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Effect of organo-mineral fertilizer and poultry litter waste on sugarcane yield and some plant and soil chemical properties

Lucélia Alves Ramos*, Regina Maria Quintão Lana, Gaspar Henrique Korndörfer and Adriane de Andrade Silva

Universidade Federal de Uberlândia – Avenida Amazonas s/n – bloco 4C – sala 111 – Bairro Umuarama – CEP: 38400-302 - Uberlândia-MG – Brazil.

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Application of organic wastes in sugarcane (*Saccharum officinarum)* is an alternative possibly replacing or supplementing mineral fertilizers. This study aimed to evaluate the effects of poultry litter, organo-mineral fertilizer and mineral fertilizer on soil chemical properties, yield and plant content of macronutrients in sugarcane. The experiment was conducted at the Jalles Machado Mill in Goianésia-GO, from July 2009 to April 2010, as randomized complete blocks design (RCBD). The mineral fertilizer was applied at the following doses: 66; 120 and 82 kg ha^{-1} of N, P_2O_5 and K_2O, respectively; poultry litter and organ-mineral fertilizer were applied at doses of 3.0, 6.0 and 9.0 t ha^{-1}, in addition to the control (no fertilization). The following variables were analyzed: organic matter, macronutrients in soil and leaves and sugarcane yield. The productivity of sugarcane was higher with poultry litter and organo-mineral fertilizer in relation to mineral fertilization, and organo-mineral fertilization was superior to poultry litter. There was an increase in soil phosphorus levels in soil by fertilizing with poultry litter and organo-mineral fertilizer. Levels of soil K, Ca, Mg contents, acidity and soil organic matter, and levels of macronutrients in sugarcane did not change by the application of poultry litter and organo-mineral fertilizer comparing with mineral fertilizer. The use of organo-mineral fertilizer, as well as pure poultry litter is recommended.

Key words: Wastes, biofertilizers, compost.

INTRODUCTION

The crop yield of sugarcane is governed by several factors intrinsic to the cultivar, climate, soil and management practices of the culture. However, all these factors interact with each other and it is up to professionals working with this culture to integrate the effects of these factors to achieve greater economic productivity (Gama 2007).

Fertilizers and pesticides have been frequent targets of criticism because of their elevated costs involved in production of sugarcane, or in other cultures. The high prices caused by the fact that raw materials for the production of fertilizers and pesticides are imported.

*Corresponding author. E-mail: luceliaar@hotmail.com Tel: (34) 99168-3428.

Table 1. Soil chemical characterization in two depths Jalles Machado Mill, 2009.

Profile (cm)	pH	P	K^+	Al^{3+}	Ca^{2+}	Mg^{2+}	SB	T	V	m	M.O.
		mg dm^{-3}	---------------------------- $cmol_c\ dm^{-3}$ ----------------------------------						---------- % ----------		g kg^{-1}
00-25	4.9	12.5	0.04	0.02	1.9	0.7	2.64	5.5	47.7	0.7	28.5
25-50	5.2	2.9	0.05	0.00	2.8	0.7	3.55	6.2	57.4	0.0	29.4

pH – $CaCl_2$; P e K - Extrator Mehlich (HCl 0.05 mol L^- + H_2SO_4 0.025 mol L^-); Ca, Mg e Al - Extrator KCl 1 mol L^{-1};; T - CTC potencial (a pH 7.0);V - saturação por bases; m - saturação por alumínio (Embrapa, 2009). MO – método colorimétrico.

About 60% of nitrogen, 50% of phosphorus and 90% of potassium used in manufacturing of fertilizers in Brazil are imported from other countries (Vieira 2009).

Proper nutrition of sugarcane is demonstrably recognized as the main cause of increments of crop yield. While mineral fertilization is widely used to supply nutrients and represent a large part of production costs, seeking alternatives benefitting sugarcane and ethanol producers by reducing their costs represents a major contribution of research institutions.

With the growth of poultry production in our country supply of animal wastes such as poultry litter has been increased. Thus, their application of organic wastes is being considered as a promising and cost-effective method to confront this challenge. These wastes have been demonstrated to provide plant nutrients and organic matter to the soil required for crop production (Roy et al., 2015). Besides that their use in agriculture as an alternative source of nutrients is important both to properly dispose of these products in order to avoid environmental pollution and to reduce high costs of synthetic fertilizers (Portugal et al., 2009).

Poultry litter is a mixture of substrate, feces, feathers and feed scraps used in bedding of broiler sheds (Chen et al., 2013). Chicken litter is usually recycled as an organic fertilizer or soil amendment for direct application to agricultural land (Enticknap et al., 2006). This residue can be used to improve physical and chemical properties of soil and the productivity of some cultures (Silva et al., 2009).

Besides animal waste, various materials are obtained from the production of sugar and ethanol as boiler ash and filter-cake. Knowledge of their composition and possible uses in crops allows their application in the form of organo-mineral fertilizers, which can provide a greater environmental control, considerable savings in fertilizer costs (Santiago and Rosseto, 2009) and significant results in productivity of sugarcane.

An alternative for the use of poultry litter and by-products of sugar and ethanol production is composting of these residues together with mineral fertilizers to improve their chemical and physical properties (Chen and Jiang, 2014). Thus, the use of waste, both of animal and industrial origin, as nutrient sources in sugarcane production is of paramount importance, because, in addition to contributing to environmental sustainability by no longer having a status of polluters, they become an alternative in soil fertilization, decreasing the use of mineral fertilizers.

Therefore, our objective was to evaluate productivity, content of macronutrients in sugarcane leaves and chemical characteristics of soil as a result of application of poultry litter and organo-mineral fertilizer in relation to mineral fertilizer in soil.

MATERIALS AND METHODS

The experiment was conducted at the Jalles Machado Mill, in Goianésia- GO, from July 2009 to April 2010, using the IAC91-1099 sugarcane variety. The soil is classified as dystrophic red-yellow latosol, clay texture (589 g kg^{-1} of clay) with the following chemical properties (Table 1).

The experiment was conducted as a randomized complete blocks design with 2 x 3 +1 + 1 strata (poultry litter and organo-mineral fertilizer x three doses + an additional treatment (mineral fertilizer) + a control treatment), eight treatments and four replications, totaling 32 plots. experimental plots had 5 rows of sugarcane spaced 1.5 m apart, with 10 m in length, with a total area of 75 m^2. The treatments were: poultry litter and organo-mineral fertilizer, whose chemical properties are shown in Table 2, at doses of 3.0, 6.0 and 9.0 t ha^{-1}; mineral fertilization (additional treatment) at doses of 66 kg ha^{-1} of N (ammonium nitrate), 120 kg ha^{-1} of P_2O_5 (monoammonium phosphate) and 82 kg ha^{-1} of K_2O (potassium chloride); as well as a control without fertilization.

The organo-mineral fertilizer had been prepared for a period of 41 days and received the following proportions of materials: 55% of filter cake, 17.8% of boiler ash, 17.8% of poultry litter and 7.1% of agricultural gypsum. At the time of application on the field 1.1% of ammonium nitrate and 1.2% of potassium chloride were added to this fertilizer.

Planting was carried out in July 2009, after five years of cane cultivation, from 2003 to 2008 and application of 1 t ha-1 of lime and 10 t ha-1 of filter cake, made in 2005. After sugarcane harvesting, soil received application of lime, gypsum and itafós phosphate, and then soybean was planted. After soybean harvesting, in 2009, cane was planted.

Leaf samples were collected 150 days after treatment application using a methodology described by Korndörfer and Ramos (2008) to analyze macronutrients (N, P, K, Ca Mg and S). Sugarcane was harvested 210 days after treatment application, weighed to obtain stalk yield and soil samples were collected between rows 0-20 and 20-40 cm depth. Analyses of plant macronutrients, soil chemical properties (pH, Ca, Mg, K and P) and organic matter of soil were carried out in the Soil Analysis Laboratory (LABAS) of the Institute of Agricultural Sciences, Federal University of Uberlândia, following the methodology described by Embrapa (2009).

The data were analyzed and means were compared by Dunnet test (Assis 2011). The means were compared using Tukey test and

Table 2. Chemical properties of poultry litter and organo-mineral fertilizers.

Determinations	Poultry litter		Organo-mineral fertilizer	
	Dry base (110ºC)	Natural humidity	Dry base (110ºC)	Natural humidity
pH in $CaCl_2$ (0.01 mol L^{-1})	----	8.2	----	8.20
Total organic matter (%)	61.80	48.22	59.90	32.20
Organic Carbon (%)	23.69	18.49	23.10	12.46
Relation C/N (C total/N total)	12/1	12/1	18/1	18/1
Relation C/N (C org./N total.)	8/1	8/1	13/1	13/1
Total humidity (%)	----	21.98	----	46.08
Total nitrogen (%)	2.81	2.19	1.81	0.98
Total phosphorus (%)	3.72	2.90	3.11	1.68
Total potassium (%)	3.64	2.84	3.98	2.15
Total calcium (%)	4.38	3.42	5.50	2.97
Total magnesium (%)	0.73	0.57	0.65	0.35
Total sulfur (%)	0.63	0.49	3.41	1.84
Total boron (mg kg^{-1})	55	43	25	13
Copper (mg kg^{-1})	394	307	270	146
Iron (mg kg^{-1})	11092	8654	6521	3516
Total manganese (mg kg^{-1})	783	611	826	445
Zinc (mg kg^{-1})	611	477	460	248
Total sodium (mg kg^{-1})	5146	4015	5075	2737

CTC: Rodella. A.A.; Alcarde, J.C.; N –[N Total] = sulfuric digestion; P, K, Ca, Mg, S, Cu, Fe, Mn, Zn = Nitro perchloric digestion; B = Colorimetric Azomethine -H.

a statistical program Assistat at 5% significance level (Assis 2011).

RESULTS AND DISCUSSION

Stalk yield

Stalk yield, was significantly higher ($p < 0.05$) when organo-mineral fertilizer was used than poultry litter (Table 3). The highest stalk yield (13.0 t ha^{-1}) was obtained with the application of 9 t ha^{-1} of organo-mineral fertilizer, and mineral fertilizers (control) (23.0 t ha^{-1}).

Although no significant difference was observed ($p > 0.05$), the treatments with 3 and 6 t ha^{-1} of poultry litter influenced positively sugarcane productivity, being superior to the control treatment and mineral fertilization, producing 13.0 and 10.9 t ha^{-1} of stalks more, respectively (Table 3).

Higher yield can be expected with the application of poultry litter and organo-mineral fertilizer in the similar areas in subsequent years, since the residual effect and increased mineralization of these products can contribute to the improvement of such parameters. Assis (2007), evaluating the influence of fertilization with poultry litter on productivity, bromatological attributes and absorption of nutrients in *B. decumbens*, noted that the influence of fertilization on yield occurred only in the second harvest and was more significant with larger doses of poultry litter.

Rao and Veeranna (1998) found that the use of combined doses of cattle manure with mineral fertilizers produced higher yields of sugarcane. It should be expected that the substitution of mineral fertilizer by fertilizing with organic waste, could be an alternative, as already pointed out by Matsuoka et al. (2002) mentioning that the production of sugarcane using organic waste is feasible with similar agricultural yields to those obtained with mineral fertilizers and Anjos et al. (2007) who concluded that it is possible to replace minerals by organic fertilizers without losses of stalk yields and artisan brown sugar.

Thus, the use of pure poultry litter or together with waste from the production of sugar and ethanol and mineral fertilizers, or as an organo-mineral fertilizer, is an alternative which can be used to replace mineral fertilizers.

Chemical properties of soil

There were no differences significant ($p > 0.05$) between soil pH (Table 4). There was a slight reduction in pH where mineral fertilizers were applied, which can be explained by fertilization with ammonium nitrate (Table 4).

Almeida Júnior (2010), comparing the effects of organic and mineral fertilization on soil and plant characteristics of sugarcane culture, found that mineral fertilization significantly reduced soil pH. According to the author, this

Table 3. Stalk yield of sugarcane with three poultry litter doses (CF) and organo-mineral fertilizer (FO).

Treatment (t ha $^{-1}$)	**Stalk yield, t ha^{-1}**		
	CF	**FO**	**Mean**
Mineral fertilization [1]	138.8		
Control [2]	128.2		
3	141.2	147.8	144.5 ^{A}
6	139.1	149.9	144.5 ^{A}
9	132.9	152.0 *	142.4 ^{A}
Mean	137.7 ^{b}	149.9 ^{a}	
CV % = 7.94; DMS CF and FO = 9.52 ; DMS Dunnet = 22.56			

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at 0.05 significance*; [1] recommended fertilization; [2] Control: no fertilizers.

Table 4. pH ($CaCl_2$) of soil as influenced by poultry litter doses (CF) and organomineral fertilizer (FO).

Treatment (t ha $^{-1}$)	**CF**	**F O**	Mean
Mineral fertilization [1]	4.9		
Control [2]	5.2		
3	5.3^{ns}	5.1^{ns}	5.2^{A}
6	5.2^{ns}	5.0^{ns}	5.1^{A}
9	5.0^{ns}	5.1^{ns}	5.0^{A}
Mean	5.2^{a}	5.5^{a}	
CV% = 5.94; DMS CF and FO = 0.25; DMS Dunnet = 0.60.			

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at 0.05 significance*; [1] recommended fertilization; [2] Control: no fertilizers.

Table 5. Phosphorus (mg dm^{-3}) and potassium (cmolc dm^{-3}) levels in soil (depending on the application of three doses of chicken litter (CF) and organo-mineral fertilizer (FO).

Treatment (t ha $^{-1}$)	**Phosphorus**		**Mean**	**Potassium**		**Mean**
	C F	**C O**		**C F**	**C O**	
Mineral fertilization [1]	19.3			0.04		
Control [2]	12.5			0.04		
3	31.0*	18.8^{ns}	24.9^{AB}	0.05^{ns}	0.04^{ns}	0.05^{A}
6	17.1^{ns}	19.0^{ns}	18.0^{B}	0.05^{ns}	0.05^{ns}	0.05^{A}
9	34.1*	29.9*	32.0^{A}	0.05^{ns}	0.05^{ns}	0.05^{A}
Mean	27.4^{a}	22.5^{a}				
CV % = 32.1; DMS CF and FO = 6.2 ; DMS Dunnet = 14.7				CV % = 17.5; DMS CF and FO = 0.006; DMS Dunnet = 0.01		

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at0.05 significance*; [1] recommended fertilization; [2] Control: no fertilizers-

was probably due to the use of ammonium sulfate in mineral fertilizer, which can acidify soil by the formation of two protons (H^+) for each nitrified NH_4^+ ion.

There was an increase significant ($p < 0.05$) in the availability of P in soil caused by the use of poultry litter and organo-mineral fertilizer (Table 5). As for K, there was no significant difference ($p > 0.05$) between treatments in the supply of this nutrient to soil (Table 5). According to CFSEMG (1999), the K contents in soil are considered low.

The increased availability of P in soil can be explained by the increase of the amount of directly available P due to the presence of this nutrient in the waste and its indirect action, which has the ability to improve soil properties (Oliveira, 2000).

Novais et al. (2007) reported that organic material

Table 6. Levels of calcium and magnesium in soil (cmolc dm^{-3}) depending on the application of three doses of poultry litter (CF) and organo-mineral fertilizer (F O).

Treatment (t ha^{-1})	Calcium		Mean	Magnesium		Mean
	C F	F O		C F	F O	
Mineral fertilization [1]	1.3			0.4		
Control [2]	1.7			0.6		
3	1.8^{ns}	1.5^{ns}	1.6^{A}	0.6^{ns}	0.5^{ns}	0.5^{A}
6	1.4^{ns}	1.4^{ns}	1.4^{A}	0.4^{ns}	0.5^{ns}	0.4^{A}
9	1.5^{ns}	1.5^{ns}	1.5^{A}	0.4^{ns}	0.6^{ns}	0.5^{A}
Average	1.5^{a}	1.4^{a}		0.5^{a}	0.5^{a}	
CV % = 33.0; DMS CF and FO = 0.4; DMS Dunnet = 1.0				CV % = 42.0; DMS CF and FO = 0.2 ; DMS Dunnet = 0,4		

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at 0.05 significance*; [1] recommended fertilization; [2] Control : no fertilizers.

Table 7. Contents of aluminum (cmolc dm^{-3}) and organic matter (kg dag^{-1}) in soil due to the application of three doses of chicken litter (CF) and organo-mineral fertilizer (FO).

Treatment	Aluminum		Mean	Organic matter		Mean
	CF	FO		CF	FO	
Mineral fertilization [1]	0.04			2.0		
Control [2]	0.05			2.1		
3 t ha^{-1}	0.05^{ns}	0.08^{ns}	0.06^{A}	2.3^{ns}	2.1^{ns}	2.2^{A}
6 t ha^{-1}	0.05^{ns}	0.09^{ns}	0.07^{A}	2.0^{ns}	2.1^{ns}	2.1^{A}
9 t ha^{-1}	0.04^{ns}	0.01^{ns}	0.03^{A}	2.2^{ns}	2.2^{ns}	2.2^{A}
Average	0.05^{a}	0.06^{a}		2.1^{a}	2.2^{a}	
CV % = 118.0; DMS CF and FO = 0.05; DMS Dunnet = 0.1				CV % = 9.9; DMS CF and FO = 0.2; DMS Dunnet = 0.4		

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at 0.05 significance*; [1] recommended fertilization; [2] Control : no fertilizers

added to soil through the application of waste such as poultry litter, brings about, in general, decreased adsorption and increased availability of phosphorus for plants. Santos et al. (2009) reported that the availability of phosphorus in soil caused by the use of organic residues possibly occured due to the action of organic and humic acids and alcohols, which provide substances such as phenols and contribute to increased availability of this nutrient

There was no significant difference ($p > 0.05$) between the treatments with mineral fertilizer, poultry litter doses and organo-mineral fertilizer regarding Ca and Mg levels in soil (Table 6). Nevertheless, the average levels of available Ca, where poultry litter and organo-mineral fertilizer were applied, were higher than mineral fertilizer, possibly due to the lack of Ca source. The average supply of Ca to soil was 1.5 cmolc dm^{-3} with poultry litter and 1.4 cmolc dm^{-3} with organo-mineral fertilizer. According to CFSEMG (1999), the levels of Ca in all treatments, are considered medium, i.e. are between the range of 1.21 and 2.4 cmolc dm^{-3}.

There was no significant difference ($p > 0.05$) between control treatment and where mineral fertilizer, poultry litter and organo-mineral fertilizer were used regarding Al content and soil organic matter (Table 7).

The average Al content is considered low to very low, according to CFSEMG (1999), which was due to lime and gypsum application applied before planting. Low aluminum contents are correlated with the mean pH values in $CaCl_2$ which was 5.2, when poultry litter was used and 5.5 with the organo-mineral fertilizer (Table 4). The high coefficient of variation (CV%) for levels of exchangeable Al in soil are due to low levels of DMS of poultry litter and organo-mineral fertilizer, that is, anything below or above the DMS is detected by the statistical analysis, which increases CV%.

Although the levels of soil organic matter were not altered by the application of poultry litter and organo-mineral fertilizer (Table 7), according to CFSEMG (1999), the values of soil organic matter are within limits considered medium, which are 2.01 – 4.0 dag kg^{-1}.

Portugal et al. (2009), studying the effects of different poultry litter doses for two consecutive years in *Brachiaria brizantha* cv. Marandú also found no significant changes in levels of soil organic matter. Similar result was found by Silva (2005) who did not obtain changes in soil organic

Table 8. Foliar nitrogen and sulfur in sugarcane as a result of application of three poultry litter doses (CF) and organic fertilizer (FO).

Treatment (t ha $^{-1}$)	Nitrogen, g kg^{-1}			Sulfur, g kg^{-1}		
	CF	FO	Mean	CF	FO	Mean
Mineral fertilization [1]	16.2			1.3		
Control [2]	16.5			1.4		
3	16.3^{ns}	16.2^{ns}	16.2^{AB}	1.4^{ns}	1.5^{ns}	1.4^{A}
6	16.8^{ns}	16.6^{ns}	16.7^{A}	1.4^{ns}	1.4^{ns}	1.4^{A}
9	15.7^{ns}	16.2^{ns}	16.0^{B}	1.4^{ns}	1.4^{ns}	1.4^{A}
Mean	16.3^{a}	16.3^{a}	16.2^{AB}	1.4^{a}	1.4^{a}	
CV% = 3.4; DMS CF and FO = 0.5; DMS Dunnet = 1.1				CV% = 9.3; DMS CF and FO = 0.1; DMS Dunnet = 0.3		

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at 0.05 significance*; [1] recommended fertilization; [2] Control: no fertilizers.

matter at 0-20 cm and 20-40 cm depth.

Another factor to consider is that this study was developed in a region where conditions favor decomposition of organic matter. Silva (2005), evaluating the influence of mineral fertilization and poultry litter on soil chemical properties, mentioned that a continuous application of organic waste might increase the level of this attribute in soil, although high temperature, moisture and microbial activities contribute to the decomposition of organic matter.

No significant increases of pH, nutrient content and soil organic matter were achieved where poultry litter and organic fertilizer were used in relation to mineral fertilization. Santos et al. (2009), evaluating the effects of organic and mineral fertilization on soil chemical properties, nutritional status and yield of sugarcane, showed that pH, organic matter, K, Mg and Al in soil were not affected by doses of organic compound. This effect can be attributed to the fact that organic and organo-mineral fertilizers have nutrients associated with organic compounds, which give them a gradual solubility, that is, the total content is not fully soluble in water gradually releasing the nutrients with time, with lower availability at first (Luz and Korndörfer, 2011).

According to Silva (2009), a long-term monitoring of an area allows an assessment of the effect of organic fertilizers, which may improve chemical, physical and biological conditions of soil, ensuring a sustainability of the area. A controlled application of organic fertilizer during the cultivation cycle can deliver nutrients in a way that meets their removal.

According to the record provided by the mill, the areas are quite homogeneous with medium fertility, which may explain the lack of response to most chemical characteristics delivered with poultry litter, organo-mineral compound and mineral fertilizer.

Regarding the lack of response of chemical properties and organic matter in soil, one must consider the form of soil sampling in the areas. The poultry litter, organo-mineral and mineral fertilizers were applied accompanied by cultivation of the crop, but on the other hand soil sampling was carried out between rows. This form of sampling between the rows may distort, or not show real effects of fertilizers on chemical characteristics and levels of soil organic matter.

Leaves macronutrients contents

There was no significant difference ($p > 0.05$) among the applications of poultry litter, mineral and organo-mineral fertilizer in relation to levels of foliar N and S (Table 8). According to Raij et al. (1996), an adequate leaf N range in sugarcane is 18-25 g kg^{-1}. Thus, the values of nutrients are below levels which are considered adequate.

The lack of response of N content in leaves to the application of litter may be related to the fact that part of it is still in organic form, which determines a lower efficiency of nutrient uptake by sugarcane (Lourenço et al., 2010). Canabarro et al. (2003) reported that organic N present in organic waste such as chicken litter, has a low mineralization rate and the decomposing microorganisms of the carbonaceous compounds of these materials immobilize part of N in the waste, decreasing the absorption of this nutrient by plants.

Regarding foliar S, there was no significant difference ($p > 0.05$) between the mineral fertilizer, poultry litter and organic fertilizer (Table 8). The average content of S in leaves with poultry litter and organo-mineral fertilizer application, was 1.4 g kg^{-1} (Table 8), and according to Raij et al. (1996), S values are below the 1.5 to 3.0 g kg^{-1} range, which is considered suitable in sugarcane.

Sulphur has high power of lixiviation and due to undeveloped root system early in the crop cycle there is low uptake of soluble S from soil with much of the nutrient amenable to lixiviation. Another point to consider is that in soil SO_4^{-2} is predominantly adsorbed by mineral and organic particles (Alvarez et al., 2007).

There was no significant difference ($p > 0.05$) between the use of poultry litter, organo-mineral and mineral fertilizer regarding foliar P concentrations (Table 9). However, according to Raij et al. (1996), the average

Table 9. Foliar phosphorus and potassium in sugarcane as a result of application of three poultry litter doses (CF) and organic fertilizer (FO).

Treatment (t ha $^{-1}$)	Phosphorus, g kg^{-1}			Potassium, g kg^{-1}		
	CF	FO	Mean	CF	FO	Mean
Mineral fertilization [1]	1.5			26.4		
Control [2]	1.5			26.1		
3	1.6	1.5	1.6	27.1^{A}	27.9	27.5^{A}
6	1.4	1.5	1.4	26.1^{A}	28.5	27.3^{A}
9	1.6	1.5	1.6	28.5^{A}	29.1	28.8^{A}
Mean	1.5^{a}	1.5^{a}		27.3^{a}	28.5^{a}	
CV % = 7.1; DMS CF and FO = 0.1; DMS Dunnet = 0.2				CV % = 5.8; DMS CF and FO = 1.3; DMS Dunnet = 3.2		

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at 0.05 significance*; [1] recommended fertilization; [2] Control : no fertilizers.

Table 10. Foliar calcium and magnesium in sugarcane as a result of application of poultry litter doses (CF) and organic fertilizer (FO).

Treatment (t ha $^{-1}$)	Calcium (g kg^{-1})			Magnesium (g kg^{-1})		
	CF	FO	Average	CF	FO	Average
Mineral fertilization [1]	3.0			1.9		
Control [2]	3.2			2.0		
3	3.0	3.1	3.0^{A}	1.8	1.8	1.8^{A}
6	2.9	2.8	2.9^{A}	1.7*	1.7*	1.7^{A}
9	2.7	2.7	2.7^{A}	1.9	1.7*	1.8^{A}
Average	2.9^{a}	2.8^{a}		1.9^{a}	1.7^{a}	
CV % = 8.6; DMS CF and FO = 0.2; DMS Dunnet = 0.5				CV % = 7.8; DMS CF and FO = 0.1; DMS Dunnet = 0.3		

Means followed by different lowercase letters in lines and uppercase in columns differ by Tukey test at 0.05 significance*; [1] recommended fertilization; [2] Control: no fertilizers.

values of this nutrient in the leaves are within the 1.5 to 3.0 g kg^{-1} range, which is considered appropriate for this culture.

The application of poultry litter and organo-mineral fertilizer did not differ significantly ($p > 0.05$) from the mineral fertilizers for plant K content (Table 9). Although not changed, plant K content is within the 10-16 g kg^{-1} range considered adequate in the cultivation of sugarcane (Raij et al. 1996). Teixeira (2013), evaluating bioavailability of P and K from mineral and organic fertilizers, mentioned that with the permanence of the root system in soil a higher P uptake is expected by ratoon, especially with the application of organo-mineral fertilizer, which has slower solubility and a higher residual effect, and could provide more P to the crop.

There was no significant difference ($p > 0.05$) between the application of poultry litter, mineral and organo-mineral fertilizer regarding leaves Ca and Mg content (Table 10). The average levels of Ca, where poultry litter, mineral and organo-mineral fertilizer were applied, were within the 2.0 to 8.0 g kg^{-1} range, which is considered adequate. Similar to Ca, Mg levels were also considered within the proper range, which is 1.0 to 3.0 g kg^{-1} (Raij et al., 1996).

At these experimental conditions, the mineral fertilizer, poultry litter and organo-mineral fertilizer did not efficiently supply certain macronutrients, both to soil and to plant, remaining below the appropriate levels proposed by Raij et al. (1996) for sugarcane.

Silva (2009), working with the application of organic waste in corn (*Zea mays*), also noted little variation in nutrient levels in soil and plants. In addition, according to the author, one can attribute this behavior of waste to the fact that an experimental area is naturally homogeneous with medium fertility. Thus, there is the necessity to follow the process in a long term enabling the observation of the performance of organic waste and organo-mineral compounds, which may improve chemical, physical and biological conditions of soil, ensuring the sustainability of the area. It is assumed that the application of these materials in a controlled manner during more crop cycles will provide nutrients in a way that meets the removals.

Conclusions

1) The stalk yield of sugarcane was higher with the poultry litter and organo-mineral fertilizer application

compared to mineral fertilizers, and organo-mineral fertilizers were superior than poultry litter;

2) There was an increase of soil phosphorus content by fertilizing with poultry litter and organo-mineral fertilizer;

3) K, Ca, Mg contents acidity and soil organic matter were not altered by the application of poultry litter, organo-mineral fertilizer and mineral fertilizers;

4) Plant contents of macronutrients of sugarcane were not altered by the application of poultry litter, mineral fertilizer and organo-mineral fertilizers.

5) The use of organo-mineral fertilizer, as well as pure poultry litter is recommended.

Conflict of Interests

The authors have not declared any conflict of interests.

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