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Long-term application of swine manure on soybean grown in no-till system in Savannah soils

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The application of liquid swine manure (LSM) in the soil as biofertilizer is one of the most recycling alternatives adopted, because the nutrients contained in this residue can override, in part or totally, commercial fertilizers, crop productivity with a reduction in production costs. The goal with this work was to evaluate the use of LSM as a substitute of mineral fertilization on soybean culture in conditions of Savannah in 2014/2015. The experimental design was of randomized blocks with three replications. The treatments consisted of the use of mineral fertilizer recommended for soybean culture; without fertilization; and doses of LSM (25; 50; 75 and 100 m³ ha^{-1}). The levels of N, P, K, Ca, Mg, Cu, Zn, Mn and Fe in leaves, seeds and dry matter from the shoot, plant height and productivity of grain was assessed. There was no statistical difference between treatments that received mineral fertilization (P and K) and the treatments that received pig manure, indicating that the use of pig waste as bio fertilizer on soybean fertilization may be a promising alternative. The mineral fertilizer in soybean culture can be replaced by shots of LSM from 80 m³ ha^{-1} with no losses in grain productivity in a clayey dystroferric Red Latosol. The applications of doses of pig manure generally did not promote increase in the content of nutrients in grains and in the extraction of nutrients by the aerial part of the soybeans plants.

Key words: Bio fertilizer, successive applications, waste, organic fertilization, animal production, organic matter.

INTRODUCTION

Soybean has great economic and social importance in the world, because it is the main oilseed crop produced and consumed. Its production is destined for animal consumption, through the soybean meal, as well as for human consumption through oil and other products (Hirakuri and Lazzarotto, 2014). In ideal conditions of environment, the soybean responds with high productivity. One of the most important management techniques to get them is the fertilization. Aiming to improve utilization and reduce dependence on fertilizers, the Brazil alternative is search of soil fertilization. In many regions, there is use of local waste connections, being viable option, when used properly (Hoffmann et al., 2001).

The use of animal waste as fertilizer is a rational alternative and of great interest in terms of environmental, economic, social and agronomic traits. Apply organic waste in the soil system promotes infiltration and water absorption, improving the ability to exchange cations, resulting in better yields (Higashikawa et al., 2010). According to Lopes and Caixeta (2000), pig farming is an activity of economic importance mainly in the agricultural sector in the region of southwest Goiano. The Rio Verde region stands out for its dynamic economy and high grain production prompted the incentive of public policies for the State of Goiás, drawing huge agribusiness of pig meat to the region.

Currently, in this region, there are a large number of pig farms, where animals are kept in confinement system which is concentrated in small areas, large volumes of waste in liquid form. The proper management of these wastes is essential to the sustainability of the Brazilian swine demonstrating the need to know the environmental aspects of the scrap (Menezes et al., 2003). The pig manure, consisting of a mixture of feces, urine, food scraps, and a variable amount of water are typically handled in liquid form (Aita and Giacomini, 2008).

Various alternatives have been proposed for utilization of such waste in agriculture, and use as fertilizer in the soil, one of the most promising, since applied with discretion (Amorim et al., 2005; Sediyama et al., 2005; Corrêa et al., 2001; Santos et al., 2012; Lourenzi et al., 2014; Sediyama et al., 2014; Sousa et al., 2014). These technical criteria take into account the extraction of nutrients, nutritional requirement of the crop, soil fertility and waste analysis (Correa et al., 2011). Successive applications of liquid swine manure in the same area may lead to environmental problems such as the possibility of contamination of the water table (Zaman and Blennerhassett, 2010; Gonzatto et al., 2013; Aita et al., 2014; Giacomini et al., 2014).

The problem of pig manure management is complex and there is no *a priori* solution, but several possibilities have both positive and negative points. The researches developed so far offer motivating results that guide the optimization, in the field, of these procedures, and of new alternatives that integrate the productivity of pigs with the environmental preservation. Rising costs of commercial fertilizers, and increased environmental pollution make the use of organic waste in agriculture an attractive option, from the point of view due to nutrient cycling. These facts generate an increase in demand for the purpose of evaluating the technical and economic feasibility for the provision of some of these residues in agricultural soils (Santos et al., 2011).

However, due to the high cost of agricultural production, mainly by the use of mineral fertilizers and for being a residue that contains high levels of organic matter and of other nutrients, primarily nitrogen and phosphorus, the use of liquid pig manure becomes viable, because currently, agriculture research aimed to increase productivity and cost reduction. As a result of this, the work aimed to evaluate the effectiveness of the use of pig manure on productivity and the supply of nutrients for the crop of soybeans grown in no-tillage system in areas of Savannah.

MATERIALS AND METHODS

The experiment was conducted in the field in an area of Savannah named "Cerrado" in Brazil, at an experimental farm in the region of Rio Verde Goiás State (17° 48 'South 50° 55' West, elevation 760 m). The soil of the region is characterized as clayey dystroferric Red Latosol with texture showing 420, 470 and 110 g kg^{-1} of sand, silt and clay, respectively (Embrapa, 2006). The main characteristics of the soil (0 to 0.20 m depth, in natural conditions) with: pH: 4.5; Ca: 1.6 cmolc dm^{-3}; Mg: 0.6 cmolc dm^{-3}; K: 0.14 cmolc dm^{-3}; Al: 0.13 cmolc dm^{-3}; P (Mehlich-1): 3 mg dm^{-3}; saturation bases: 21% and organic matter content: 23 g kg^{-1}.

The region has a typical tropical climate, alternately wet and dry with cold average temperature exceeding 18°C, the rainfall is less than 2000 mm per year with rains in the summer and fall, according to the Köppen classification (Alvares et al., 2013). The first experiment was installed in 1999/2000. The soil was plowed, securely and acidity of the soil was corrected with lime (2.2 Mg ha^{-1}), as is usually done in the Cerrado, in order to raise the soil pH to 5.5 - 6.0 and bases saturation 60%, which is recommended for growing soybeans. The no-tillage system in the straw was adopted in all years subsequent farming.

Soy and corn crops were interspersed in succession and waste was applied annually in the following rates: 0 (control), 25, 50, 75 and 100 m^3 ha^{-1}, when soy was grown and 0, 25, 50, 100 and 200 m^3 ha^{-1} for the cultivation of corn. For comparison, the additional treatments with application of mineral fertilizers (NPK) we used.

For the 2014/2015 cropping, the soil received the 15th waste application. The experimental design was of randomized blocks with three replications. The treatments consisted of four doses of LSM (no LSM, 25 m^3 ha^{-1}, 50 m ^{3} ha^{-1}, 75 m^3 ha^{-1} and 100 m^3 ha^{-1}) and mineral fertilization with PK suggested by Shankar and Lobato (2004) at a ratio of 188 kg ha^{-1} of P_2O_5 in the form of monoammonium phosphate (MAP)+ 80 kg ha^{-1} of K_2O in the form of KCl applied before seeding culture of soybean with a total of 6 treatments and 18 installments. The area of each installment is 150 m^2 (15 m x 10 m).

Waste products used were from a farm of vertical system terminator with a capacity of 4000 piglets having remained 120 days in advance of anaerobic stabilization pond and was spread the day, 10/28/2014, ten days before seeding of soybean, by measuring

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Table 1. Chemical composition of the liquid waste of pigs used in soil in 2014.

N[1]	P[2]	K[3]	Ca	Mg
		kg m^{-3}		
1.3	0.83	0.60	1.51	0.74
pH	Density	MO*	MS*	$S\text{-}SO_4$
	-- g cm^{-3} --	----- % ----		-- kg m^{-3} --
7.53	1.009	1.96	2.94	0.29

Percentage of conversion of nutrients applied: N = 50%[1], P=60%[2] e K = 100%[3] (CFSEMG, 1999)*.

the quantity of wastes by the flow of the distributor in a given period.

Manure samples were taken for determination of dry matter and chemical profiling (Pavan et al., 1992). The results of the chemical analysis of the used waste are presented in Table 1.

Organic and dry matters

Sowing was done in 11/6/2014 day, through mechanized planting; variety seeds were NS 7300 IPRO2 with 0.5 m spacing and planting density corresponding to 19 seeds per meter. During the cycle, all cultural practices needed for the culture were conducted (Embrapa, 2008).

In the flowering stage, R1/R2, foliar tissue samples were collected for determination of the levels of N, P, K, Ca, Mg, Cu, Zn, Mn and Fe as the methodology described by Sousa and Lobato (2004). After sampling, the leaves were washed, dried and then taken to an oven, at 65°C. After this process, the leaves were ground into Wiley type mill, stainless steel, passed sieves of mesh sizes of 0.84 mm^2 and wrapped in paper packaging properly identified for chemical analyses. In the dry material and ground, sulphuric and digestion was determined with the content of N by Kjeldahl distillation method. For the determination of the levels of P, Ca, Mg, Cu, Fe, Mn, Zn and K, the plant material underwent nitric-perchloric acid digestion method (AOAC, 1990), and then quantified by UV-vis spectrophotometry (UV-vis), and flame Atomic absorption spectrophotometry (Silva et al., 2009).

In determining the mass production of the shoot, three plants were collected per plot. The plant material collected was taken to the laboratory oven for drying, at 65°C. In the dry material, the levels of N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn was determined in accordance with the methodology described by Silva et al. (2009). At the time of harvest, the average height of five plants (cm) from ground level to the upper terminal part of the plant was determined.

For the harvest, soybean plants were collected from an area of 7.5 m^2 (6 rows with spacing of 0.5 and 2.5 m in length each). The grains of the plants of each plot were collected and weighed in the balance and given the moisture of grains of each parcel. The productivity of grain was adjusted to 13% moisture. The mass of 100 grains for each treatment was determined based on recommendation of the rules for seed analysis (Brasil, 1992). The beans were sent for chemical analysis and determination of the levels of macro and micro-nutrients according to Silva et al. (2009).

Foliar levels of macronutrients and micronutrients in soybean culture were compared with the critical levels of their nutrients suggested by Shah and Lobato (2004). The Sisvar software (Ferreira, 2011) was used for statistical analysis of the variables. The averages of the treatments, when significant, were compared, by the Tukey test, to 5% of probability. When significant difference in the interaction among the factors was found, regression analysis was carried out.

RESULTS AND DISCUSSION

For the chemical composition of the liquid pig manure (LSM) as shown in Table 1 and the mineral fertilizers applied on the plots, the amounts of nutrients applied in function of the treatments were calculated (Table 2).

It was observed that the fertilization with liquid pig manure (LSM) overcame the mineral nitrogen fertilization, regardless of the dose applied. The dose of 75 m^3 ha^{-1} of LSM was similar to phosphorus mineral fertilizer and the dose of 100 m^3 ha^{-1} of LSM was similar to the mineral potassium fertilizers.

The mineral fertilization did not provide Ca, Mg, and S, whereas with the LSM, the higher the dose, the greater the supplies of these nutrients (Table 2). Unlike mineral fertilizers, which have minimum composition set for each condition of soil and culture, the pig waste composition is extremely unbalanced, varying according to the power supply, water management, storage conditions and the age of the animals (Scherer et al., 1995; Konzen and Barros, 1997) making hard to recommend. Therefore, continuous applications can cause imbalance of nutrients in the soil and the gravity of the problem will depend on the composition and amount of waste, time of application, the ability to extract by crops and the soil type.

According to Konzen and Barros, (1997), it is fundamental to develop a technical management and fertilization plan so that it becomes a viable alternative to increase water availability, which can reduce treatment costs and also serve as a source of nutrients for the plants, and the costs of acquiring commercial chemical fertilizers. The foliar contents of N, P, K, Ca, Mg, S, Fe, Mn, Cu and Zn in soybeans were not affected ($p > 0.05$) by treatments (Table 3). Similar results were obtained by Santos et al. (2012), Sediyama et al. (2014), Seidel et al. (2010) and Bócoli et al. (2016), which detected no changes in foliar concentrations of N, P and K in squash, peppers and corn, respectively, with the application of pig manure. However, Corrêa et al. (2008) noted that, with increasing doses of organic waste, N content increased in soybean leaves. Araújo et al. (2013) verified that the application through mineral fertilizer reduced foliar N content in soybeans.

Comparing the levels of macronutrients in soybean

Table 2. Amount of nutrients applied in soil in 2014 on the basis of the treatments.

Treatments	N	P	K	Ca	Mg	S (SO_4)
	------------------------ kg ha^{-1} --------------------					
Control (0)	0	0	0	0	0	0
25 m^3 ha^{-1} de LSM	32.5	20.7	15.0	37.7	18.5	7.2
50 m^3 ha^{-1} de LSM	65.0	41.5	30.0	75.5	37.0	14.4
75 m^3 ha^{-1} de LSM	97.5	62.3	45.0	113.5	55.5	21.6
100 m^3 ha^{-1} de LSM	130	83.0	60.0	151.0	74.0	28.8
Mineral fertilizer	16.9	64.8	66.7	0	0	0

Table 3. Nutrient content in foliar tissue of soybeans due to the application of liquid swine manure.

Variable	M.F.	Doses of liquid waste of swine (m^3 ha^{-1})					Average	F value	CV (%)
		0	25	50	75	100			
N (g kg^{-1})	36.7	37.0	42.3	31.1	41.7	34.7	37.3	1.30^{NS}	17.32
P (g kg^{-1})	3.3	3.0	3.1	3.7	3.4	4.1	3.44	2.84^{NS}	12.59
K (g kg^{-1})	17.3	18.5	17.0	19.1	18.4	19.5	18.32	0.78^{NS}	10.81
Ca (g kg^{-1})	8.5	10.6	10.8	10.1	10.4	9.6	10.01	2.02^{NS}	10.27
Mg (g kg^{-1})	3.2	4.1	4.0	4.0	4.2	4.0	3.91	2.12^{NS}	11.13
S (g kg^{-1})	1.8	1.5	1.5	1.7	1.8	2.0	1.73	1.24^{NS}	16.07
Fe (mg kg^{-1})	87.0	78.3	81.3	74.2	82.8	87.2	81.82	1.06^{NS}	10.30
Mn (mg kg^{-1})	55.2	61.4	61.4	56.5	55.7	51.7	57.01	2.24^{NS}	7.68
Cu (mg kg^{-1})	7.0	5.8	6.2	6.3	66.0	6.0	6.32	1.16^{NS}	10.53
Zn (mg kg^{-1})	32.9	28.2	28.3	32.8	33.4	41.2	32.8	2.20^{NS}	16.84

^{NS}- Not significant by the F test ($p > 0.05$); M.F.- mineral fertilization; CV- coefficient of variation.

plant tissue with their respective critical levels (reference) according to Sousa and Lobato (2004), it was found that the levels of P, K, Ca and Mg were suitable, demonstrating nutritional balance for these elements. Detected deficiency of nitrogen (N) and sulphur (S) is independent of treatments (Table 3). Although results of other authors indicate that fertilization with pig manure is efficient for nutrition and productivity of crops, a dose suited to the requirement of culture is applied (Konzen and Alvarenga, 2005). However, in this experiment, the fertilization failed to meet the nutritional demands of the plant in N and S (Table 3).

In the culture of soybean, nitrogen fertilizer is not recommended due to biological nitrogen fixation (BNF) and doses greater than 30 kg ha^{-1} of N may interfere negatively with BNF (Hungria et al., 2001). Another factor that may have limited the use of N may have been N losses by volatilization of ammonia ($N\text{-}NH_3$) during the application of the waste. According to Sommer and Hutchings (2001), N losses by volatilization of ammonia can be up to 75% of the ammoniacal N of the waste.

The recommendation of sulfur for crops is of 20-30 kg ha^{-1} (Sousa and Lobato, 2004), and the doses of 75 and 100 m^3 ha^{-1} of LSM would supply this requirement, though inefficient in plant nutrition. Possibly, most of the S contained in the waste is in organic form for digestion. Although there has been a deficiency of N and S visual symptoms of these nutrients were not observed.

According to the data in Table 4, no significant difference among the treatments with regard to productivity and mass of 100 grains of soy was seen. The different doses of manure used on the base fertilizer, as compared to the chemical fertilizer (NPK), did not differ statistically, demonstrating the efficiency of waste as bio fertilizers on grain production this crop (Table 4). Some authors also performed work with pig manure on soybean culture (Konzen, 2003; Menezes et al., 2007; Blanco, 2015) and verified these beneficial effects on productivity of culture. This demonstrates that the fertilization of soybean culture in this soil was required, even if the nutrient supplies were carried out with application of mineral fertilizer or through pig manure. The pig manure provided production gains as compared to the mineral fertilization; therefore, total or partial form in fertilization programs can be replaced.

The average yield of grain with the experiment was above the national average (2999 kg ha-1) and the State of Goias (2595 kg ha^{-1}) in 2014/2015 (Conab, 2015). According to the data in Table 5, it can be seen that only significant differences occurred between treatments (p <

Table 4. Yield kg grain ha^{-1} (PG) and weight of 100 grains g (M100G) of soybeans due to the application of liquid swine manure.

Variable	M.F.	Doses of liquid waste of swine (m^3 ha^{-1})					Average	F value	CV (%)
		0	25	50	75	100			
PG	4002	3682	3785	4550	4314	4369	4117	0.96^{NS}	14.88
M100G	16.4	12.0	17.1	15.9	16.1	15.7	15.53	1.48^{NS}	16.57

^{NS}- Not significant by the F test (p > 0.05); ** significant at 1% probability; PG- grain productivity; M100G- mass of 100 grains; M.F.- mineral fertilization; CV- coefficient of variation.

Table 5. Levels of nutrients in soy beans related to application of liquid swine manure.

Variable	M.F.	Doses of liquid waste of swine (m^3 ha^{-1})					Average	F value	CV (%)
		0	25	50	75	100			
N (g kg^{-1})	44.1	47.8	47.8	54.0	44.1	53.7	46.54	2.72^{NS}	15.66
P (g kg^{-1})	4.8	4.3	4.3	5.0	4.6	5.2	4.67	1.29^{NS}	14.02
K (g kg^{-1})	19.5	18.0	18.0	19.2	18.0	18.6	18.57	1.11^{NS}	5.80
Ca (g kg^{-1})	2.8	2.5	2.5	2.8	2.6	3.0	2.81	0.46^{NS}	18.18
Mg (g kg^{-1})	3.0	3.0	3.0	3.1	3.0	3.0	3.02	0.61^{NS}	5.51
S (g kg^{-1})	2.9	3.0	3.0	2.8	2.7	3.2	2.89	0.93^{NS}	11.85
Fe (mg kg^{-1})	623.2^{ab}	461.9^{abc}	461.9^{abc}	559.2^{ab}	682.1^{a}	305.5 ^{c}	507.1	7.66**	17.34
Mn (mg kg^{-1})	39.2 ^{b}	60.8 ^{a}	60.8 ^{a}	43.7 ^{b}	37.8 ^{b}	34.8 ^{b}	44.28	8.64**	12.74
Cu(mg kg^{-1})	9.4	11.1	11.1	11.2	11.0	9.2	10.27	2.05^{NS}	10.90
Zn (mg kg^{-1})	35.2	35.4	35.4	37.0	36.6	37.0	35.93	0.35^{NS}	9.30

^{NS}- Not significant by the F test (p > 0.05); ** significant at 1% probability; M.F.- mineral fertilization; CV coefficient of variation.

0.05) for contents of Fe and Mn in soy beans. Despite the significance in the doses of liquid pig waste, the equations showed no adjustment, with low coefficient of determination. It is observed in Table 5 that while the application of pig waste at a dose of 100 m^3 ha^{-1} were observed with lower levels of iron and manganese in soy beans.

As compared with the work carried out by Embrapa (2008) in relation to quantity exported by the nutrient culture of soybean grain (Table 6), similar values observed in relation to levels of N, P, K, Ca, Mg, Mn, Cu and Zn and lower values relative to Fe (70 mg kg^{-1}) and above in relation to the S (5.4 g kg^{-1}). This occurs due to nutritional requirement of soybeans and export potential of culture is characteristics determined by genetic factors, but influenced by climatic factors, the fertility of the soil and the cultural management. Nutrient content in the dry matter of the aerial part of the culture of soybeans were not affected by treatments except for sulphur and zinc nutrients in which significant differences were observed (Table 6). Despite the significance in the doses of liquid pig waste, the equations showed no adjustment, with low coefficient of determination.

It can be concluded from Table 6 that the extraction of nutrients by the aerial part of the plant of soybean occurred in the following order: K>Ca>N>Mg>P>S> Fe> Mn>Zn>Cu. Contrary to the one obtained by Pedrinho Junior et al. (2004) working with soybeans in protected environment, it was found that the greatest accumulation of nutrients in soy was to P, Mg and S. Data was obtained by Caires and Fonseca (2000) working with soybeans in no-tillage system showing that nutrient extraction from the shoot by plant soybeans have the following sequence N>K>Ca>P>Mg>S. Certainly, these values vary according to the levels available in each soil, with the environment and with the ability to extract each cultivar. The average yield of soya beans increased depending on the dose of LSM, fitting by regression to the second degree polynomial function (Figure 1), and the dose that presented the greatest productivity was 80.3 m^3 ha^{-1} of liquid pig manure, 4412 kg ha^{-1} of grain. Similar results were found by Penha et al. (2015). The authors applying doses of LSM in the culture of soybean in 2008/2009 in the same experimental area of this study found that the maximum efficiency (4111 kg ha^{-1}) was obtained with the application of 88 m^3 ha^{-1} of liquid pig manure.

In accordance with results obtained by Borre (2008) in which the biggest returns in productivity from soybeans occurred with doses of 50 and 75 m^3 ha^{-1} of liquid manure from pigs with 3918 and 3870 kg ha^{-1}, respectively, Konzen (2003) also obtained with the dose of 50 m^3 ha^{-1} of liquid pig manure, the highest rates in productivity of soya beans, which is higher than the

Table 6. Nutrient content in the dry matter of the aerial part of the soy culture related to the application of liquid swine manure.

Variable	M.F.	Doses of liquid waste of swine ($m^3\ ha^{-1}$) 0	25	50	75	100	Average	F value	CV (%)
N ($g\ kg^{-1}$)	5.4	5.4	5.1	6.1	6.0	6.2	5.70	0.38^{NS}	21.98
P ($g\ kg^{-1}$)	0.7	0.8	0.7	0.7	1.1	0.9	0.80	2.46^{NS}	20.73
K ($g\ kg^{-1}$)	13.4	12.7	13.4	11.1	15.6	16.9	13.85	1.58^{NS}	20.68
Ca ($g\ kg^{-1}$)	7.8	7.1	7.8	8.3	8.3	8.0	7.87	0.41^{NS}	15.23
Mg ($g\ kg^{-1}$)	5.2	4.2	4.8	5.2	5.5	5.5	5.07	0.99^{NS}	16.41
S ($g\ kg^{-1}$)	0.8a	0.4cd	0.4c	0.3d	0.9a	0.6b	0.57	80.04**	8.83
Fe ($mg\ kg^{-1}$)	447.4	433.4	551.3	563.6	473.2	458.2	487.9	1.89^{NS}	14.37
Mn ($mg\ kg^{-1}$)	31.6	26.7	30.4	33.0	25.2	28.6	29.30	0.84^{NS}	19.30
Cu($mg\ kg^{-1}$)	4.0	4.3	4.4	4.1	4.0	4.2	4.20	0.56^{NS}	8.87
Zn ($mg\ kg^{-1}$)	4.3 a	3.7ab	3.4ab	4.3a	2.4b	4.5a	3.76	5.67**	15.27

^{NS}- Not significant by the F test ($p > 0.05$); ** significant at 1% probability; M.F.- mineral fertilization; CV- coefficient of variation.

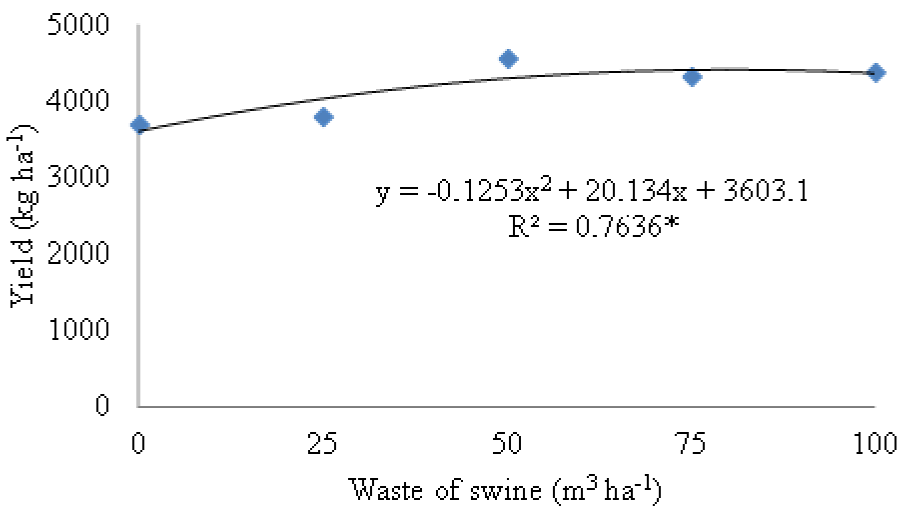

Figure 1. Productivity of soya beans in increasing doses function of pig manure, Cropping 2014/2015. Value of F-1.047 * – by the Tukey test at 5%.

maximum dose (100 $m^3\ ha^{-1}$) used in the work.

Conclusions

There was no statistical difference between treatments that received mineral fertilizer (NPK) and treatments that received pig manure, indicating that pig waste utilization as bio fertilizer can be one of the alternatives to this culture of soybean.

The mineral fertilizer in soybean culture can be replaced by doses of liquid pig manure from 80 $m^3\ ha^{-1}$ in a clayey dystroferric Red Latosol without damage of the components of yield and not significant increase in grain productivity from this dose. Successive applications of doses of pig manure generally did not promote increase in the content of nutrients in grains and in the extraction of nutrients by the aerial part of the plant.

CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

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