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SOYBEAN CROP FERTILIZATION WITH CRAMBE CAKE

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ABSTRACT

Organic fertilizer based in crambe cake can improve plant growth and nutritional absorption, this present work contains some useful findings on soybean fertilization with crambe cake in camparision with mineral fertilization. Crambe cake is a by-product of vegetable oil production. Because its high nutrient content, it use as an organic fertilizer, what would reduce environmental contamination caused by improper disposal and turn this residue into a valuable agricultural input. Therefore, the objective of this work was to evaluate soybean fertilization with crambe cake in comparison with mineral fertilization. The experiment was carried out at the Rural Development Institute of Paraná in Brazil. Doses of 0, 2, 4, and 8 t ha^{-1} of crambe cake applied by topdressing and an additional treatment with mineral fertilization were evaluated. The adopted design was randomized blocks with four replications. The following variables were analyzed: yield, plant height, one thousand seed weight, lodging, and soil and foliar nutrient status. Obtained data were subjected to analyses of variance, regression analysis and means were compared using the Tukey test at 5 % probability; in addition, comparisons with the additional treatment were made by contrast analysis. High doses of crambe cake resulted in taller plants, higher lodging index, and higher one thousand seeds weight. No statistical differences in yield and nutrient levels in the soil and leaves were observed in response to treatments. In conclusion, costly chemical fertilization in soybean production can be replaced by crambe cake.

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INTRODUÇÃO

For the proper development of any crop, it is essential that the soil provides the nutrients required by the crop throughout the growth cycle. Motter *et al.* (2012) state that plant nutrition is one of the most important components responsible for high yields. Accordingly, by-products of vegetable oil production can become nutrient suppliers, turning agro-industrial wastes into useful agricultural inputs (Scotti *et al*. 2018). According to Severino *et al*. (2006) the amount of a fertilizer to be applied is usually based on the need of the crop. Aiming at efficient fertilization, it is also essential to evaluate the soil and climate conditions in the region, and to consider the amounts of nutrients extracted and exported by the crop. The application of jatropha cake in low fertility soil, for example, in addition to increased crop yield, boosted nutrient levels in the soil (Anand *et al*. 2015). Industrial applications of vegetable oils have increased substantially in recent decades, addressing the need to reduce dependence on fossil derivatives. Crambe oil (*Crambe abyssinica* Hoschst. Ex R. E. Fries) owes its commercial value to its physico-chemical characteristics suitable for various industrial purposes, such as thermoelectric insulation and biodiesel production (Bassegio *et al*. 2016; Rosa *et al*. 2014).

The main by-product of crambe oil extraction is known as crambe cake, whose properties, use, and agro-industrial value need to be explored. Often discarded, the crambe seed cake, from the *Brassicaceae* family, is made after oil extraction by extrusion. Disposing of this material has negative impacts on the environment because of high volumes produced and its toxicity, as the crambe seed contains high levels of erucic acid (Onorevoli *et al*. 2014). Consequently, it is necessary to come up with adequate uses for this residue, and a promising crambe cake application is its use as an organic fertilizer due to a high nutrient content.

Among these nutrients stand out nitrogen, phosphorus, potassium, calcium, and magnesium, which are the major nutrients taken up by crops. Because of its profitability, soybean is the most cultivated crop in agricultural lands in Brazil. However, its nutritional requirements maintain production costs high. A possible low-cost alternative is fertilization using agro-industrial by-products. Therefore, this study aimed to investigate the effects of soil fertilization with crambe cake at various doses on the productive characteristics of soybean in comparison with mineral fertilization.

MATERIAL AND METHODS

The experiment was carried out at the Experimental Station of the Rural Development Institute of Paraná (IRD - Paraná, Brazil), located in the municipality of Santa Teresa do Oeste in the State of Paraná at coordinates 25° 04' 57.22" south latitude and 53° 35' 03.33" west longitude, average altitude of 757 m, and characterized by a humid subtropical climate (Köppen climate Classification: Cfa). The average annual precipitation in the region was 1886 mm during the study year. According to Santos *et al*. (2014), the soil is classified as Dystroferric Red Latosol of very clayey texture (650 g kg^{-1} clay). In August 2016, soil samples were collected on the experimental site at 0-20 cm depth to quantify physical and chemical soil attributes before the implementation of the experiment. The soil in the area presented the following chemical characteristics: pH ($CaCl_2$) = 4.8; carbon = 28 g dm^{-3}; p (Mehlich-1) = 16 mg dm^{-3}; H+Al = 7.2 cmol$_c$ dm^{-3}; K (Mehlich-1) = 0.31 cmol$_c$ dm^{-3}; Ca = 6.5 cmol$_c$ dm^{-3}; Mg = 2.8 cmol$_c$ dm^{-3} and base saturation = 57 %. The adopted design was randomized blocks with four replications. Four doses of crambe cake were evaluated: 0, 2, 4, and 8 t ha^{-1} applied by topdressing, and one treatment with mineral fertilization: 200 kg ha^{-1} of NPK mixture 04-30-10 applied at planting into furrows, and topdressing 15 days after plant emergence with 50 kg ha^{-1} K_2 (KCl as the source). Each experimental plot had nine rows, each five meters long, spaced 0.45 m apart, totaling an area of 20.25 m^2. Crambe cake used in this work was obtained after mechanical extraction of crambe seed oil in a continuous cold system, without the use of solvents. A TEC SLIM 2000 extruder and a TEC SLIM 2000 softpress were used in this process. The crambe cake contained 5 % N, 1.5 % P_2O_5, 1.4 % K_2O, 1 % Ca, and 0.5 % Mg. Supplied amounts of N, P, and K in each dose are presented in Table 1.

Table 1. Amounts of N, P_2O_5, and K_2O supplied in treatments

Treatments	N	P_2O_5	K_2O
	------- (kg ha^{-1}) -------		
Control	0	0	0
2 t ha^{-1}crambe cake	100	30	28
4 t ha^{-1}crambe cake	200	60	56
8 t ha^{-1}crambe cake	400	120	112
Mineral fertilizer*	8	60	70

* 200 kg ha^{-1} of NPK mixture 04-30-10 into planting furrows, and topdressing with 50 kg ha^{-1} of K_2O (KCl).

Soybean seeding was carried out in October 2016 using a continuous flow seeder with 0.45 m row spacing and 2-3 cm seeding depth. The evaluated soybean cultivar was 'Lança IPRO'. The application of crambe cake took place on the day of sowing. Crop treatments were carried out according to crop requirements. The following variables were evaluated: plant height, lodging, one thousand seed weight, foliar levels of N, P, K, Ca, and Mg, seed yield, and levels of P, K, Ca, and Mg in the soil. Plant height was determined on the day of harvest and comprised the distance from the soil to the top of the plant. The percentage of lodged plants was evaluated on the harvest day. It was determined by counting lodged plants and the total number of plants in an area of 10 m^2 in each experimental plot. In each plot, 30 newly mature leaves, each with the petiole, were collected when plants presented the phenological stage of full flowering. After collection, they were washed with distilled water, packed in paper bags, and dried in a forced-air circulation oven at 65°C for 72 h. They were then ground in a Wiley-type mill with a 0.84-mm mesh sieve. Dry matter was mineralized by nitric-perchloric mixture (3:1 v v^{-1}). The level of K was determined by flame emission photometry and P by colorimetry. The semi-micro-Kjeldahl method was used to determine N level using sulfuric acid to mineralize the samples. All chemical analyses of leaf tissues were performed according to the methodology described by Tedesco *et al*. (1995). The harvest was carried out using a Precision Automotive Harvester developed for experimental units, Wintersteiger Seed Mech®, Model Nursery Master Elite®. To determine the yield, the useful area was comprised of five central rows discarding 0.5 m from both ends, totaling a harvested area of 9 m^2. Harvested seeds were sent to the laboratory for processing, weighing, and moisture determination. Subsequently, the yield (kg ha^{-1}) was calculated by correcting to 13 % humidity. The weight of one thousand seeds was determined according to the rules for seed analysis (RAS 2009). Eight repetitions of 1000 seeds were carried out on each plot. Then, they were weighed. When the soybean harvest was completed, soil samples were collected in each plot at 0-10 cm depth. Six sub-samples were collected in each plot, one in a row and two between rows. After collection, the sub-samples were homogenized forming one sample of approximately 500 g. Next, the sample was cleaned in the laboratory, sieved through a 2 mm mesh, and placed for air drying. Then, P and K levels were checked using the Mehlich-1 extractor, and Ca and Mg levels using the KCl 1 mol L^{-1} extractor, according to the methodology described by Pavan *et al*. (1992). Obtained data were submitted to analysis of variance (ANOVA). The effect of crambe cake doses on growth components was evaluated by regression analysisand fitted to mathematical models with best levels of significance and the highest value of determination coefficient (R^2). The effect of the additional treatment was compared by contrast analysis with the dose of 4 t ha^{-1} crambe cake, since both provide 60 kg ha^{-1} of P_2O_5. Means were compared by the Tukey test at 5% probability and all analyses were performed using the Assistat application (Silva; Azevedo 2016).

RESULTS AND DISCUSSION

Results of plant height, lodging index, one thousand seeds weight, and grain yield in function of crambe cake doses are presented on Figure 1. Were verified that plant heights (Figure 1A), lodging index (Figure 1B), and one thousand seed weight (Figure 1C) fitted significantly to a second-order polynomial regression, increasing according to doses of crambe cake, reaching 103 cm, 5.5 %, and 172.8 g with the dose of 8 t ha^{-1}, respectively. Increasing doses of crambe resulted in higher lodgind index. Lodging is directly influenced by plant growth (Linzmeyer Junior *et al*. 2008). Studies comparing doses of organic residues applied in soybean crops found that high doses tend to promote lodging (Carvalho *et al*. 2011). The availability of N in abundance leads to disordered growth of above-ground parts in relation to root growth, resulting in lodging of plants, as stated by Taiz and Zeiger (2017). In the case of the treatment with 8 t ha^{-1} of crambe cake, 400 kg ha^{-1} of N were available (Table 1), which may have boosted growth and thereby lodging. Evaluating the application of filter cake, an organic residue from the sugarcane agro-industry, Nulla *et al*. (2017) also found taller soybean plants, reaching the maximum height at 20 t ha^{-1} of this residue. A high lodging index can pose a problem for mechanized harvest and generate yield losses. Thus, these data should be considered when higher doses of crambe cake are applied to prevent yield losses. It is therefore suggested to reduce plant population or apply lower doses of the cake. One thousand seeds weight showed rise in function of crambe cake doses increase. Similarly, Schuroff *et al*. (2020), when evaluating crambe cake doses, it was found that raising doses increased one thousand seeds weight, reaching the maximum at 12.1 t ha^{-1}, and decreased above this dose. There was no significant difference in N, P, K and Ca and Mg foliar levels in function of crambe cake doses (Table 2). In relation to the nitrogen foliar levels observed, according to the reference levels recommended by the Manual of Fertilization and Liming for the state of Paraná (NEPAR-SBCS, 2017), N levels above 41 g kg^{-1} in soybean leaves collected with petiole are considered adequate. Consequently, N levels found in leaves in treatments in this work are suitable for soybean cultivation. Foliar P levels between 2.8 and 3.6 g kg^{-1} are considered sufficient (NEPAR-SBCS, 2017). Thus, in the present study, all crambe cake doses provided plants with sufficient P levels. To all doses studied, foliar K levels were also considered sufficient, i.e., higher than 22 g kg^{-1} (NEPAR-SBCS 2017). Pereira (2017) fertilized crambe crop with different doses of pig manure and poultry manure and compared to mineral fertilization. That study also did not show a significant difference in foliar K levels in crambe. In that experiment, soil K level before crop planting was 0.31 cmol$_c$ dm^{-3}, and soil K level

Table 2. Foliar levels of nitrogen, phosphorus, potassium, calcium, and magnesium in soybean leaves as a function of fertilization with doses of crambe. Santa Tereza do Oeste, Paraná, Brazil 2017

Crambe cake	N	P	K	Ca	Mg
($t\ ha^{-1}$)			($g\ kg^{-1}$)		
0	41.04	3.00	22.71	17.29	5.33
2	42.53	2.86	22.47	15.59	5.01
4	41.85	2.85	22.21	15.61	5.05
8	42.03	2.94	22.28	15.84	5.21
Mean	41.86 ^{ns}	2.91 ^{ns}	22.42 ^{ns}	16.08 ^{ns}	5.15 ^{ns}
CV (%)	4.56	9.51	3.99	11.55	10.01

^{ns} = do not differ by the F test at 5 %.

Table 3. Levels of phosphorus, potassium, calcium, and magnesium in soil as a function of fertilization with crambe cake after soybean harvest. Santa Tereza do Oeste, 2017

Crambe cake	P	K	Ca	Mg
($t\ ha^{-1}$)	($mg\ dm^{-3}$)		($cmol_c dm^{-3}$)	
0	16.67	0.48	5.94	2.31
2	11.63	0.52	5.98	2.34
4	12.19	0.44	5.18	2.03
8	13.71	0.57	5.53	2.19
Mean	13.55 ^{ns}	0.50 ^{ns}	5.66 ^{ns}	2.22 ^{ns}
CV(%)	49.21	22.78	17.9	28.26

^{ns} = do not differ by the F test at 5 %.

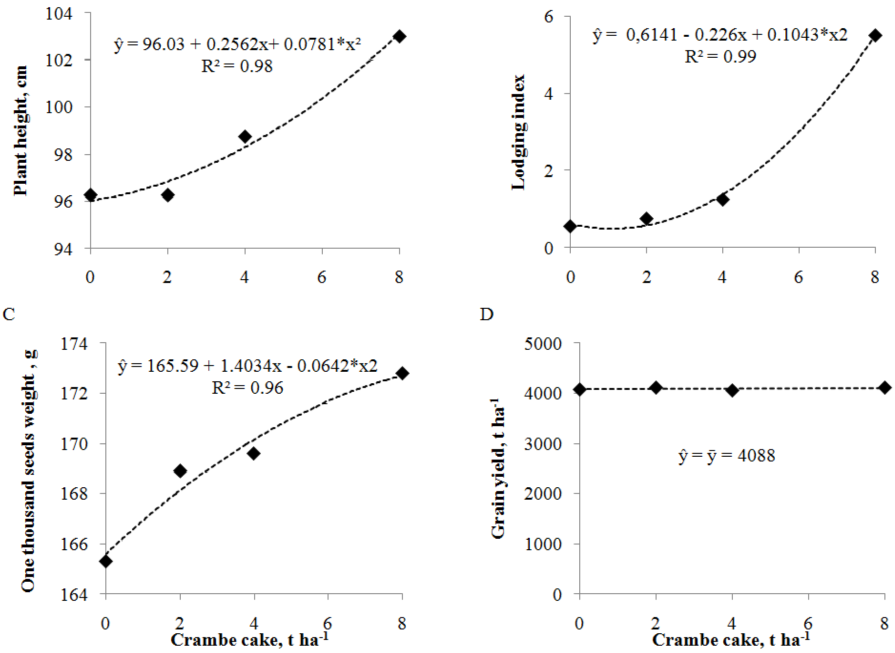

Fig. 1. Plant height (A), lodging index (B), one thousand seeds weight (C), and grain yield (D) of soybean cultivar 'Lança IPRO' in function of camber cake applied to soil, Santa Tereza do Oeste, Paraná, Brazil, 2017

Table 4 Plant height (PH) and soybean lodging index (LI), one thousand seeds weight (TSW), yield of soybeans, foliar levels (FL) of nutrients and levels of phosphorus, potassium, calcium, and magnesium in soil as a function of fertilization with doses of crambe cake compared to mineral fertilization

	4 $t\ ha^{-1}$ crambe cake (60 $kg\ ha^{-1}$ P_2O_5)	Mineral fertilizer* (60 $kg\ ha^{-1}$ P_2O_5)
PH, cm	98.75 a	97.00 a
LI, %	1.25 a	0.75 b
TSW, g	169.60 a	170.20 a
Yeld, $kg\ ha^{-1}$	4053.66 a	4136.70 a
FL N, $g\ kg^{-1}$	41.85 a	42.04 a
FL P, $g\ kg^{-1}$	2.85 a	2.93 a
FL K, $g\ kg^{-1}$	22.21 a	22.01 a
FL Ca, $g\ kg^{-1}$	15.61 a	15.13 a
FL Mg, $g\ kg^{-1}$	5.05 a	4.93 a
P soil, $mg\ dm^{-3}$	12.19 a	14.05 a
K soil, $cmol_c\ mg\ dm^{-3}$	0.44 a	0.59 a
Ca soil, $cmol_c\ mg\ dm^{-3}$	5.18 a	5.53 a
Mg soil, $cmol_c\ mg\ dm^{-3}$	2.03 a	2.12 a

Averages followed by the same letter in columns do not differ by the F test at 5 %. *200 $kg\ ha^{-1}$ of NPK mixture 04-30-10 at sowing and 50 $kg\ ha^{-1}$ of K_2O (KCl) in broadcast before planting in the present work was equivalent to the work mentioned above. Urano *et al*. (2006) evaluated 111 soybean plots in the state of Mato Grosso do Sul, 39 of which were considered high yields. Plants on those plots had foliar contents 40.6 g kg^{-1} N, 3.0 g kg^{-1} P, and 23.1 g kg^{-1} K. Those values are similar to the values observed in this study. Levels above 8-11 g kg^{-1} and 3.0-4.8 g kg^{-1} of Ca and Mg, respectively, are considered adequate foliar contents. Therefore, the absence of a significant difference between doses may be related to high nutrient levels available in the soil prior to the experiment. In relation to P, K, Ca, and Mg levels in the soil, no statistical difference between the experimental doses and the control plots were observed (Table 3). The uptake of nutrients by soybeans met the crop requirements regardless of the treatment. The impact of physico-chemical characteristics of the soil and the climate in the region on plant growth and nutrient uptake should be considered. Observed agronomic characteristics of soybeans may not have been affected by fertilization with crambe cake due to good soil fertility. In relation to P, K, Ca, and Mg levels in the soil, there was no statistical difference between the experimental doses and the control plots (Table 3). Possibly, levels of these nutrients, except K, were native to the soil since pre-treatment analyses already showed P, Ca, and Mg levels similar to those found after the harvest; however, it is important to note that pre-treatment soil data were not included in statistical analyses. Another hypothesis is that adopted treatments had a replacement fertilization effect since there was an uptake of nutrients by soybean plants at adequate levels. Replacement fertilization is recommended when nutrient levels are high or too high for the cultivation of the species, and is based on the replacement of nutrients extracted or exported by the crop (Santin *et al*. 2017). The contrast analysis showed the application of crambe cake did not produce significant differences in evaluated variables compared to mineral fertilization (Table 4). This fact shows that crambe cake can totally replace mineral fertilization in soybean crops in rich soils, like those on the experimental site. In contrast, cakes from oilseed crops, such as sunflower, castor, jatropha, and from *Brassicaceae,* such as canola and mustard, used as organic fertilizers have been proven efficient in providing nutrients and improving the fertility of sandy soils and/or low fertility soils (Anand *et al*. 2015, Schultz *et al*. 2019, Scotti *et al*. 2018). Studies indicate that oilseed cake can be considered an alternative source of fertilization because it is rich in organic matter, which, upon decomposition, provides a slow release of nutrients, rendering it an effective short- and long-term nutrient source in crop production (Anand *et al*. 2015 Scotti *et al*. 2018). Evaluating the application of filter cake in soybean cultivation under sandy soil conditions with low fertility, Nolla *et al*. (2017) found that the dose of 20 t ha^{-1} provided the best seed yield. Soils under these conditions usually respond to fertilization more than other soils since they demand nutrients immediately. Probably, crambe cake would also meet the demand for nutrients in this type of soil, but there are no data available on the use of this residue in low fertility soils.

CONCLUSION

Crambe cake can be used to fertilize soybean crops in soils with high fertility. In these cases, mineral fertilization can be replaced by crambe cake, bringing more sustainability to the production. Further studies with the application of crambe cake in low fertility soils are suggested to evaluate its efficiency in the development of soil fertility.

REFERENCES

Anand, K. G.; Kubava, D., Trivedi, K., Agarwal, P. K., Wheeler, C., Ghosh, A. 2015. Long-term application of Jatropha press cake promotes seed yield by enhanced soil organic carbon accumulation, microbial biomass and enzymatic activities in soils of semi-arid tropical wastelands. Eur J Soil Biol. 69, pp. 57-65. https://doi.org/10.1016/j.ejsobi.2015.05.005

Bassegio D, Zanotto MD, Santos RF, Werncke I, Dias PP, Olivo M (2016). Oilseed crop crambe as a source of renewable energy in Brazil. Renew Sust Energ Ver. 66, pp. 311-321. https://doi.org/10.1016/j.rser.2016.08.010

Carvalho, E. R., Rezende, P. K., Andrade, M. J. B., Passos, A. M. A., Oliveira, J. A. 2011. Mineral fertilizer and organic waste on soybean crop and soil nutrients. Rev Cienc Agron. 42,pp. 930-939. https://doi.org/10.1590/S1806-66902011000400015.

https://doi.org/10.1016/j.scitotenv.2019.133652

https://doi.org/10.1590/S0100-204X2006000400003.

https://doi.org/10.1590/S0101-31222009000100008

Lima,E. V., Crusciol, C. A. C., Cavariani, C., Nakagawa, J. 2009. Agronomic traits, yield and physiological quality of "safrinha" (off-season) soybean under no till as a function of plant cover and surface liming. Rev Bras Sem. 31, pp. 69-80.

Linzmeyer Junior, R., Guimarães, V. F., Santos, D., Bencke, M. H. 2008. Influence of vegetal retardant and densities of sowing on the growth, fallen plant index and yield of soybean. Acta Sci, Agron. 30, pp. 373-379. https://doi.org/10.4025/actasciagron.v30i3.3547.

Motter, A., Giongo, L., Rossono, M. E., Meneghetti, M. L., Matos, R. E., Oliveira, R. C. 2012.Nutrição mineral e aincidência de patógenosemplantas. In: Viecelli CA Nutrição mineral e aincidência de doençasemplantas. Cascavel: Assoeste, pp.15-30.

NEPAR-SBCS SociedadeBrasileira De Ciência Do Solo- NúcleoEstadual Paraná. 2017. Manual de adubação e calagem para o estado do Paraná. Curitiba.

Nolla, A. (2017). Growth and soybean yield submitted to filter cake doses in a sandy oxisol. J Agronom Sci. 6, pp.1-11.

Onorevoli, B., Machado, M. E., Dariva, C., Franceschi, E., Krause, L.C., Jacques, R.A., Caramão, E.B. 2014. A one-dimensional and comprehensive two-dimensional gas chromatography study of the oil and the bio-oil of the residual cakes from the seeds of Crambe abyssinica. Ind Crop Prod. 52, pp. 8-16. https://doi.org/10.1016/j.indcrop.2013.09.034

Pavan, M. A., Bloch, M. F., Zempulski, H. C., Miyazawa, M., Zocole, R. D. C. 1992. Manual de análisequímica do solo e controle de qualidade. IAPAR: Londrina.

Pereira, N. 2017.Crambe fertilization with animals manure. Dissertation, Western Paraná State University.

RAS. 2009.Regras para análise de sementes. Ministério da Agricultura, Pecuária e Abastecimento: Brasília.

Rosa, H. A., Wazilewski, W. T., Secco, D., Chaves, L. I., Veloso, G., Souza, S. N. M., Silva, M., Santos, R. F. 2014. Biodiesel produced from crambe oil in Brazil—A study of performance and emissions in a diesel cycle engine generator. Renew Sust Energ Rev. 38, pp. 651-655. https://doi.org/10.1016/j.rser.2014.07.013

Santin, D., Benedetti, E. L., Barros, N. F., Fontes, L. L., Almeida, I. C., Neves, J. C. L., Wendling, I. 2017. Harvest handling and phosphate nutrition in yerba-matte (*Ilex paraguariensis*) culture during production stage. Cienc Florest. 27, pp. 783-797. https://doi.org/10.5902/1980509828629

Santos, H. G., Jacomine, P. K. T., Anjos, L. H. C., Oliveira, V. A., Lubreras, J. F., Coelho, M. R., Almeida, J. A., Cunha, T, F., Oliveira. J. B. (eds). Sistema brasileira de classificação de solos. 4rdedn. Embrapa, Brasília: Embrapa.

Schultz, N., Leite, T. O., Coelho, A. L. M., Pinheiro Junior, C. R., Zonta, E. 2019. Chemical attributes of soil and growth of castor beans fertilized with drilling gravel from oil wells and castor pie. Sci Total Environ. 695, pp. 133652.

Schuroff, C. K., Weber, T., Lopes, C. L., Andrade, E. A.,Doreto, L., Pereira, N.,Zanão Júnior, L. A. 2020. Canola fertilization with crambe cake. Acta Iguazu. 9, pp. 53-61.

Scotti, R., Pane, C., Zaccardelli, M. 2018. Short-term interaction between organic matter from biofuel defatted seed cakes and soil microbiota in two intensive horticulture systems. Eur J Soil Biol. 85, pp. 30-35. https://doi.org/10.1016/j.ejsobi.2018.01.002

Severino, L. S., Ferreira, G. B., Moraes, C. R. A., Gondim, T. M. S., Freire, W. S. A., Castro, D. A., Cardoso, G. D., Beltrão, N. E. M. 2006 Growth and yield of castor bean fertilized with macronutrients and micronutrients. PesqAgropec Bras. 41, pp. 563-568.

Silva, F. A. S., Azevedo, C. A. V. 2016. The Assistat Software version 7.7 and e its use the analysis of experimental data. Afric J Agri Res. 11, pp. 3733-3740.

Taiz, L., Zeiger, E. 2017.Fisiologia vegetal. 6thed. Artmed: Porto Alegre.

Tedesco, M. J., Gianello, C., Bissani, C. A., Bohnen, H., Volkweiss, S. J. 1995.Análises de solo, plantas e outros materiais. 2nd ed. UFRGS: Porto Alegre.

Urano, E. O. M., Kurihara, C. H., Maeda, S., Vitorino, A. C. T., Gonçalves, M. C., Marchetti, M. E. 2006. Soybean nutritional status evaluation. PesqAgropec Bras. 41, pp. 1421-1428. https://doi.org/10.1590/S0100-204X2006000900011.

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