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RESEARCH ARTICLE

AGRONOMIC PERFORMANCE OF CRAMBE (*Crambe abyssinica*) IN THE FUNCTION OF FERTILIZATION WITH SEWAGE SLUDGE AND ECOGYPSUMS

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ABSTRACT

The demand for biofuels in the world is growing and some crops have presented great potential for producing raw material for biodiesel production. The objective of this study was to evaluate the feasibility of the use of sewage sludge associated with ecogypsum for crambe cultivation. The experiment was conducted in a greenhouse and the sludge was applied in the non-composted and composted form. The statistical design was completely randomized in a factorial scheme 5 x 2 + 2: five doses of sewage sludge (0 t ha^{-1}, 5 t ha^{-1}, 10 t ha^{-1}, 15 t ha^{-1}, 20 t ha^{-1}), two ecogypsum (calcitic and dolomitic) based on the content of soil clay and its pH and two additional treatments (conventional fertilization with calcitic ecogypsum and with dolomite ecogypsum). Phytotechnical characteristics were evaluated: plant height, collar diameter, seed dry weight, aerial parts dry weight, and seed oil content. It was observed that fertilization with sludge produced significant results in the development of Crambe plants. The best performance of the plants occurred with the dose of 13 t ha^{-1} of sewage sludge associated with application of ecogypsum for the cultivation of *Crambe abysinica*.

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INTRODUCTION

Projections of population growth, rising energy demand, the imminence of oil depletion and environmental impacts caused by the burning of fossil fuels have been stimulating the demand for renewable energy. The current matrix of global energy consumption is still essentially supplied by oil, gas and coal; however, there is already a significant increase in the production of biodiesel and ethanol (Borugadda& Goud, 2012). The need for environmentally beneficial energy sources, low-carbon, low-energy energy sources has encouraged demand for plant raw materials for the production of biofuels (Barbosa *et al*., 2008).

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In this context, crambe (*Crambe abyssinica* Hochst) appears as an option because it is rich in triglycerides and presents similarities in relation to soybean and other species in the production of vegetable oils (Vazquez *et al*., 2014). The crambe comes from Ethiopia (Knights, 2003). It was introduced in Brazil in the 1990s and for many years was used as forage, crop rotation, and as a phytomass producer to cover soils in no-tillage areas (Falasca *et al*., 2010). Currently, Brazilian farmers have shown interest in cultivating crambe due to its potential for biodiesel production, low management costs, short cycle, pest resistance, mechanized harvesting and use as winter crop in the soybean off season (Laghetti *et al*., 1995). The use of residues, such as sewage sludge, in agriculture, is notable for reducing the use of mineral fertilizers, enabling the recycling of nutrients, promoting physical and chemical improvements in the soil and for presenting a solution for the disposal of discarded mineral nutrients (Modesto, Vieira & Fernandes, 2009). The calcitic and dolomitic ecogypsum act as soil conditioners, raise the pH, provide sulfate and calcium to the plants, reduce the potential acidity and the saturation of aluminum. In addition to improving the chemical conditions in depth, the gypsums are also a source of sulfur for the plants, an important aspect, since the deficiency of this nutrient is generalized in the soils of the Cerrado (Soratto *et al*., 2010; Neis *et al*., 2010). Ecogypsum are so called because they are produced with residual H_2SO_4 from automotive batteries, with potential for use in agriculture. In view of the above, the present study aimed to evaluate the feasibility of the use of sewage sludge associated with ecogypsum, for crambe cultivation in the north of Minas Gerais.

MATERIAL AND METHODS

The experiment was carried out from February to May 2017, in a greenhouse at the Institute of Agricultural Sciences (ICA) of Federal University of Minas Gerais (UFMG), located in Montes Claros - MG (latitude 16º 51 '38 "S and longitude 44º 55' 00" W , altitude of 650 m). The climate of the region, according to the classification of Köppen, is Aw (tropical savannah, with dry winter and rainy summer). Two experiments were carried out using sewage sludge in the non-composted form and in the composted form, arranged in a completely randomized design, in a 5x2 + 2 factorial scheme: five doses of sewage sludge composted and non-composted, two ecogypsum (calcitic and dolomitic) and two additional treatments (conventional fertilization with calcitic ecogypsum and conventional fertilization with dolomite ecogypsum). Both experiments were composed of four roundsper treatment, totaling 48 plots. The experimental unit was formed by two plants per pot. In relation to the crambe seeds, the variety FMS Brilhante was used. These were acquired from the Mato Grosso do Sul Foundation, resulting from the genetic improvement carried out at the Foundation (Pitol *et al*., 2010). The soil used to prepare the substrate was collected in the rural area of Montes Claros and classified as Quartz arenic Neosoil (Embrapa 2013). The composting was performed with pruning debris (predominantly Batatais grass, Emerald grass, and legume tree leaves) and sewage sludge in the proportion 3: 1 (v / v), respectively. For 90 days this material was humidified daily and homogenized once a week. The calcitic ecogypsum was produced by Antares Reciclagem through the chemical reaction of hydrolyzed sulfuric acid with the residual calcium carbonate from the pulp mill production process. Sulfuric acid was obtained from the dismantling of used automotive batteries and filtered through a cellulose filter to remove the lead. The dolomite ecogypsum was also produced by Antares through the chemical reaction of the residual sulfuric acid of batteries with the dolomitic limestone. Three-liter pots containing Neosoil soil were used to prepare the substrates. To these were added the non-composted (LNC) and composted (LS) sludge at the dosages of 0g.vase^{-1}, 7,5g.vase^{-1}; 15g.vase^{-1}; 22.5g.vase^{-1} and 30.0g.vase^{-1}, equivalent to 0 t ha^{-1}5 t ha^{-1}, 10 t ha^{-1}, 15 t ha^{-1}, 20 t ha^{-1}. In this same phase, liming by the base saturation method (V%) was performed. The vases received 0.9 g of calcitic and dolomitic ecogypsum (600 kg.ha^{-1}). The calculation of the gypsum was formulated according to the clay content of the soil. Additional treatment received 0.45 g.vase^{-1} (300 kg ha^{-1}) of NPK (4-14-8) according to Soratto *et al* (2013). The soil was always maintained near the field capacity, and distilled water was used for irrigation. The chemical and physical analysis of the soil used were performed according to the methodologies recommended by Tedesco *et al* (1995) and EMBRAPA (1999). The chemical analysis of the sludge and ecogypsum followed the standards determined by the EPA (2010). Table 1 shows the chemical and physical characteristics of the sludge used in this experiment. Table 2 shows the toxic metal contents present in the sewage sludge. According to Resolution 375/2006 of the National Environmental Council (CONAMA), this material is suitable to be used in agricultural environments. Table 3 shows the chemical and physical characteristics of the Cerrado soil used as substrate and Table 4 shows the chemical characteristics of the ecogypsum used as soil conditioners in this experiment.

Table 1. Chemical characteristics of non-composted sewage sludge and composted sludge used as fertilizers in the cultivation of *Crambe abyssinica*

	Ph	N	P	K	Ca	Mg	S	B	Fe	Mn	MO	CO	C/N
	$CaCl_2$							%					
LNC	6,05	2,43	1,8	<1	2,32	<0,5	4,1	<0,1	1,77	<0,05	18,3	<1,8	0,69
LC	6,15	2,43	2,1	<1	2,44	<0,5	2,4	<0,1	2,45	<0,05	10,2	17	6,87

Source: Author

Notes: LNC = sewage sludge not composted; LC = composted sewage sludge. MO = organic matter; CO = oxidizable carbon; C / N = carbon nitrogen ratio.

Table 2. Limits of the maximum concentration of toxic metals present in the sludge or by-products for soil application, and toxic metal content determined in the samples of non-composted and composted sewage sludge

Metal	Rec. Conama, 2006	LNC	LC
	mg /kg^{-1}		
Ba	1300	118,25	161,8
Cu	1500	<0,05%	<0,05%
Zn	2800	0,09%	0,09%
As	41	1,12	<0,02
Cd	39	<0,02	<0,02
Pb	300	<0,02	<0,02
Cr	1000	40,2	4,2
Hg	17	0,60	0,51
Ni	420	28,75	22,2
Mo	50	<0,01	<0,01
Se	100	<0,2	<0,2

Source: Author

Note: Rec. = Recommendation; LNC = non-composted sewage sludge; LC = composted sewage sludge.

Table 3. Chemical and physical characteristics of soil Neosoil used as substrate for *Crambe abyssinica* cultivation

pH	P	K	Ca	Mg	Al	MO	Ar Gr	Ar F	Arg	Sil	Tex
(em H_2O)	_ g/dm-³ _		__cmolc/dm-³ __			___________	dag/kg-¹ __________				
5,3	0,08	10	0,4	0,16	0,5	2,9	34,5	43,5	12	10	Ar

Table 4. Chemical characteristics of the ecogeyspum used in the substrate for cultivation of *Crambe abyssinica.*

Ecogypsum	MgO	CaO	Ca	S	Cd	Hg	Ar	Cr	Se	Ni	Pb
		_______ % _______			________________	mg/kg-¹	__________________				
Calcitic	-	35,21	25,16	13,39	< 5,00	< 0,10	< 10,00	15,93	< 10,00	< 10,00	14,44
Dolomitic	8,54	30,58	-	12,33	2,07	< 0,10	< 20,00	15,47	< 10,00	11,31	22,22

Source: Author.

Plant height (ALT) was evaluated weekly for 71 days (crambe cycle observed in this experiment). The measurements were made with a ruler, from the soil surface to the newest leaf expanded in the apical meristem. After this period the plants were collected and their agronomic characteristics were evaluated: collar diameter (DIA), dry weight of seeds (PS), dry weight of aerial parts (PA), number of days for flowering (NDF), number of days for granulation (NDG) and the oil content in the seeds (TO). The stem diameter of the plants was measured with a ZAAS digital pachymeter, with resolution of 0.01 mm, at the end of the experimental cycle at the beginning of the harvest stage. After the senescence of the plants, the weight of the seeds and the aerial part of the crambe were measured on a precision scale.

For determination of NDF and NDG, daily visual observations were performed in all the experimental plots. The oil content in the seeds was obtained by the Soxhlet method, described by Lara *et al*. (1985), while oil yield was obtained from seed yield and oil percentage. The factorial scheme 2x5 + 2 was considered in the analysis of variance. The F-test ($p \leq 0.05$) was used to compare the calcitic and dolomitic ecogypsum at the dose tested. In order to compare the witnesses with the use of the ecogypsum in soils fertilized with NPK, the Dunnet test ($p \leq 0.05$) was used. In order to study the influence of sewage sludge doses associated with each type of ecogypsum, regression analysis was used. Linear and quadratic regression models (R CORE TEAM) were adjusted. The best model adjusted for each case was selected considering the significance of the parameters.

For plant height, which was measured at different stages of development, multiple regression models were adjusted. Twelve regression models were tested:

1- 1- $Z_i = a + bx_i + cy_i + e_i$; 2-$Z_i = a + bx_i + cx_i^2 + dy_i + e_i$; 3-$Z_i = a + bx_i + cy_i + dy_i^2 + e_i$; 4-$Z_i = a + bx_i + cx_i^2 + dy_i + fy_i^2 + e_i$; 5-$Z_i = a + bx_i + cy_i + dx_iy_i + e_i$; 6-$Z_i = a + bx_i + cx_i^2 + dy_i + fx_iy_i + e_i$; 7-$Z_i = a + bx_i + cy_i + dy_i^2 + fx_iy_i + e_i$; 8-$Z_i = a + bx_i + cx_i^2 + dy_i + fy_i^2 + gx_iy_i + e_i$; 9-$Z_i = a + bx_i + cx_i^2 + dy_i + fy_i^2 + gx_iy_i + hx_i^2y_i + e_i$; 10-$Z_i = a + bx_i + cx_i^2 + dy_i + fy_i^2 + gx_iy_i + hx_iy_i^2 + e_i$; 11-$Z_i = a + bx_i + cx_i^2 + dy_i + fy_i^2 + gx_iy_i + hx_i^2y_i + jx_iy_i^2 + e_i$; 12-$Z_i = a + bx_i + cx_i^2 + dy_i + fy_i^2 + gx_iy_i + hx_i^2y_i + jx_iy_i^2 + k_i^2y_i^2 + e_i$.

Where Zi refers to the plant height of the i-th sample, xi is the i-thdose of sludge and yi is the i-thday after planting. The best model was selected based on the lowest estimate of the Akaike Information Criterion (AIC). From the adjusted models the predicted values were obtained, which were used to make surface response graphs.

RESULTS

In general, soil organic matter interferes positively in the development of plants, considering their physical and chemical aspects. The presence of sewage sludge in the soil exerted significant influence ($p \leq 0.05$) at the height of the crambe in all evaluated periods (Figure 1). The increase of the doses of non-composted sludge (LNC) and composted sludge (LC) promoted a linear increase in the growth of *C. abyssinica* up to the average dose of 13 t ha^{-1} with a reduction of the growth rate of the plants with application of 20 t ha^{-1}. It was observed a tendency to fall less accentuated at the time, after optimal dose, in the treatments that received composted sludge as fertilizer. At the end of the experiment, plants with a maximum average height of 95 cm (substrates with composted sewage sludge) and 84 cm (substrates with non-composted sewage sludge) were observed. The results showed that the increase of LNC and LC levels in the substrates containing calcite ecogypsum or dolomite ecogypsum favored the increase of the diameter of the collar, the dry weight of the seeds (g) and the dry weight of the aerial part (g) of the crambe. Polynomial regression curves were adjusted for the aforementioned variables, and average optimal values close to the 13 t ha^{-1} dose were observed (Figure 2).

A linear behavior of the collar diameter was observed only in the substrates that received the combination of non-composted sludge and dolomite ecogypsum (Figure 2). In relation to the dry weight of the seeds and the dry weight of the aerial part of the crambe, all the treatments formulated with conventional fertilization were statistically similar to the treatments that received doses equal to or greater than 5 t $ha^{-1}$of LNC and LC sludge (Table 5). For the variables calcitic gypsum and dolomitic gypsum no significant statistical differences were obtained. The crambe cycle extended from planting to harvesting for a total of 71 days. In relation to the oil content of the crambe, curves were also adjusted for the variables and again, the optimum dose established in this test was close to 13 t ha^{-1} for non-composted sludge (LNC) and composted sludge (LC) (Figure 2). According to the results of the average oil contents in the grains, it was observed that the average of treatments formulated with LC were slightly higher than the average of the LNC, and the two were equal to or higher than the control treatments. The combinations: 5 and 10 t ha^{-1} of LC plus the calcitic and dolomitic ecogypsum and 20 t ha^{-1} LNC plus dolomite ecogypsum were the ones that yielded higher oil production (Table 5).The maximum production of oil by the seeds reached values close to 25% with the use of composted and non-composted sewage sludge, at doses ranging from 10 to 15 ton.ha^1. The emergency occurred in the period between 7 to 10 days. Flowering started between the 36th and 40th days of the cycle.

Table 5. Comparison of average between treatments for height (ALT), diameter of the collar (DIAM), dry weight of seeds (PESO-SEM), aerial parts dry weight (PESO-PA), and percentage of oil in the seeds (PO) according to the dose of non composted sewage sludge (LNC) and composted (LC) and of the calcitic ecogypsum (Gypsum 1) and dolomitic ecogypsum (Gypsum 2) applied to the substrate

Gypsum	Non-composted sewage sludge dose (t ha^{-1})					Composted sewage sludge dose (t ha^{-1})				
	0	5	10	15	20	0	5	10	15	20
					Height (cm)					
Gypsum1	18,87a*	73,25a*	83,87a	78,25a*	57b*	18,87a*	87,37a	83,87a*	91a	88a
Gypsum 2	12 a+	78,25a	74,75a+	78 a	76a+	12a+	86,62a	85,25a	95,87a	89a
			Test 1 (96,00*)					Test 1 (96,00*)		
			Test 2 (93,87+)					Test 2 (93,87+)		
					Collar diameter (mm)					
Gypsum 1	1,56 a*	3,76a	4,45a	4,75a	4,65 a	1,56a*	3,78a*	4,16a	4,22a	4,68a
Gypsum2	1,38 a+	3,67a	4,35a	4,80a	5,34 a	1,38a+	3,97a+	4,17a	4,70a	4,60a
			Test 1 (4,58*)					Test 1 (4,58*)		
			Test 2 (4,69+)					Test 2 (4,68+)		
					Seed dry weight (g)					
Gypsum 1	0a*	1,41a	2,41 a	2,45 a	2,38a	0a*	1,37a	1,50a	1,80a	1,83a
Gypsum2	0a+	1,45a	2,12 a	2,29a	2,30a	0a+	1,36a	1,39a	1,84a	1,90a
			Test 1 (1,61*)					Test 1 (1,61*)		
			Test 2 (1,68+)					Test 2 (1,67+)		
					Aerial parts dry weight (g)					
Gypsum 1	0,58a*	3,78a	5,58a	5,75a	5,52a	0,58a*	4,08b	5,26a	5,27a	5,17a
Gypsum 2	0,61a+	3,98a	6,11a	6,65a	6,20a	0,31a+	5,50a	5,05a	5,55a	4,54a
			Test 1 (4,75*)					Test 1 (4,75*)		
			Test 2 (4,90+)					Test 2 (4,90+)		
					Oil Percentage					
Gypsum 1	0a*	20,33b	19,50a	21,20a	24,40a*	0a*	24,28a*	22,77a*	20,36a	18,81b
Gypsum 2	0a+	23,28a+	20,75a	20,89a	20,13b	0a+	23,70a+	23,41a+	21,57a	22,56+a
			Test 1 (19,04*)					Test 1 (19,04*)		
			Test 2 (19,45+)					Test 2 (19,45+)		

Average followed by the same letters in the column do not differ by the test Fa level of 5% of significance. Average followed by an asterisk and the plus sign differ statistically from control 1 and 2, respectively, by the Dunnet test at the 5% level of significance.

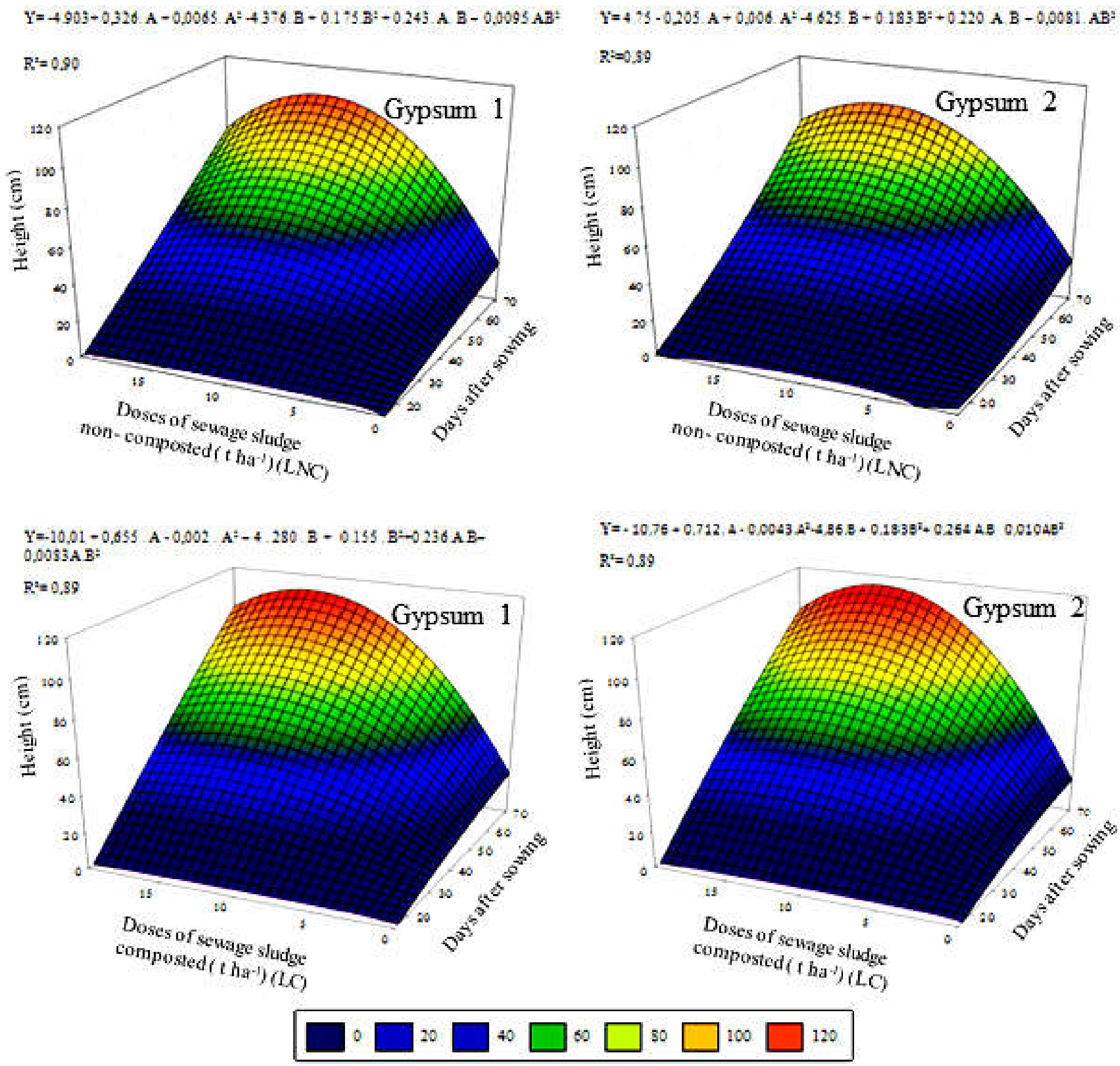

Figure 1. Response surface of crambe (*Crambe abyssinica*) height as a function of the doses (0 t ha $^{-1}$, 5 t ha $^{-1}$, 10 t ha $^{-1}$, 15 t ha $^{-1}$, 20 t ha $^{-1}$) non-composted sludge and composted sludge and calcitic (gypsum 1) and dolomitic (gypsum 2) ecogypsum applied to the substrate and days after sowing

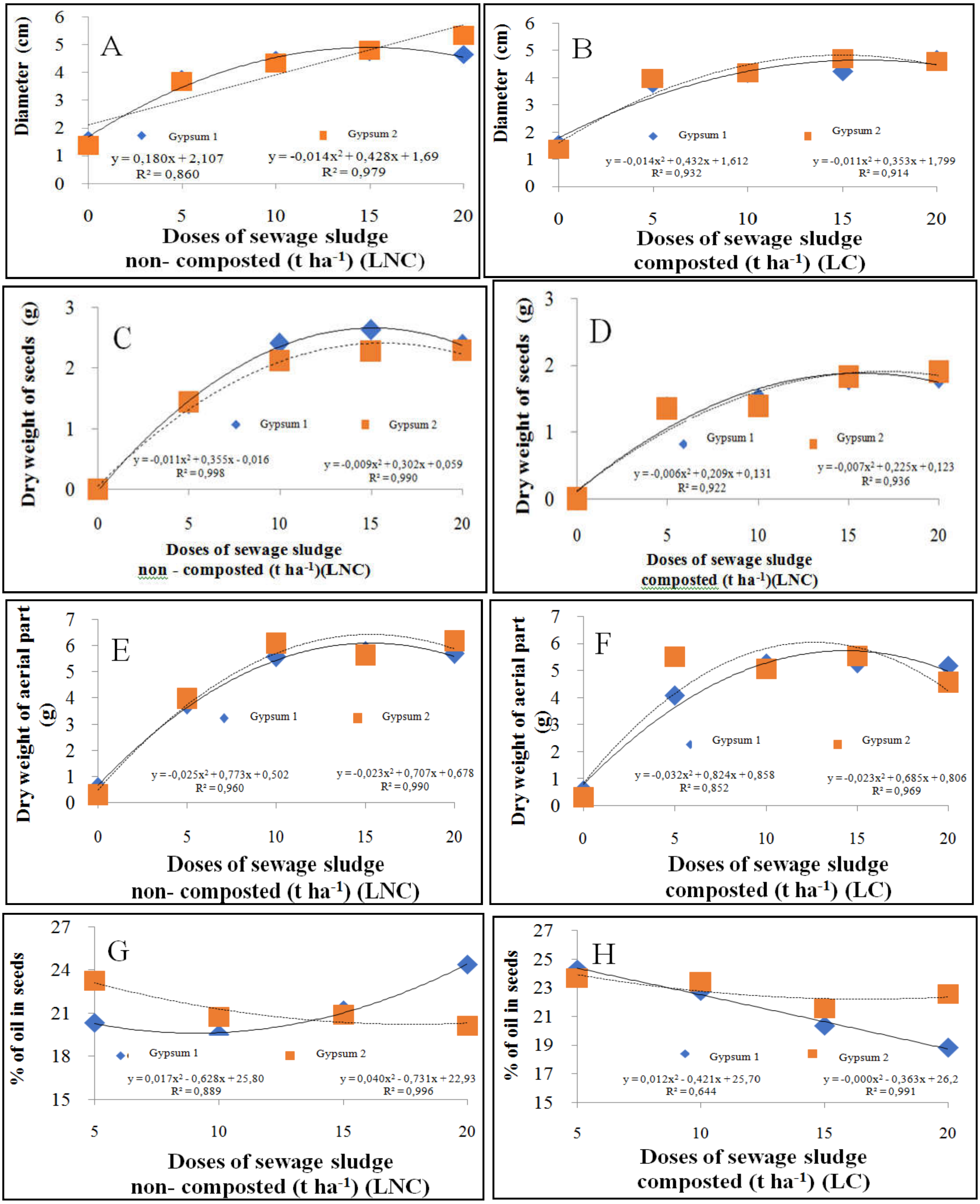

Figure 2. Diameter (cm) (A, B), dry weight of seeds (g) (C, D), dry weight of aerial part (g) (E, F) and percentage of oil in seeds (G, H) of crambe (*Crambe abyssinica*) as a function of doses (ranging from 0 to 20 t ha^{-1}) of the sewage sludge non-composted and composted and ecogypsum calcitic (gypsum 1) and dolomitic (gypsum 2) applied to the substrate

However, it was observed that the substrates based on LC presented plants with higher averages of height (96 cm). The transformation of organic matter by composting, increase of oxidizable organic carbon (labile carbon and readily available to plants) (Blair *et al*., 1995) and C / N ratio (N mineralization) may explain this behavior. Moreover, the increased availability of organic compounds in the soil can increase CTC (Bayer & Bertol, 1999), decrease the negative effects of toxic aluminum (Ciotta *et al*., 2002). Viana *et al*. (2012) verified that the growth of *C. abyssinica* was influenced by the variation of doses of NPK resulting in the average height of 109.54 cm. According to Pitol *et al.* (2010) the crops in the fields of seed production reaches an average height of 80 cm. Jasper, Biaggioni & Silva (2010), using a dose of 200 kg ha-1 (NPK 08-28-16) in Botucatu, SP, reached a maximum height of 95 cm. It was observed that the crambe cycle in the present study (71 days) was lower than those reported in the literature (average between 90 and 100 days) (Pitol *et al*., 2010), presenting short flowering period and early granulation and drying. Probably the temperature influenced this result considering that in the period of cultivation of the oilseed (February to April of 2017) were observed maximum daily temperatures above 30 ºC. Pilau *et al*. (2011) in an experiment carried out in 2009 and 2010 verified different cycles, varying from 77 to 136 days. According to the authors, the air temperature was responsible for the variation of the development cycle of the crambe. These effects are due to the influence of temperature on rise (elevated temperature) or on decrease (low temperature) in the plant's internal metabolic processes. It is thus evident that the higher the temperature, the lower the number of days required for the crambe to develop, resulting in reduced cycle. The average oil content of the seeds was 21% for the non-composted sludge and 22% for the composted sludge (Table 5), which is lower than those reported by Pitol (2008), who mentioned a variation of 26-38%. The shortening of the cycle, which lasts an average of 90 days according to the MS Foundation (2015), and consequent decrease of the crambe granulation period, may justify the difference between the oil content found in the present experiment and those described in the literature (Brito, 2013 (Silva *et al*., 2011). It is known that the oil content can vary according to the conditions of climate, soil and fertilization (Silva *et al*., 2011). Freitas (2010), working with doses of N in cover, found statistical difference in two crops, presenting a reduction in the oil content when increasing the doses of N.

For doses of P_2O_5 and K_2O at sowing there was also a statistical difference; however, the increase in the doses provided an increase in the oil content. Considering that the experimental plot consisted of two plants, theaverage values, per plant, aerial parts dry weight and dry weight of crambe seeds (Table 5) were lower than the values described by Silva *et al*. (2011) and Alves (2015 E / OR 2016). These authors, using increasing doses of chemical fertilizers, found between 5.8 and 7.4 g dry aerial parts mass and 2.0 and 4.5 g dry seed weight respectively. The temperature, by affecting the duration of the phenological phases of the crambe, may have altered the time of capture of light energy, affecting the production and distribution of biomass. Grain dry matter and biomass accumulation in many species are associated with the number of days to maturity, indicating that varieties with higher yield potential would be those with a longer time available for grain filling. If correctly fertilized the crambe has potential to be cultivated in the cerrado or semiarid because it has proven to be tolerant to high temperatures. The hardening of environmental legislation encouraged companies to go beyond appropriate disposal and seek alternatives for reuse of by-products.

Thus came the idea of transforming the residue of the lead-acid type of automotive batteries into agricultural eco-grains. According to the chemical analyzes, the toxic metals content of the ecogypsum (Table 4) are within the limits allowed by CONAMA 2009 for use in agriculture. In the case of crambe cultivation, it is possible to affirm that the use of calcitic ecogupsum or dolomite ecogypsum in the substrates did not negatively interfere in the development of the plants, becoming an option of reuse and promoting the ecogypsum of residue for co-product. It was expected that the use of dolomite ecogypsum as soil conditioner would provide better performance in crambe cultivation, considering the presence of magnesium. However, the calcitic and dolomitic ecogypsum did not differ significantly in productivity, indicating that the nutrient is not limiting to the development of crambe in the soil used. The use of sludge and ecogypsum incorporates greater sustainability to the cultivation of crambe destined to the production of biofuels, making possible to reduce and even eliminate the use of chemical fertilizers. It has been proven that among disposal options, waste recycling in agriculture stands out once again as an interesting choice from the economic, environmental, and social point of view.

Conclusion

The use of composted, non-composted sludge and calcitic and dolomitic ecogypsum are viable fertilization alternatives for crambe and favor the growth and development of oleaginous. Fertilizing with sludge produced significant results when compared to conventional fertilization. The dose of 13 t ha^{-1} of sewage sludge is recommended, with application of ecogypsum based on soil clay content and pH close to neutral, for the cultivation of *C. abysinica* in Cerrado soil.

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REFERENCES

ALVES, J. M. 2013. Resposta crambe (*Crambe abyssinica*) a calagem e adubação mineral em solos o Cerrado. 2013. 103p. Tese (Doutorado em Agronomia) - Universidade Federal de Goiás, Goiânia, GO.

BAYER, C.; BERTOL, I. 1999. Características químicas de um Cambissolo húmico afetadas por sistemas de preparo, com ênfase à matéria orgânica. RevistaBrasileira de Ciência do Solo, Viçosa, v. 23, p. 687-694.

BORUGADDA, V. B.; GOUD, V. V. 2012. Biodiesel production from renewable feeds tocks: Status and opportunities. Renewable and Sustainable Energy Reviews, v. 16, p. 4763-4784.

BRITO, D. M. C. Aspectos do metabolismo de plantas de crambe (*Crambe abyssinica*) submetidas a diferentes doses de nitrogênio visando a produção de óleo para biodiesel. (2009). 64 f. Dissertação (Mestrado em Química) – Universidade Federal Rural do Rio de Janeiro, Seropédica, 2009.

CIOTTA, M. N.; BAYER, C.; ERNANI, P. R.; FONTOURA, S. M. V.; ALBUQUERQUE, J. A.; WOBETO, C. 2002. Acidificação de um latossolo sob plantio direto. Revista Brasileira de Ciência do Solo , Viçosa, v. 26, p. 1055-1064.

FALASCA, S. L.; FLORES, N.; LAMAS, M. C.; CARBALLO, S. M.; ANSCHAU, A. 2010. *Crambe abyssinica*: Analmost unknown crop with a promissory future to produce biodiesel in Argentina. *International Journal of Hydrogen Energy,* v. 35, p. 5808-5812.

FREITAS M. E. E. 2010. Comportamento agronômico da cultura do crambe (*Crambe abyssinica* Hochst) em função do manejo empregado. 42 f. Dissertação (Programa de Pós Graduação em Agronomia – Produção Vegetal). Universidade Federal da Grande Dourados – UFGD. Dourados, MS.

JASPER, S. P.; BIAGGIONI, M. A. M.; SILVA, P. R. A. 2010. Comparação do custo de produção do crambe (*Crambe abyssinica* Hochst) com outras culturas oleaginosas em sistema de plantio direto. Revista Energia na Agricultura, Botucatu, v. 25, n. 4, p. 141- 153.

KNIGHTS, S. 2003. Crambe: A North Dakotan case study. Disponível em: . Acesso em: 20 mar. 2012.

LAGHETTI, G.; PIERGIOVANNI, A. R.; PERRINO, P. 1995. Yield and oil quality in selected lines of *Crambe abyssinica* grow in Italy. Industrial CropsandProducts, London, v. 4, n. 3, p. 205-212.

LIU, H.-T. 2016. Achilles heel of environmental risk from recycling of sludge to soil as amendment: A summary in recent ten years (2007–2016). Waste Management, v. 56, p. 575-58.

MODESTO, P. T.; VIEIRA, I. G.; FERNANDES, G. D. 2009. Alterações em algumas propriedades de um latossolo degradado com uso de lodo de esgoto e resíduos orgânicos. Revista Brasileira de Ciência do Solo, Viçosa, v. 33, n. 5, p. 1489-1498.

PITOL, C. 2008. Cultura do crambe. In: Tecnologia de produção: Milho safrinha e culturas de inverno. Maracajú: Fundação MS, p. 85-88.

PITOL, C.; BROCH, D. L.; ROSCOE, R. 2010. Tecnologia e produção: crambe 2010. Maracaju: Fundação MS.

QUINTANA, N. R. G.; CARMO, M. S.; MELO, W. J. 2011. Lodo de esgoto como fertilizante: produtividade agrícola e rentabilidade econômica. Nucleus, v. 8, n. 1, p. 183-192.

SILVA, T. R. B.; LAVAGNOLLI, R. F.; NOLLA, A. 2011. Zinc and phosphorus fertilization of crambe (*Crambe abyssinica* Hoechst). Journal of Food, Agriculture & Environment, Helsinki, v. 9(1), p. 264-167.

VAZQUEZ, G. H; LAZARINI, E; CAMARGO, F. P.; FERREIRA, R. B; PERES, A. R. 2014. Produtividade, qualidade fisiológica e composição química de sementes de crambe em diferentes doses de fosforo, Biosci. J., Uberlândia, v. 30, n. 3, p. 707-714, May/June,.

VIANA, O. H.; SANTOS, R. F.; SECCO, D.; DE SOUZA, S. N. M.; CATTANÊO, A.J. 2012. Efeitos de diferentes doses de adubação de base no desenvolvimento e produtividade de grãos e óleo na cultura do crambe. Acta Iguazu, Cascavel, v.1, n.1, p. 33-41.

VIEIRA, R. F; TANAKA, R. T.; SILVA, C. M. M. S. 2004. Utilização do Lodo de Esgoto na Cultura de Soja. Embrapa: Boletim de Pesquisa e Desenvolvimento Jaguariúna –SP, Julho, 26p.

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