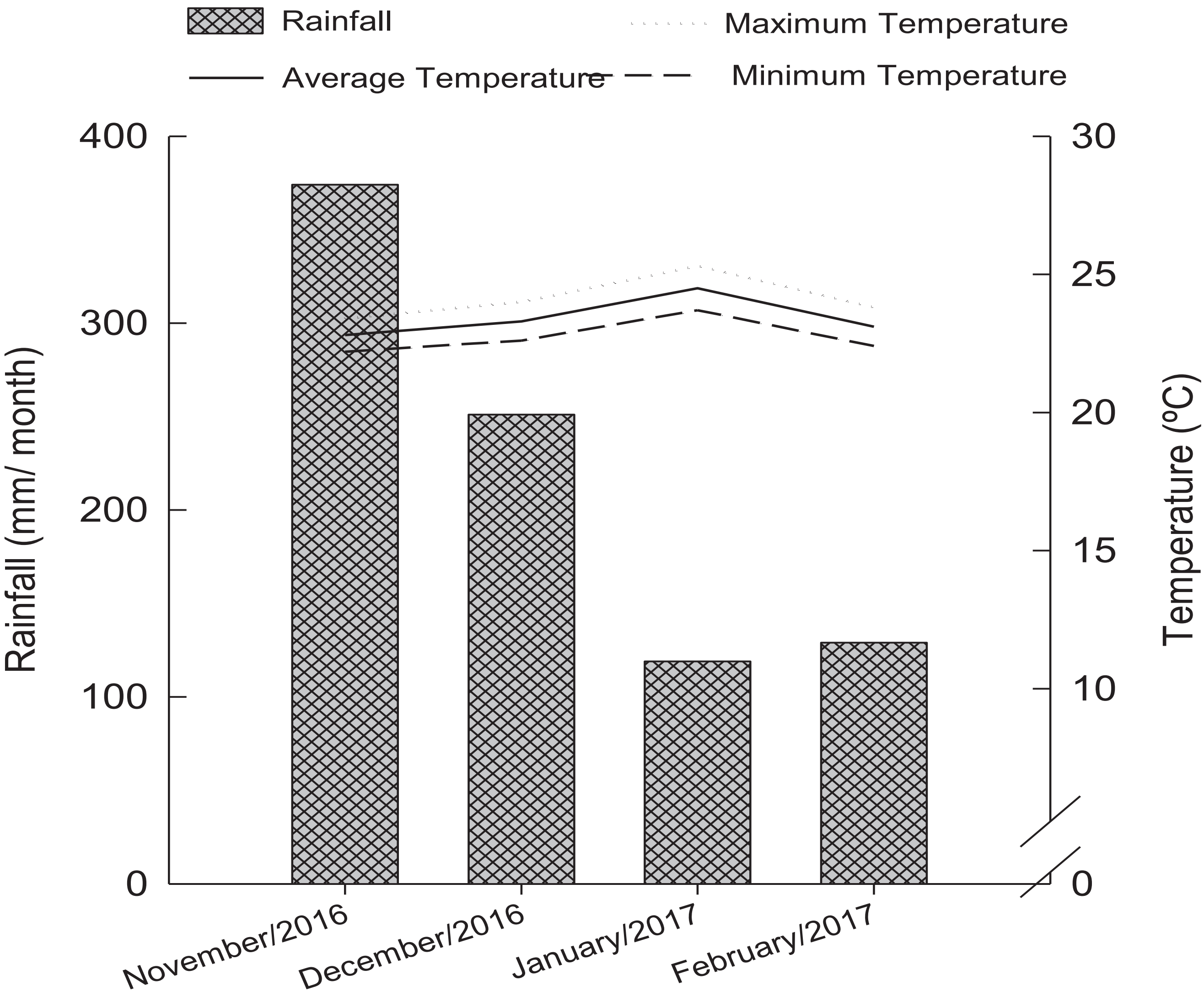

Figure 1. Monthly rainfall and monthly mean temperatures in the municipality of Sete Lagoas, Minas Gerais State, Brazil, during the experimental period. Source: Data from INMET Network.

Table 1. Soil chemical and physical attributes (0-20 cm) before the experimental installation.

pH	Al^{+3}	Ca^{+2}	Mg^{+2}	P	K^{+}	SOM	V	m
H_2O	——— $cmol_c\ dm^{-3}$ ———			—— $mg\ dm^{-3}$ ——		———%———		
5.5	0.0	4.6	1.0	26	135	2.0	51	0

Areia	Silte	Argila
——————	$g\ kg^{-1}$	——————
15.5	15.0	69.5

pH in water (ratio 1:2.5). Soil organic matter (SOM)= C x 1.724 – extraction by sodium dichromate and sulfuric acid. Al^{+3}, Ca^{+2}, and Mg^{+2} extraction by KCl (1 mol/L). P and K extraction by Mehlich-1. Saturation by bases (V %) and saturation by Al (m %).

of organic and mineral fertilization in cultivating corn (*Zea mays* L., hybrid RB 9004 VTPRO) used for silage. Nine treatments were evaluated in a randomized block design, with four replications, totaling 36 plots of 15 m² each (Figure 2) and a useful area of 6 m² (a stand with 70,000 plants ha^{-1} spaced at 0.5 m).

The treatments consisted of combinations of mineral (200 to 400 kg ha^{-1} of 30-0-10) and organic fertilization (4 to 8 t ha^{-1}) in topdressing applied on the soil surface close to the planting row, in addition to the control treatment (without fertilization). At planting, all treatments (except for the control) received 230 kg ha^{-1} of 09-44-00 (N-P_2O_5-K_2O) and 70 kg ha^{-1} of 00-00-60 (N-P_2O_5-K_2O). There was one treatment only with organic fertilization, with the application of 6 t ha^{-1} of compost barn both at planting and in topdressing (Table 2).

The compost barn consisted of manure and urine from dairy cows mixed with pieces of eucalyptus wood, and the mixture was turned over with a tractor twice a day for 12 months. After the tanning period, the chemical characterization of this organic fertilizer was carried out (Table 3).

After 90 days of planting, ten plants were harvested in each plot. The production variables were analyzed: number of rows per ear (NRPE), number of grains per row (NGPR), number of grains per ear (NGPE), dry mass of one hundred grains (DMHG in g), grains mass per ear (GMPE in g), shoot dry mass (SDM in t ha^{-1}), and grain yield- GY (PROD in t ha^{-1}). After harvesting the aerial part (stem, leaves, and ears) in each plot, three of the ten plants were oven-dried (70 ºC) for 96 h, ground, and the samples were sent to the laboratory to determine the concentrations of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn. The values of nutrient concentrations and SDM were used to estimate the nutrient accumulation (extraction) in the shoots of corn plants.

Soil samples (0-20 cm) were also collected during corn harvest season using a Dutch auger. A composite sample of soil (constituted of five simple samples) of each plot was sent to the laboratory to determine soil fertility attributes: pH in water, soil organic matter (SOM) (Walkley-Black Method), Al^{+3}, Ca^{+2}, and Mg^{+2} extracted with KCl (1 mol/L), P and K extraction by Mehlich-1 and potential

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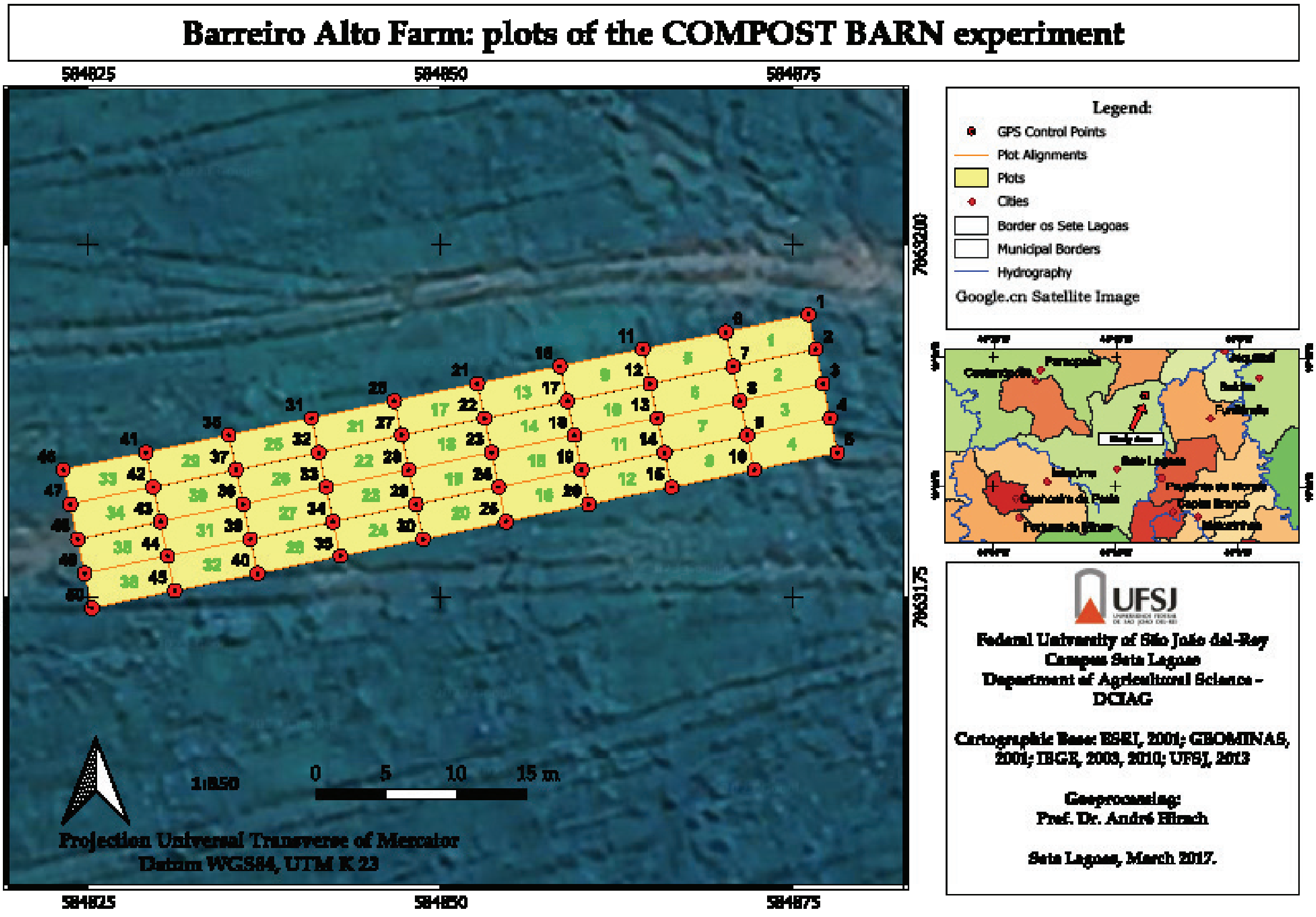

Figure 2. Overview of the experimental plots (36) located at Fazenda Barreiro Alto, Sete Lagoas, Minas Gerais State, Brazil.

acidity (H + Al) with the buffer solution SMP pH 7.5. The soil base saturation (V %) was also estimated using the results.

All results were submitted to analysis of variance (ANOVA) ($p < 0.05$) and the mean comparison test (Tukey) using the Sisvar program (Ferreira, 2011).

Results and Discussion

The study site has a history of lower crop yield than other agricultural regions in Brazil because of the need for ideal conditions of altitude and rainfall for corn crops (Padilha et al., 2015). Nevertheless, during the experimental period, monthly temperature averages of 23 ºC and rainfall of 218 mm (Figure 1) were observed, favorable climate conditions for corn crop development (Fancelli, 2017).

The treatments did not significantly influence corn production variables ($p > 0.05$) (Table 4), possibly due to favorable soil (Table 1)

Table 2. Description of the Mineral (Min.) and Organic (Org.) sources and the doses applied at planting and in topdressing (V4 stage) in corn cultivation in each treatment.

	Source		**Dose**	
Treatment	**Planting**	**Topdressing**	**Planting**	**Topdressing**
			kg ha^{-1}	
1	-	-	0	0
2	Mineral	Mineral	230^1+70^2	400^3
3	Mineral	Organic 1	230^1+70^2	4000
4	Mineral	Organic 2	230^1+70^2	6000
5	Mineral	Organic 3	230^1+70^2	8000
6	Mineral	½ Min.+Org. 1	230^1+70^2	200^3+4000
7	Mineral	½ Min.+Org. 2	230^1+70^2	200^3+6000
8	Mineral	½ Min.+Org. 3	230^1+70^2	200^3+8000
9	Organic 2	Organic 2	6000	6000

Organic fertilization (Org.) 1, 2, and 3 refer to the application of compost barn at doses of 4,000, 6,000, and 8,000 kg ha^{-1}, respectively. $^{1,\ 2 \text{ and } 3}$ Sources 09-44-00, 00-00-60 and 30-00-10 (N-P_2O_5-K_2O), respectively.

Table 3. Characterization of the compost barn used in the experiment.

pH	CO	N	P	K	Ca	Mg	S	H	C/N	CEC
	%									cmol$_c$ dm^{-3}
9.2	16.7	1.0	2.5	2.5	1.5	0.7	0.3	21.5	16	64.5

pH in $CaCl_2$. CO- organic carbon. H- Humidity (65 ºC). CEC- cation exchange capacity.

and climate (Figure 1) conditions prevailing in the study site. Thus, grain yield did not increase significantly regardless of the type of fertilizer used (mineral or organic), with an average of 6.9 t ha^{-1} for all treatments.

Rodrigues et al. (2012) evaluated corn crops in a dystroferric Red Oxisol with high availability of P, K, Ca, and Mg, and they also verified a negligible effect on the dry mass of one hundred grains (DMHG) when cultivated in a no-tillage system, with mineral and organic fertilization. However, the same authors reported a significant effect on grain yield (GY) with an average of 10.3 t ha^{-1} of grains in the treatment with the application of 900 kg ha^{-1} of pelleted earthworm humus.

Padilha et al. (2015) observed that mineral fertilization did not influence NGPR in the region of Sete Lagoas, Minas Gerais State, Brazil, in corn cultivated in constructed fertility soil with adequate nutrient availability. However, Gonçalves Jr. et al. (2008) found a significant effect on NGPE and GY of corn cultivated with mineral fertilizer (NPK) in the soil with low P and

Table 4. Corn production variables submitted to organic and mineral fertilizations (treatments).

	Treatment										
	1	2	3	4	5	6	7	8	9	Mean	CV(%)
NRPE^{ns}	16.8	17.9	17.7	17.0	17.7	18.3	17.7	18.4	17.5	17.7	4.75
NGPR^{ns}	27.9	28.1	28.5	27.2	27.4	28.2	27.4	28.8	29.3	28.1	7.75
NGPE^{ns}	471.6	503.1	503.0	463.8	485.6	516.6	486.8	532.1	512.1	497.2	9.74
DMHG^{ns}	20.2	19.0	21.1	19.5	19.2	19.5	19.9	20.1	19.7	19.8	6.19
GMPE^{ns}	95.5	95.5	106.6	90.7	94.0	101.0	96.9	106.9	100.9	98.6	14.33
SDM^{ns}	20.4	23.4	25.5	21.3	22.8	24.0	24.2	25.3	26.8	23.7	13.16
GY^{ns}	6.7	6.7	7.5	6.3	6.6	7.1	6.8	7.5	7.1a	6.9	14.35

NRPE- number of rows per ear, NGPR- number of grains per row, NGPE- number of grains per ear, DMHG- dry mass of one hundred grains (g), GMPE- grains mass per ear (g), SDM- shoot dry mass (t ha^{-1}), GY- grain yield (PROD, t ha^{-1}). ns represents non-significant at 5 % by the F-test (p>0.05). CV= coefficient of variation.

medium K availability, conditions that increase the response potential for these variables.

Contrasting the results of the present study, Rodrigues et al. (2012) found greater NRPE (18.1 rows/ear) and greater NGPE (669 grains/ear) in treatment with mineral fertilization (225 kg ha^{-1}) + pelleted earthworm humus (225 kg ha^{-1}). Gazola et al. (2014) showed that increasing the dose of mineral N fertilizer applied in topdressing up to 180 kg ha^{-1} also increased NGPR up to 22 grains/row. Novakowiski et al. (2013) also found a significant effect for NGPR (37 grains/row) with an increasing dose of poultry litter up to 8 t ha^{-1}.

The supply of nutrients to plants using organic residues, compared to mineral fertilizers, presents distinct results. Andreola et al. (2000) verified a negligible response to organic and mineral fertilization for grain yield of maize cultivated with winter cover. Conversely, Costa et al. (2011) observed higher corn yield (7.3 t ha^{-1}) in the summer season due to mineral fertilization when compared to organic fertilization. Mahmood et al. (2017) found an increase in corn yield with the application of mineral fertilizer in combination with organic fertilizer. The continuous use of organic and mineral fertilizers in maize crops has shown a significant increase in grain yield (Novakowiski et al., 2013).

In silage corn, the dry mass production capacity should be considered. Thus, although different fertilizations had no influence, SDM presented values close to expected levels for modern maize cultivars, between 21 and 24 t

ha^{-1}, as shown by Bender et al. (2013) and Silva et al. (2018). Bacca et al. (2020) reported an increase (30 %) in SDM production in maize fertilized with pig manure compared to plants cultivated with mineral fertilization in soil with 16 applications of organic fertilizers in no-tillage.

Soil fertility attributes also showed negligible influence ($p>0.05$) of different sources and doses of fertilizers (Table 5), possibly due to the adequate initial soil fertility before the experimental installation (Table 1). In the present study, soil fertility attributes (Table 5) were considered adequate to maintain an environment with high productive potential for corn cultivation in the Brazilian Cerrado (Resende et al., 2012), with emphasis on the average saturation by bases-V (60 %). Therefore, under these conditions, compost barn supplies nutrients to corn similarly to mineral fertilizers, indicating the possibility of using the organic fertilizer mainly when it is produced on the farm.

The treatments displayed an average soil pH 5.7, remaining close to the value before the experimental installation (Table 1). The acidity levels in the cultivated soil were considered average, according to Alvarez et al. (1999). However, despite a pH below 6.0, the Ca and Mg levels remained reasonable and excellent. Based on the evaluation of more than 78,000 soil samples by Resende et al. (2016), the constructed fertility soils of the Brazilian Cerrado are considered to have acidity controlled, low exchangeable Al content, and a base saturation between 36 and 60 %, similar to the values in the present study. The absence of exchangeable Al in the soil was significant both before and after corn cultivation (Tables 1 and 5), which may be attributed to the management of the area in a minimum cultivation system in addition to acidity correction by liming. Conservationist cropping systems promote a more excellent supply of plant residues on the soil surface, and when decomposed, these residues release organic acids that complex Al, decreasing its activity and its toxic effect on plants (Anghinoni, 2007), which is vital to crops in the Brazilian Cerrado. Furthermore, the absorption and exportation of cations by the maize also results in the removal of basic cations and replacement by Al^{3+} in the soil (Malvetti et al., 2017).

Mahmood et al. (2017) reported an increase in the total contents of organic C, N, P, and K in the soil when mineral fertilizers were applied alone or combined with organic fertilizers. These results are different from the observations in the present study, as both types of fertilization did not significantly influence the soil chemical parameters. Regarding the initial fertility of the soil (Table 1), higher levels of P and K occurred in the soil after corn cultivation with the use of compost barn, mainly with organic fertilization (6 t ha^{-1}) at sowing and in topdressing (Treatment 9), raising the K content in the soil to 263 mg dm^{-3}, a value considered high for clayey soils (Alvarez et al., 1999).

After maize cultivation, the P content in the soil also increased significantly, mainly with mineral fertilization at sowing and in topdressing (Treatment 2), rising from 26 mg dm^{-3} to 56 mg dm^{-3}, considered high for this soil type (Alvarez et al., 1999). Mahdy (2009) reported that the available P content in the soil only increased significantly using mineral fertilizers without adding organic compost. However, for the available K content in the soil, the same author observed a significant increase when the mineral

Table 5. Soil fertility attributes (0-20 cm) after maize cultivation submitted to organic and mineral fertilization (treatments).

	Treatment										
	1	2	3	4	5	6	7	8	9	Mean	CV (%)
pH^{ns}	5.8	6.0	5.6	5.8	5.6	5.6	5.6	5.6	6.0	5.7	5.87
SOM^{ns}	3.2	3.3	3.1	3.2	3.1	3.2	3.1	3.1	3.0	3.1	5.03
$Al^{+3\ ns}$	0	0	0	0	0	0	0	0	0	0	0
$Ca^{+\ 2\ ns}$	4.5	3.5	4.0	4.3	4.0	4.2	4.2	4.5	4.7	4.2	17.68
$Mg^{+2\ ns}$	1.2	1.1	1.0	1.3	1.1	1.1	1.1	1.3	1.4	1.2	19.36
$K^{+\ ns}$	213.1	234.7	202.1	244.4	196.2	200.9	195.7	215.9	262.8	218.4	14.13
$P^{\ ns}$	22.2	55.9	34.3	36.6	33.0	37.2	38.1	40.7	38.5	37.4	52.53
$V^{\ ns}$	62.6	59.3	55.9	65.0	56.3	59.6	56.2	62.8	65.1	60.3	14.43

pH in water (ratio 1:2.5). Soil organic matter (SOM, %)= C x 1.724 – Method Walkley-Black. Al^{+3}, Ca^{+2}, and Mg^{+2} ($cmol_c/dm^3$) extraction by KCl (1 mol/L). P and K (mg/dm^3) extraction by Mehlich-1. Saturation by base (V %). ns represents non-significant at 5 % by the F-test (p>0.05). CV= coefficient of variation.

fertilizer was applied in combination with the organic one.

Ayeni and Adejumo (2012) observed that soil attributes (pH, SOM, N, P, and K) increased with organic, mineral, and organomineral fertilizers after maize cultivation. Mantovani et al. (2015), however, verified that the SOM content was not influenced by the application of whey (16.2 g L^{-1} of organic carbon- OC) in corn cultivation. In the present study, the SOM content increased after maize cultivation, moving from 2.0 % to an average of 3.1 %. Nevertheless, there was no significant effect of treatments on the SOM levels; therefore, treatments with compost barn application (16.7 % OC) did not increase the SOM levels when compared to treatments with mineral fertilization (Table 5).

Kulhánek et al. (2014) observed a lower availability of Ca contents in the soil with the use of mineral fertilizer (NPK) compared to the application of sewage sludge. As for the Mg content in the soil, the same authors reported an increase with barnyard manure, compared to mineral fertilizer. According to Zhang et al. (2015), when NPK is applied in combination with organic fertilizer (barnyard or poultry manure), nutrient availability increases in the soil.

Similar to soil fertility, organic and mineral fertilization did not influence the macronutrient concentrations in the shoots of corn plants (p>0.05) (Table 6). We observed average concentrations (g kg^{-1}) of 10.7, 1.4, 8.9, 2.2, 1.5, and 0.8 for N, P, K, Ca, Mg, and S, respectively. Compared with the ranges of nutritional sufficiency for corn (Martinez et al., 1999), these nutrient concentrations are below adequate levels reported in the literature. However, in the present study, the nutrient concentrations were determined in the entire aerial part (stem, leaves, and ears) of corn plants, and the sampling was carried out at the end of the cultivation cycle (90 days). To diagnose the nutritional crop status, Martinez et al. (1999) considered the evaluation 60 days after planting (close to full flowering) by sampling the basal third of the fourth leaf without the midrib. Moreover, regardless of the discrepancy in nutrient concentration values (Table 6) with critical levels reported in the literature, corn production was satisfactory (Table 4) due to the proper soil fertility (Tables 1 and 5) managed in a system of minimal cultivation.

Mahdy (2009) observed a higher N concentration (26.51 g kg^{-1}) in the shoots of corn plants when mineral fertilizers were applied in combination with the organic fertilizer (soil + 25 % NPK + 75 % compost). However, Campos et al. (2013) also observed a negligible response in the N concentration in the shoots of corn plants treated with organic fertilization (pig manure). Contrasting, the P concentration was higher (28.01 g kg^{-1}) in the same treatment. According Mahdy (2009), the K concentration (46.72 g kg^{-1}) showed an increase in corn grains in treatments with a combination of organic and mineral fertilization (75 % mineral + 25 % organic), up to 11.2 g kg^{-1} higher than treatment with only mineral fertilizer and 13.3 g kg^{-1} higher than treatment with only organic fertilizer.

Studies have reported a significant increase in the macronutrient concentrations in

Table 6. Macro (g kg^{-1}) and micronutrient (mg kg^{-1}) concentrations in the shoots of corn plants 90 days after planting and submitted to organic and mineral fertilization (treatments).

	Treatment										
	1	2	3	4	5	6	7	8	9	Mean	CV(%)
N^{ns}	10.3	12.4	10.2	10.6	10.7	10.6	11.0	10.0	10.3	10.7	12.11
P^{ns}	1.4	1.3	1.5	1.5	1.3	1.3	1.3	1.4	1.5	1.4	22.55
K^{ns}	8.3	9.5	9.1	8.8	8.6	8.6	9.1	9.3	9.0	8.9	9.52
Ca^{ns}	2.1	2.7	2.0	2.2	2.1	1.8	2.2	2.5	2.5	2.2	24.53
Mg^{ns}	1.5	1.8	1.5	1.5	1.3	1.1	1.5	1.6	1.6	1.5	29.23
S^{ns}	0.8	0.9	0.8	0.8	0.8	0.8	0.80	0.90	0.8	0.8	19.74
B^{ns}	6.1	10.3	8.0	9.1	8.2	7.4	6.7	7.0	7.9	7.9	25.23
Cu^{ns}	2.6	3.3	2.2	2.2	2.3	2.3	2.9	3.0	2.9	2.6	25.48
Fe^{ns}	51.8	53.7	58.4	47.7	55.6	50.3	48.0	50.4	59.1	52.8	24.38
Mn^{ns}	40.6	42.3	40.2	36.3	38.5	35.1	48.1	38.4	38.7	39.8	33.23
Zn^{ns}	23.0	20.6	21.3	21.2	18.7	16.2	18.6	20.7	23.6	20.4	15.90

ns: non-significant at 5 % by the F-test (p>0.05). CV: coefficient of variation.

the shoots of corn plants using organic fertilizer. Campos et al. (2013) reported significant increases in the Ca and Mg concentrations in the shoots of corn plants with N doses in combination with pig manure. The S concentration in the shoots of corn plants increased significantly under fertilization with sewage sludge. Also, the N-S ratio presented values within the ideal range for the crop (Gondek, 2010).

The concentrations of micronutrients in the shoots of corn plants were not significantly influenced by the treatments (Table 6). Average concentrations of B, Cu, Fe, Mn, and Zn were 7.9, 2.6, 52.8, 39.8, and 20.4 mg kg^{-1}, respectively.

Campos et al. (2013) observed higher concentrations of B, Cu, Fe, Mn, and Zn in corn plant shoots with the combined application of mineral N and organic fertilization (pig manure), different from the results of the present study. For Zhang et al. (2015), applying NPK individually in the soil can lead to plant micronutrient deficiency. Conversely, these authors verified that the application of organic fertilizer in the soil increased the concentrations of micronutrients in corn when compared to the use of mineral fertilizers.

The use of organic or mineral fertilizers did not significantly influence the extraction (total accumulation) of nutrients in the shoots of corn plants ($p> 0.05$) (Table 7).

Silva et al. (2018) reported similar extraction levels of almost all macronutrients except for P and K, which were higher in the present study. The authors observed that the use of mineral fertilization alone in constructed fertility soil generated mean extraction values for silage corn at the R5 stage of 237, 26, 92 57, 41, and 18 kg ha^{-1} of N, P, K, Ca, Mg, and S, respectively. The contribution of K promoted by the organic fertilizer is rather expressive since K accumulation in the treatment using only organic fertilization reached 243 kg ha^{-1} of K, much higher than that of Silva et al. (2018). Gutiérrez et al. (2018) reported greater extraction of micronutrients, except for Mn, by corn plants under mineral fertilization than the extraction levels observed in the present study. The authors reported extraction (g ha^{-1}) of 70, 1,855, 496, and 393 for Cu, Fe, Mn, and Zn, respectively, indicating that corn under mineral fertilization in a constructed fertility soil, accumulated roughly 600 g ha^{-1} more Fe than the general average observed in the present study. On the other hand, this difference decreases to 265 g ha^{-1} Fe when compared with organic fertilizer alone (Treatment 9) (Table 7).

In general, the treatment using only organic fertilizer provided a trend towards higher values of accumulation of all nutrients in the corn plant shoots, in absolute terms (Table 7). However, there was no significant statistical difference between using mineral or organic fertilizer in the cultivation conditions evaluated. This result indicates that using compost barn as a fertilizer is a viable alternative in soil with adequate availability of nutrients (Tables 1 and 5), reducing costs without compromising crop yield while providing an adequate disposal of animal waste produced on dairy farms.

Conclusions

The use of organic or mineral fertilizers does not influence the crop yield of maize cultivated in soil with adequate chemical fertility. Thus, compost barn can provide the same

Table 7. Total extraction of macronutrients (kg ha^{-1}) and micronutrients (g ha^{-1}) in the shoots of corn plants 90 days after planting was submitted to organic and mineral fertilization (treatments).

	Treatment										
	1	2	3	4	5	6	7	8	9	Mean	CV(%)
N^{ns}	207	289	260	228	244	257	266	257	276	254	20.87
P^{ns}	28	31	38	31	30	30	32	36	40	33	29.48
K^{ns}	169	220	232	189	197	208	222	235	243	213	15.96
Ca^{ns}	43	63	51	47	48	43	54	64	65	53	29.49
Mg^{ns}	30	42	38	32	31	27	37	41	43	36	36.97
S^{ns}	16	20	21	17	18	19	19	22	22	19	28.87
B^{ns}	128	243	206	198	184	178	166	179	209	188	31.06
Cu^{ns}	54	77	56	49	54	54	70	77	78	63	31.73
Fe^{ns}	1059	1258	1481	1023	1251	1230	1195	1283	1590	1263	30.19
Mn^{ns}	848	994	999	808	887	851	1151	983	1050	952	36.51
Zn^{ns}	467	483	543	449	430	395	456	533	629	487	22.35

ns: non-significant at 5 % by the F-test (p>0.05). CV: coefficient of variation.

nutritional level to corn as mineral fertilizers offer when applied to soil with desirable initial fertility.

Corn production using only mineral fertilization is 23.4 t ha^{-1} of SDM and 6.7 t ha^{-1} of grain yield, while only organic fertilization yielded SDM of 26.8 t ha^{-1} and grain yield of 7.1 t ha^{-1}.

The average nutrient extraction at 90 days after planting is 254, 33, 213, 53, 36, and 19 kg ha^{-1} for N, P, K, Ca, Mg, and S, respectively, and 188, 63, 1263, 952, and 487 g ha^{-1} for B, Cu, Fe, Mn, and Zn, respectively.

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