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Organic matter sources in the composition of pelletized organomineral fertilizers used in sorghum crops

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Organomineral fertilizers have been used to meet plants' nutritional needs and reduce producers' reliance on mineral fertilizers. This study aimed to determine the effect of organic matter sources for organomineral fertilizers and traditional mineral fertilizers to the sorghum initial development. The experiment followed a randomized complete block design in a '4 x 3 + 2' factorial arrangement, with four fertilizer doses (50, 75, 100 and 125%) of the recommended dose for sorghum crops (450 kg ha^{-1}), three organic matter sources to compose the organomineral fertilizers (sewage sludge, filter cake, peat), a control (mineral fertilizer), and an untreated check (no fertilizers). Each experimental plot consisted of four plants divided into two pots. Plant height, stem diameter, chlorophyll *a*, chlorophyll *b*, and leaf area were performed at 30 and 60 days after seeding (DAS) when shoot dry mass was also measured. Organomineral fertilizers outperformed both control and untreated check plots for most variables at 30 DAS. Sorghum fertilized with organomineral fertilizers also showed positive results at 60 DAS, even with dose reductions. Considering the variables herein reported, organomineral fertilizers can replace mineral fertilizers in the development of sorghum, even with dose reductions.

Key words: Biofertilizer, sewage sludge, filter cake, peat, plant nutrition.

INTRODUCTION

High grain yields require high agronomic inputs, and among these, mineral fertilizers represent major investments, with approximately 13 and 24% of the total investment on sorghum (*Sorghum bicolor* (L.) Moench) crop production cycle (Wylie, 2008; USDA, 2016). However, despite the large costs, appropriate management of fertilizers and consequently of the soil fertility increases considerably the productivity of crops (Lopes and Guilherme, 2007; Hawkesford et al., 2014).

The fertilization with organic compounds is an option to the exclusive use of mineral fertilizers in agricultural production systems. Organic fertilizers are any product derived from plants, animals, urban or industrial residues, which is composed of degradable carbon, and may also be any substance that is present in the soil and has as source plants, microorganisms, excretions of fauna and everything that turns into humus after the decomposition (Silva and Mendonça, 2007; Chem, 2015). However, the

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Table 1. Chemical characterization of the Red Latosol (Oxisoil) used.

pH H_2O	$Pmeh^{-1}$	K^{+1}	Ca^{+2}	Mg^{+2}	Al^{+3}	H+ Al	BS	t	T	V	m	O.M.	C.O
----mg dm^{-3}----		-----------------------------cmolc dm^{-3}--------------------------								----%-----		--dag Kg^{-1}---	
6.2	2.3	0.31	2.3	0.8	0	2.8	3.41	3.41	6.21	55	0	2.7	1.6

Water pH (1:2.5); P, K: extractor (HCl 0.05 mol L^{-1}); Al, Ca, Mg: extractor (KCl 1 mol L^{-1}); SB: base sum; t: effective CTC; T: CTC at pH 7; V: base saturation; m: Al saturation; O.M.: organic matter; O.C.: organic carbon.

exclusive organic fertilization is technically feasible only for some crops or in small areas; usually, the great amount of organic fertilizer needed to accomplish the nutritional requirement of most cultures would raise the cost of freight and turn organic fertilization impracticable.

The association of organic fertilizers with mineral fertilizers is an alternative for the production of organomineral fertilizers which have characteristics of both sources. Organomineral fertilizer formulation is variable as it is influenced by the amount of organic and mineral source used for its composition. Organomineral fertilizers have some characteristics in common, such as the gradual release of nutrients, increased agronomic efficiency of soil fertilization, can correct soil acidity and improvement of its physical characteristics (Kiehl, 2008).

The organic fraction mineralization of organomineral fertilizers can greatly contributes to increase the levels of nitrogen, phosphorus and sulfur in soil (Vezzani et al., 2008; Antille et al., 2013). This organic matter present in organomineral fertilizers also helps to reduce phosphorus fixation by oxides of iron and aluminum that are abundant in weathered soils (Rheinheimer et al., 2008; Castro et al., 2015). Moreover, the advantages of organomineral fertilization are not limited only to the crop season that receive the application, there is a cumulative residual effect in subsequent years, favoring the chemical, physical and biological properties of the soil (Ghosh et al., 2009). The organomineral fertilizers also have environmental benefits because they reduce the amount of organic wastes placed incorrectly on the environment, which could pollute water, soil and air.

Despite the benefits cited for organomineral fertilizers, information about its benefits in several cultures are incipient, important agricultural crops, as sorghum are still in need of studies with organomineral fertilizers. Sorghum is a C4 plant of tropical origin, adapted to conditions of high temperature and drought, and tolerant to various conditions of soil fertility. These features allow sorghum to be cultivated in a wide range of latitude, including areas where other cereals have low economic production (Smith and Frideriksen, 2000).

The sorghum high productivity is dependent upon a good initial plant development and the availability of nutrients during its crop cycle. Therefore, the adequate management of fertilization, and its sources, is one of the main reasons for proper establishment and productivity of sorghum. The study and development of options of fertilizers for the proper management of plant nutrition must be constant to allow the sorghum producers to use appropriately the fertilizers available.

Due to the need to find alternative sources to reduce production costs related to mineral fertilization, also, the lack of information on organomineral fertilizer application in sorghum and the possibility of correctly allocate an environmental waste produced by different sectors, this study aimed to evaluate the ability of organomineral fertilizers made from different sources of organic compounds to replace the application of mineral fertilizers on sorghum crop.

MATERIALS AND METHODS

The experiment was conducted from March to May 2015, in a greenhouse of the Universidade Federal de Uberlândia (UFU), located in Uberlândia, Minas Gerais state, Brazil (18°54' S, 48°15' W, 843 meters above sea level). The predominant climate of the region is subtropical climate type Cwa according to Köppen's (1948) classification.

The experimental design consisted of randomized blocks with four replications in a factorial structure '4 x 3 + 2', corresponding to four levels of organomineral fertilizer (50, 75, 100 and 125% of the dose of 450 kg ha^{-1} of NPK 5-17-10, according to the recommendation of Ribeiro et al., 1999), three sources of organic matter for the organomineral fertilizer (sewage sludge, filter cake, peat), and two additional treatments, being a treatment with mineral fertilization corresponding to 100% of the dose of organomineral fertilizer, and a control treatment with no fertilization. All fertilizers were produced with the formulation 0.1% of B, 3% of Si, 0.4% of Zn and 8% of total organic carbon (TOC).

The treatments plots were composed of two 5 liters pots, where four sorghum seeds (single-cross hybrid 1G100) were sown, at 3 centimeters depth. After 14 days, thin was performed to two plants per pot. Fertilization treatments were applied and mixed with soil prior to sown. The soil used was the Red Ratosol (Oxisoil) according to the classification of EMBRAPA (2013). Table 1 presents the soil chemical attributes. Analyses were performed at the laboratory of soil analysis (LABAS-UFU).

At 30 and 60 DAS after sowing, plant height, stem diameter, chlorophyll *a*, chlorophyll *b* and leaf area were analyzed. At 60 DAS, the plant shoot was harvested and dried in an air driven oven to obtain dry mass after observation of constant weight, about 72 h after drying. For plant height measuring ruler was used, being considered the distance of the neck until the end of the last leaf completely developed. The stem diameter was measured 1 cm above ground level with the aid of a digital caliper. For evaluation of chlorophyll *a* and *b*, chlorophyll meter was used (ClorofiLog Falker CFL 1030, Brasil) to evaluate the last two fully developed leaves, totalizing eight samples per plot.

Leaf area assessment were considered only by the leaves fully

Table 2. ANOVA of plant height (cm), stem diameter (mm), chlorophyll *a*, chlorophyll *b* and leaf area (cm^2), according to the source of organic matter (Source) and levels of organomineral fertilizer (Level) at 30 DAS of sorghum.

Source of variation	DF	Square mean				
		Height	Diameter	Chlorophyll *a*	Chlorophyll *b*	LA
Source	2	8.53*	0.66^{ns}	30.39^{ns}	5.46^{ns}	73.18^{ns}
Level	3	10.85**	0.88^{ns}	25.81^{ns}	2.14^{ns}	5667.78**
S x L	6	2.64^{ns}	0.05^{ns}	8.13^{ns}	0.56^{ns}	618.71^{ns}
Error	39	2.29	0.32	17.55	2.08	1020.60
CV%	-	10.34	13.58	16.28	21.91	28.20

** = Significant at 0.01 (p≤0.01); * = Significant at 0,05 significance (p≤0,05); ns = non significant; LA = leaf area.

Table 3. ANOVA of plant height (cm), stem diameter (mm), chlorophyll *a*, chlorophyll *b*, leaf area (cm^2) and dry mass (g), depending on the sources of organic matter in the composition (S) and levels of organomineral fertilizer (L) at 60 DAS of sorghum.

Source of variation	DF	Square mean					
		Height	Diameter	Chlorophyll *a*	Chlorophyll *b*	LA	SDM
Source	2	1.95^{ns}	0.68^{ns}	3.23^{ns}	0.54^{ns}	2966^{ns}	1.40^{ns}
Level	3	4.88**	2.44**	0.98^{ns}	0.51^{ns}	69260**	11.06**
S x L	6	0.43^{ns}	0.43^{ns}	2.85^{ns}	0.43^{ns}	12703^{ns}	2.20^{ns}
Error	39	0.91	0.50	3.50	0.60	6518	8.79
CV%	-	4.44	9.56	7.70	13.30	14.76	15.78

** = Significant at 0.01 (p≤0.01); ns = non significant; LA = leaf area; SDM = shoot dry mass.

submitted to the formula: leaf height × greatest leaf width × 0.75.

After attending the ANOVA assumptions (normality of residues (Kolmogorov-Smirnov), and homocedascity (Levene), both at p≤0.01), all data proceed its respective ANOVA analysis. When differences among organomineral sources were significant (ANOVA, p≤0.05), their averages were compared to each other by Tukey's test (p≤0.05); when differences among organomineral doses were significant (ANOVA, p≤0.05), their averages were compared by regression models.

The treatments including organomineral fertilization were compared to the additional treatments (mineral fertilizer and untreated check) by Dunnet's test (p≤0.05) when differences were significative (ANOVA, p≤0.05). Pearson correlation coefficient was calculated between plant height and shoot dry mass at 60 DAS only for treatments including the organominerals, excluding the data from the two additional treatments.

The statistical programs used were the SPSS 19.0 for Windows, Assistat (Silva and Azevedo, 2002), SISVAR (Ferreira, 2010) and SigmaPlot (Systat, 2008).

RESULTS AND DISCUSSION

The summary of the analysis of variance for the sorghum variables were analyzed at 30 DAS as presented in Table 2. The analysis of variance showed that the different sources of organic matter for the organomineral fertilizer composition significantly affected only plant height, while, for the levels of organomineral fertilizer, height and leaf area were significant. The interaction between the sources of organic matter and the levels of organomineral fertilizer was not significative for all variables at 30 DAS sorghum.

The summary of the analysis of variance for plant height, stem diameter, chlorophyll *a*, chlorophyll *b*, leaf area and dry mass as a function of sources of organic matter and levels of organic material fertilizers at 60 DAS for the sorghum crop is presented in Table 3. The different levels of fertilization significantly influenced the plant height, stem diameter, leaf area and dry mass. No significant interaction for any variables analyzed was detected.

Differing from what was observed at 30 DAS (Table 2), the evaluations at 60 DAS of sorghum presented no significant differences between the sources of organic matter used to compose the organomineral fertilizer (Table 3). Dereje et al. (2016) found parallel results by evaluating the development of sorghum in Ethiopia. The sorghum grain yield evaluated presented similar results among inorganic and organic fertilizers, and their combinations.

Stem diameter, chlorophyll *a*, chlorophyll *b* and leaf area, analyzed at 30 DAS of sorghum did not differ among organomineral sources (p≤0.05). However, at 30 DAS, the organomineral fertilizers formulated with peat resulted in the greater plant height (16.1 cm) than sewage sludge (14.73 cm). The plant height of the organomineral formulated with filter cake (14.97 cm) did not differ from the others (p≤0.05).

Table 4. Test of Dunnet for plant height (cm), chlorophyll *a*, chlorophyll *b*, stem diameter (mm) and leaf area (cm^2) of sorghum at 30 DAS with different levels of organomineral fertilizer composed with sewage sludge, filter cake and peat.

Treatments (%)	Height	Diameter	Chlorophyll *a*	Chlorophyll *b*	LA
Sewage sludge (50)	13.18	26.60	7.30*	3.77	88.70*
Filter cake (50)	13.49	23.40	6.08	3.81	97.94*
Peat (50)	15.81*[1]	27.25	6.54	4.27	105.41*[1]
Sewage sludge (75)	14.26*	26.11	7.31*	3.85	117.10*[1]
Filter cake (75)	14.96*[1]	23.30	6.11	4.24	109.37*[1]
Peat (75)	15.56*[1]	26.81	6.43	4.28	128.38*[1]
Sewage sludge (100)	15.13*[1]	29.08*[1]	7.56*	4.20	142.58*[1]
Filter cake (100)	16.18*[1]	27.60	7.03	4.37*	155.16*[1]
Peat (100)	15.47*[1]	25.81	5.99	4.56*	124.76*[1]
Sewage sludge (125)	16.37*[1]	30.49*[1]	8.15*[1]	4.49*	151.56*[1]
Filter cake (125)	15.25*[1]	27.00	6.93	4.42*	146.63*[1]
Peat (125)	17.56*[1]	27.83	7.49*	4.78*	133.46*[1]
Control	10.49	19.48	4.29	3.21	31.64
Mineral	11.39	19.45	5.00	4.04	53.21

* = Averages that differ from the control by Dunnet's test at 0.05 significance; [1] = Averages that differ from the mineral by Dunnet's test at 0.05 significance. LA = leaf area.

The height of the plant is of great morphophysiological importance, by directly reflecting on plant growth and differentiation (Taiz and Zeiger, 2010). This parameter influences all process that is involved with the soil-plant system and indicates that the sources of peat and filter cake are more appropriate to sorghum cropping. Comparisons of plant height, chlorophyll *a*, chlorophyll *b*, stem diameter and leaf area, at 30 DAS of sorghum, between the treatments with organomineral fertilizers and the treatment without fertilization (control) or with mineral fertilizer (Table 4).

There was a superiority of the organomineral fertilizers in relation to mineral for plant height and leaf area. Even reducing the application in 50% of the recommended dose, the use of organomineral fertilizers based on peat (T3) was enough to have a greater average height of plants when compared with mineral fertilization. The organomineral fertilizers, even at 50% of the recommended dose, also stood out as good sources to increase leaf area in sorghum in relation to exclusive mineral fertilization. For the other sources of organic matter, only doses from 75% of the recommended achieved the same effect (Table 4).

For chlorophyll *a*, two levels of organomineral with sewage sludge managed to overcome the control, being 100% or 125% of the recommended dose of 450 kg ha^{-1} for sorghum crop (Ribeiro, 1999). However, to achieve similar results of the mineral fertilization, any level of organomineral fertilizer can be used, regardless of the organic matter source used for its composition (Table 4).

The chlorophyll *b* contend was superior to control for the filter cake and peat at 100% dose, or for any of the organic source at 125%. Sources or doses did not differ from the mineral fertilizer. Both chlorophylls are important for sorghum plant development. Chlorophyll *a* is essential to the photochemistry phase of the photosynthesis, and while this photosynthetic phase is ongoing, other pigments assists light absorption and radiation transferring to the centers of reaction, and among these pigments there is chlorophyll *b* (Taiz and Zeiger, 2010). In this way, it can argued that there is great importance for the evaluation of these parameters during the development of sorghum.

In Table 5, comparisons of plant height, chlorophyll *a*, chlorophyll *b*, stem diameter, leaf area and sorghum dry mass at 60 DAS of sorghum, between the treatments with organomineral fertilizers and the treatments without fertilization (control) and with mineral fertilizer are presented.

At 60 DAS of sorghum, the organomineral fertilizers showed results similar to those found by mineral fertilizer for the variables plant height, chlorophyll *a* and *b*, and stem diameter, even at levels below the recommended for the crop. The exception was the lowest application (50%) for sewage sludge which showed lower chlorophyll content than with the use of mineral fertilizer. For leaf area, doses equal or superior to 75% of sewage sludge showed leaf area greater than exclusive mineral fertilizer treatment.

Despite the low concentrations of N, P and K in organic fertilizers, there is a complement of their concentration by the mineral fraction present in the organomineral. Therefore, there is a great efficiency in the use of organomineral fertilizer due to the slow release of nutrients during the plant growth (Ramesh at al., 2009; Hazra, 2016). Thus, even with the application of small

Table 5. Test of Dunnet for plant height (cm), chlorophyll *a*, chlorophyll *b*, stem diameter (mm), leaf area (cm^2) and sorghum shoot dry mass (g) at 60 DAS of sorghum with different levels of organomineral fertilizer composed with sewage sludge, filter cake and peat.

Treatments (%)	Height	Diameter	Chlorop. *a*	Chlorop. *b*	LA	SDM
Sewage sludge (50)	20.84¹	22.21*¹	4.75¹	6.70	420.11	15.35
Filter cake (50)	20.53¹	24.55	5.69	6.82	429.76	14.15
Peat (50)	21.32	25.02	5.90	7.74	514.20	19.45*
Sewage sludge (75)	20.74¹	23.36¹	5.63	6.96	619.91*	18.60*
Filter cake (75)	20.88¹	23.73	5.69	7.72	543.71	19.25*
Peat (75)	20.91¹	23.36¹	5.60	7.37	495.06	17.00
Sewage sludge (100)	21.80	24.24	5.86	7.66	598.56*	19.50*
Filter cake (100)	21.90	23.25¹	5.49	8.32*¹	679.02*	24.00*¹
Peat (100)	22.22	24.76	5.95	7.70	564.44	19.80*
Sewage sludge (125)	21.38	24.06	5.80	7.89*	617.25*	21.15*
Filter cake (125)	21.69	23.89	5.94	7.77	629.99*	24.13*¹
Peat (125)	22.84	24.32	6.06	8.14*	604.00*	22.80*¹
Control	21.34	26.09	6.06	6.69	398.19	11.35
Mineral	23.28	27.40	7.06	6.40	545.89	16.55

* = Averages that differ from the control by Dunnet's test at 0.05 significance; ¹ = Averages that differ from the mineral by Dunnet's test at 0.05 significance. LA = leaf area. Chlorop. = Chlorophyll; SDM = shoot dry mass.

amounts of organomineral fertilizer, there is a great advantage for the plant due to the nutrient slow release.

The plants fertilized with the lowest levels of organomineral fertilizers composed of filter cake or sewage sludge showed an average plant height lower than those found with the mineral fertilization. The stem diameter of the s sewage sludge 50% dose was lower when compared to mineral and control treatment. The sorghum plants fertilized with organomineral fertilizers composed of peat at low level, 50% of recommended presented plant height and stem diameter equal to that found with exclusive mineral fertilizer (Table 5). No treatment was different from plant height from the control at 60 DAS of sorghum. Santana (2012) observed the same results presented in this work for maize crop, because the organomineral fertilizer showed no difference from the control even when varying the dose of fertilizer applied. For the variable chlorophyll a, the two lower levels of filter cake and the lowest level of peat organomineral were the treatments that stood out, which not differ from the mineral fertilization despite the lower quantity of nutrients applied (Table 5).

Reducing the amount of fertilizer applied may be due to increased cation exchange capacity of organic matter present in the organomineral fertilizer. This characteristic leads to greater availability of mineral nutrients for plants and reduction of losses by leaching (Troeh and Thompson, 2005). Neumann et al. (2005) observed promising results using a fertilizer organomineral, with lower concentrations of nutrients in relation to mineral fertilizer, managing to reduce in 5.72% the total cost of sorghum crop.

The chlorophyll *b* presented lower values when compared to mineral fertilization, for low doses of organomineral fertilizer (Table 5). Santana (2012) also found that there is no influence of organomineral fertilizers on the rates of chlorophyll *a* and *b* in maize, because none of the organomineral fertilizer showed no difference with respect to the control or even between different sources and forms of application.

In this study an increase in sorghum shoot dry mass at 100 and 125% organomineral fertilizer dose of from all organic matter source was observed (Table 5). Audu and Samuel (2015) also found good results for rice growth and yield mass with the use of organomineral fertilizer when compared with the exclusive mineral fertilization. The lower doses of organomineral fertilizers did not differ from the mineral fertilization for leaf area. However, with the use of fertilizer organomineral composed of sewage sludge, it was possible to verify greater leaf area with doses from 75% of recommended for the crop. The 125% dose of all organic matter source presented greater leaf area when compared to control, where no fertilizer was applied.

The plant height data at 30 DAS of sorghum were submitted to a regression analysis for the different levels of organomineral fertilizer based on sewage sludge, filter cake and peat (Figure 1A, B and C). The increased levels of sewage sludge as a source of organic matter caused a linear and positive response over the sorghum plant height at 30 DAS of sorghum (Figure 1A). Being observed that for every kilogram of organomineral fertilizer added, with up to 125 kg ha^{-1}, there was an increase of 0.0462 cm in height.

Using filter cake (Figure 1B) and peat (Figure 1C) as sources for production of organomineral fertilizers, the

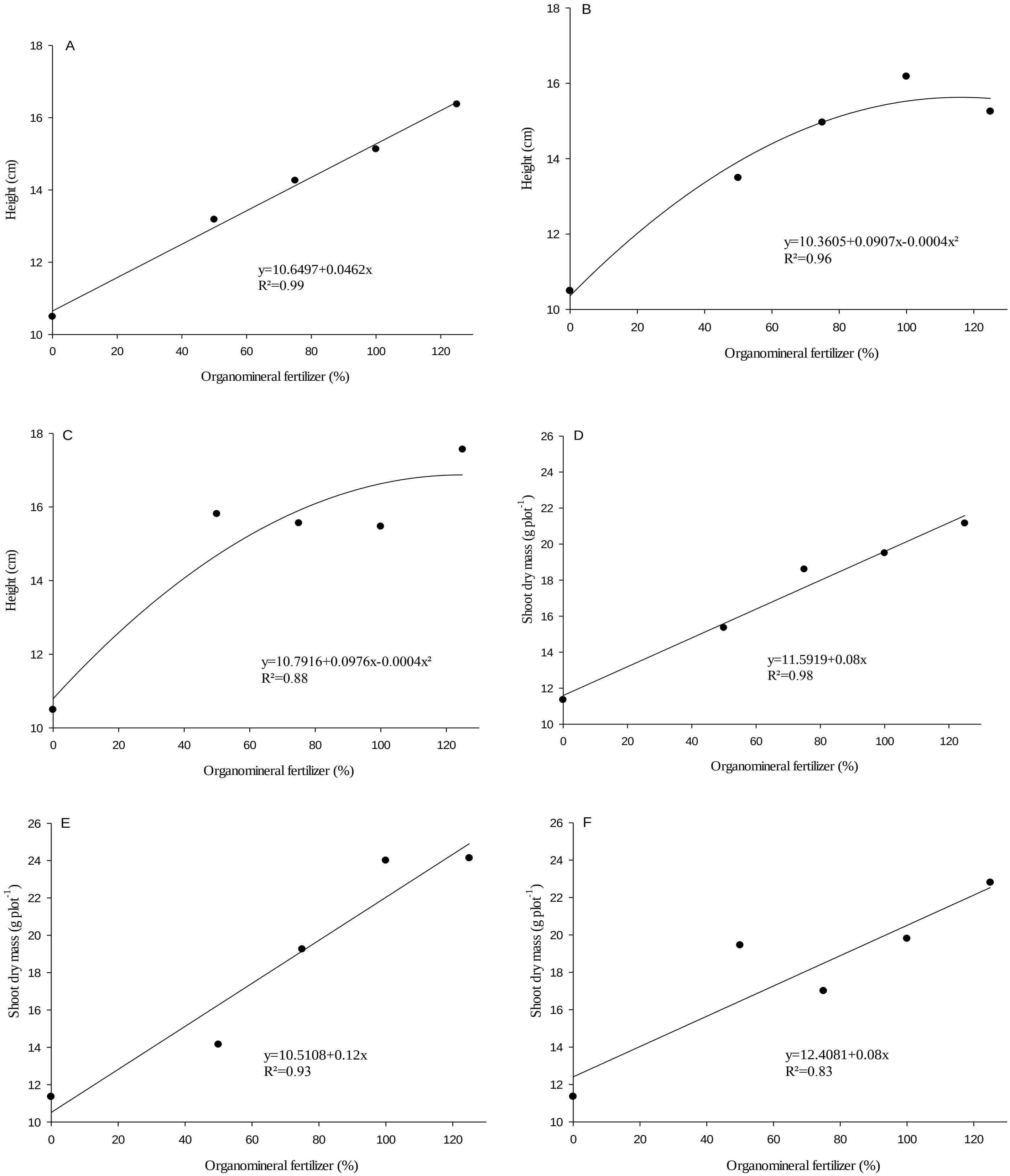

Figure 1. Sorghum plant height at 30 DAS and shoot dry mass at 60 DAS for sewage sludge (A, D), filter cake (B, E) and peat (C, F) based organomineral.

increase in height, at 30 DAS of sorghum, was positive until the doses between 113.38 and 122 kg ha^{-1}, resulting in a height of 15.5 and 16.7 cm, respectively. After these doses, there was a reduction of growth until the maximum dose of 125 kg ha^{-1}. As occurred with plant height, the diameter increase with the use of peat was linear until the dose of 125 kg ha^{-1}, with an increase in diameter of 0.012 mm for each kilogram of peat applied to the soil. However, Makinde (2015) studding amaranthus (*Amaranthus caudatus* L.) found that exclusive mineral nutrition produced taller plants, while a combination of organomineral with mineral fertilizer sources (50:50%) originated similar results to exclusive mineral fertilization regarding stem diameter, leaf area and mass yield.

The data of sorghum shoot dry mass at 60 DAS were submitted to a regression analysis for the different levels of organomineral fertilizer composed of sewage sludge, filter cake and peat (Figure 1D, E and F). At 60 DAS of sorghum, all sources of organomineral fertilizer presented linear increase on sorghum shoot dry mass as it increased the doses (Figure 1D, E and F).

Similar to this study findings, Smith et al. (2015) studding the use of organomineral as a replacement for mineral fertilizers found that in barley, wheat, maize and silage maize the dry silage matter production from both sources did not differ. In this study, the filter cake presented the best results at the highest dose, reaching the highest shoot dry weight part among the sources (Figure 1E).

The Pearson correlation coefficient involving plant height and shoot dry mass of the organomineral treatments at 60 DAS indicated a significative and positive correlation between these traits ($p<0.000$; r=0.506). Other studies also reported similar correlations between sorghum dry mass and plant height (Abubakar and Bubuche, 2013; Perazzo et al., 2014; Castro et al., 2015), suggesting that the use of organomineral fertilizers affects favorably sorghum plant development. The dry mass of plants is an indication of plant development. This parameter is affected mainly by plant shoot - depending on, for example, the number of leaves and leaf area - responsible for the interception of solar energy and, therefore, by the assimilation of carbon, which acts on the accumulation of dry mass.

Conclusions

The organomineral fertilizers formulated from sewage sludge, peat and filter cake can be used to replace exclusive mineral fertilization. Under greenhouse conditions, the organomineral fertilizers showed increase of plant biomass, plant height, stem diameter, chlorophyll *a* and *b* and leaf area in relation to control (no fertilizer) or exclusive mineral fertilization, what indicate organomineral fertilizers as feasible replacement for exclusive inorganic fertilization. This study demonstrate that it is possible to reduce the dose of organomineral fertilizer recommended for sorghum crop, and still reaching the same results or exceeding the values found in areas fertilized with the recommended mineral fertilizer dose. The use of organic residues for the production of organomineral fertilizer also is an alternative to the correct allocation of those.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abubakar L, Bubuche TS (2013). Correlation analysis of some agronomic traits for biomass improvement in sorghum (*Sorghum bicolor* L. Moench) genotypes in North-Western Nigeria. Afr. J. Agric. Res. 8(28):3750-3756.

Antille DL, Sakrabani R, Tyrrel SF, Le MS, Godwin RJ (2013). Characterisation of organomineral fertilisers derived from nutrient-enriched biosolids granules. Appl. Environ. Soil Sci. 11 p.

Audu M, Samuel I (2015). Influence of organomineral fertilizer on some chemical properties of soil and growth performance of rice (*Oryza sativa* L.) in Sokoto, Sudan Savanna Zone of Nigeria. J. Nat. Sci. Res. 5(14):64-68.

Castro FMR, Bruzi AT, Nunes JAR, Parrella RAC, Lombardi GMR, Albuquerque CJB, Lopes M (2015). Agronomic and energetic potential of biomass sorghum genotypes. Am. J. Plant Sci. 6:1862-1873.

Castro GSA, Crusciol CAC, Calonego JC, Rosolem CA (2015). Management impacts on soil organic matter of tropical soils. Vadose Zone J. 14:1-8.

Chem S (2015). Organic fertilizers formulations encyclopedia. Solverchem P 763.

Dereje G, Bogale T, Raghavaiah CV, Walelegn B, Chavhan AB (2016). On-farm productivity response of rainfed grain Sorghum (*Sorghum bicolor* L.) to integrated nutrient supply system in Assosa Zone, Western Ethiopia, East Africa. Int. J. Life Sci. 4(2):169-175.

EMBRAPA (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA) (2013). Sistema brasileiro de classificação de solos. 3.ed. Brasil P. 353.

Ferreira DF (2010). Sisvar: versão 5.3, DEX/UFLA, Lavras: UFLA. Available at:http://www.dex.ufla.br/~danielff/programas/sisvar.html.

Ghosh PK, Tripathi AK, Bandyopadhyay KK, Manna MC (2009). Assessment of nutrient competition and nutrient requirement in soybean/sorghum intercropping system. Eur. J. Agron. 31(1):43-50.

Hawkesford MJ, Kopriva S, De Kok LJ (2014). Nutrient use efficiency in plants – concepts and approaches; Springer P 279.

Hazra G (2016). Different Types of Eco-Friendly Fertilizers: An Overview. Sustain. Environ. 1(1):54-70.

Kiehl EJ (2008). Fertilizantes organominerais. 4. ed. Piracicaba: Degaspari P 160.

Köppen W (1948). Climatologia: con un estudio de los climas de la tierra: Fondo de Cultura Econômica. México: Editora P. 479.

Lopes AS, Guilherme LR (2007). Fertilidade do solo e produtividade agrícola. In: Novais RF, Alvarez VH, Barros, NF, Fontes RLF, Cantarutti RB, Neves JCL. (Org.). Fertilidade do solo. Viçosa (MG): Soc. Bras. Ciênc. Solo P 1017.

Makinde EA (2015). Effects of fertilizer source on growth and cumulative yield of Amaranthus. Int. J. Veg. Sci. 21(2):167-176.

Neumann M, Restle J, Maccari M, Souza A, Pellegreini L, Freitas A (2005). Produção de forragem e custo de produção da pastagem de sorgo (*Sorghum bicolor* L.), fertilizada com dois tipos de adubo, sob pastejo contínuo. Curr. Agric. Sci. Technol. 11:2.

Perazzo AF, Carvalho GGP, Santos EM, Pinho RMA, Campos FS, Macedo CHO, Azevêdo JAG, Tabosa JN (2014). Agronomic evaluation of 32 sorghum cultivars in the Brazilian semi-arid region. Rev. Bras. Zootec. 43(5):232-237.

Ramesh P, Panwar NR, Singh AB, Ramana S, Rao AS (2009). Impact of organic manure combinations on the productivity and soil quality in different cropping systems in central India. J. Plant Nutr. Soil Sci. 172(4):577585.

Rheinheimer DS, Gationi LC, Kaminski J (2008). Fatores que afetam a disponibilidade do fósforo e o manejo da adubação fosfatada em solos sob sistema de plantio direto. Ciênc. Rural 38(2):576-586.

Ribeiro AC, Guimarães PTG, Alvarez VH (1999). Recomendações para o uso de corretivos e fertilizantes em Minas Gerais: 5º Aproximação. Comissão de Fertilidade do Solo do Estado de Minas Gerais. Viçosa P 359.

Santana CTC (2012). Comportamento de milho (*Zea mays* L.) e propriedades físicas do solo, no sistema plantio direto, em resposta a aplicação de fertilizante organomineral. Botucatu: UNESP, 2012. Dissertação de Mestrado 49 p.

Silva FAS, Azevedo CAV (2002). Versão do programa computacional Assistat para o sistema operacional Windows. Rev. Bras. de Prod. Agroind., Campina Grande 4(1):71-78.

Silva IR, Mendonça ES (2007). Matéria orgânica do solo. In: Novais RF, Alvarez VH, Barros, NF, Fontes RLF, Cantarutti RB, Neves JCL. (Org.). Fertilidade do solo. Viçosa (MG): Soc. Bras. Ciênc. Solo pp. 275-374.

Smith CW, Frederiksen RA (2000). Sorghum: Origin, History, Technology, and Production. Wiley Series Crop Sci. P 840.

Smith GH, Chaney K, Murray CMS (2015). The Effect of Organo-Mineral Fertilizer Applications on the Yield of Winter Wheat, Spring Barley, Forage Maize and Grass Cut for Silage. J. Environ. Prot. 6:103-109.

Systat Software, Inc (2008). SigmaPlot for Windows, version 11.0. Available at: https://systatsoftware.com/downloads/download-sigmaplot/

Taiz L, Zeiger E (2010). Plant Physiology. 5th Edition. Sinauer Associates. Sunderland, MA. P 782.

Troeh FR, Thompson LM (2005). Soils and Soil Fertility, 6th Edition. Wiley-Blackwell P 498.

USDA (United States Department of Agriculture)(2016). Economic Research Service: Garin sorghum 2014-15. Available at:http://www.ers.usda.gov/data-products/commodity-costs-and-returns

Vezzani FM, Conceição PC, Mello NA, Dieckow J (2008). Matéria orgânica e qualidade do solo. Fundamentos da matéria orgânica do solo: Ecossistemas trop. Subtrop. 2:483-494.

Wylie P (2008). Managing sorghum for high yields a blueprint for doubling sorghum production. Grain res. Dev. corporation. ISBN: 978-1-875477-57-9. Available at: http://www.grdc.com.au.