

Organic fertilization with turkey litter for maize cultivation in tropical region

Diego Oliveira Ribeiro¹, Gustavo Castoldi¹, Manuel Rodriguez Carballal², Mariângela Brito Freiberger¹, Warlles Domingos Xavier¹, Franciele de Freitas Silva^{*1}, Andrisley Joaquim da Silva², Raphael Krauspenhar de Oliveira Santos³, Gildomar Alves dos Santos²

¹Goiano Federal Institute (Instituto Federal Goiano), Rio Verde Campus, Rio Verde-GO, Brazil

²University Center of Mineiros (UNIFIMES), Mineiros-GO, Brazil

³Agronomist Engineer, Mineiros-GO, Brazil

*Corresponding author: franciellefreittas@hotmail.com

Abstract

Residues from agroindustry activity have been commonly used as a source of fertilizer for fertilization of annual crops. Sometimes these residues can replace the mineral fertilizers totally or partially, while their effects can be extended to the soil attributes. Thus, the objective of this study was to evaluate the effects of replacing conventional chemical fertilization with organic fertilization using turkey litter on maize grain yield and in the chemical attributes of an Oxisol in tropical region. The experiment was carried out in two crop seasons with various quantities of turkey litter, or in blend with chemical fertilizers, in a randomized block design with six treatments and five replicates. The treatments were as follows: T1 – Control treatment; T2 – Chemical fertilization with 450 kg ha⁻¹ of 10-27-10 (NPK); T3 – Application of 3,800 kg ha⁻¹ of turkey litter; T4 – Application of 7,600 kg ha⁻¹ of turkey litter; T5 – Chemical fertilization with 450 kg ha⁻¹ of 10-27-10 + 1900 kg ha⁻¹ of turkey litter; T6 – Chemical fertilization with 450 kg ha⁻¹ of 10-27-10 + 3,800 kg ha⁻¹ of turkey litter. The organic fertilization with turkey litter presented potential for total or partial replacement of chemicals fertilization for maize cultivation with no loss in grain yield. Therefore, the treatments of T3 and T5 could be recommended to farmers at a lower cost. The treatment T4 increased the P and K contents in the soil, reaching to 24 mg dm⁻³ and 3.1 cm_c dm⁻³, respectively, after two crop seasons.

Keywords: Oxisol; organic residue; phosphorus; potassium; soil fertility; *Zea Mays*.

Abbreviations: AQ225+CP 1900_Application of 225 kg ha⁻¹ from 10-27-10+1900 kg ha⁻¹ of turkey litter; AQ225+CP 1900_Application of 225 kg ha⁻¹ from 10-27-10+3800 kg ha⁻¹ of turkey litter; AQ450_Chemical fertilization with 450 kg ha⁻¹ from 10-27-10; Ca_Calcium; CP3800_Application of 3800 kg ha⁻¹ of turkey litter; CP7600_Application of CP 7600 kg ha⁻¹ of turkey litter; KCl_Potassium chloride; Mg_Magnesium; N_Nitrogen; K₂O_Potassium oxide; NPK_Nitrogen Phosphorus Potassium; P₂O₅_Phosphorus pentoxide; S_Sulfur.

Introduction

The southwest of Goiás state is characterized by large areas of grain production, with emphasis on soybean and maize crops (CONAB, 2019). This large amount of grains available in the region is a key factor in the existence of intensive systems of poultry production, especially chicken and turkey. Such activities generate great amounts of poultry litter, which can be used as a nutrient source of fertilizer in the livestock farming activities (Pinto et al., 2012; Ribeiro et al., 2017; Silva et al., 2018).

Residues from the poultry activity have been employed as fertilizer for some agricultural crops as reported in some studies. In pastures with clayey soil, the poultry has shown positive effects on chemical and biological soil attributes when used as only source of fertilizer (Pinto et al., 2012). Silva et al., 2018 reported that replacing the chemical fertilizers with turkey litter in a sandy soil of pasture has positive effects on the productivity of *Urochloa Decumbens*, increasing the content of some nutrients, compared to

chemical fertilizers and acidity soil correctives. In soybean, the use of a turkey litter associated with chemical fertilizers or even applied isolated was able to replace chemical fertilizers without causing any loss in the grain yield (Ribeiro et al., 2017).

The use of these residues may also result in positive effects on soil attributes, both chemical and biological (Pinto et al., 2012; Silva et al., 2018), as much as in physical attributes (Gomides and Borges, 2014). At high doses (higher than 16.5 ton ha⁻¹) the use of these residues as the only source of fertilizer may elevate soil pH, and reduce toxic aluminium, as occurred in a clayey Oxisol (Pinto et al., 2012). However, such effect on soil pH may not exist when used in smaller doses or in blend with chemical fertilizers (Ribeiro et al., 2017; Silva et al., 2018).

The effect on soil pH may be related to the presence of lime as a substance used to disinfect the bedding and reduce the load of pathogens, leading the pH of some poultry litter to

near 8 (Rondón, 2008). The reduction of toxic aluminium with the use of organic residues may be related to the presence of organics with low molecular weight derived from the decomposition of residues, which reduce the activity of aluminium (Pinto et al., 2012). These residues can reduce the aluminium content in the soil and raise the base saturation, the cation exchange capacity (CEC), the phosphorus (P) and potassium (K) contents available (Silva et al., 2018). In addition, it can contribute to raising carbon and nitrogen soil stocks (Pinto et al., 2012). In the soils of the Brazilian Cerrado, classified as tropical region, the organic carbon content is extremely important for CEC, accounting for up to 90% of the same (Meurer, 2012).

Although some specific results have shown the potential use of poultry litter in agricultural activities, the results for some annual crops are still scarce. In this context, the objective of this study was to evaluate the effect of total and partial replacement of the chemical fertilization with organic material such as turkey litter on the grain yield of maize and in the chemical attributes of a dystroferic red Oxisol.

Results and Discussion

Grain yield of maize

The grain yield of maize was influenced by the different fertilization management, in both seasons 2011/12 and 2012/13 (Figure 1). The grain yield varied among the treatments from 8,012 to 12,115 kg ha⁻¹ in the crop season 2011/12, and from 6,587 to 8,738 kg ha⁻¹ in the crop season 2012/13. In both seasons, the lowest grain yield was observed in the control treatment. In 2011/12, the highest yield was occurred by T2 treatment, being ~50% higher compared to the control. The other treatments were intermediate compared to the control and the T2 treatment. In 2012/13, the control produced less grain yield (approximately 33%) when compared to T6 treatment. The other treatments, however, were similar regardless of the type of fertilization and even their different combinations. The lowest grain yield in the 2012/13 crop season compared to the 2011/12 crop season (Figure 1) may have been caused due to the water stress occurred during the vegetative development of the maize. In 2012/13, between 5 to 58 days after emergence, the accumulated precipitation was 185.3 mm, and from this total 75 mm was occurred in only two days (data not presented). In the initial developmental stages (up to nine extended leaves), all the leaves and cobs and number of grain per rows that the plant will eventually produce are formed (Magalhães et al., 2002). Therefore, water stress in this period may have led to a reduction in the grain yield.

The nutrient release of poultry residues is slow and may limit the productivity of short cycle crops. For example, the released N content remained up to 85%, evaluated 270 after plantation (Silva et al. 2014). Conte et al. (2014) evaluated different sources of fertilizers and doses of poultry litter in maize crop and observed higher grain yield of maize fertilized with poultry litter, compared to mineral fertilization in no-tillage system in the first year of experiment.

Even providing greater amount of nutrients, T4 treatment (Table 1) was not able to increase the maize productivity in relation to the other treatments that provided less amount

of nutrients. The similarity among these treatments may be due to the high levels of nutrients in the area, in which the experiment was conducted; except for P element, showing medium level (Sousa and Lobato, 2004). The same nutrient may have limited the grain yield in the control treatment, demonstrating the need of use fertilizers to supply any deficiency. The soil used in the experimental area is a clayey Oxisol, and it tends to adsorb high amounts of P, which in the Cerrado region of Brazil can achieve maximum adsorption capacity of more than 2,600 mg kg⁻¹ (Pinto et al., 2012). Phosphorus in poultry residue can remain 32% of the total in the organic residues even 270 days after its application (Silva et al., 2014), which may have limited maize yield in T4 in the 2012/13 crop season.

Soil chemical attributes

The levels of P and K in the soil were altered with the treatments applied (Table 1). The contents of exchangeable P were higher in the T4 treatment (7,600 kg ha⁻¹ of turkey litter), being lower than control (T1) and T2. The T4 treatment showed approximately 85 and 71% higher P compared to the control and T2, respectively. The highest level of P found in the T4 treatment could be attributed to the large amount of nutrients available in the soil due to organic fertilization (Table 4).

Even though P levels in the soil were statistically similar in treatments T2 and T3, the trend of elevation of P content in T3 treatment was evident, which was 50% higher than that found in T2 treatment (Table 1). The T3 treatment, released nutrients to the soil slowly because it is an organic fertilizer (Silva et al., 2014), reducing the fixation of this element by the soil. Therefore, the turkey litter has adequate chemical conditions to be adopted in the phosphate fertilization of maize crop, both with possibility of increase the grain yield and the soil fertility. In a pasture of *Urochloa Decumbens*, higher contents of P were also observed when turkey litter (3 ton ha⁻¹) was used in substitution to chemical fertilizers (NPK 20-00-20, single superphosphate and KCl) (Silva et al., 2018).

Corroborating the results of this study, after long use of turkey litter in a pasture, the increase in the P levels in superficial layer of the soil could be observed (Pinto et al., 2012). This management is an alternative for fertilization in soils with low or even medium P levels. It may even allow greater availability of this element for soybean cultivation in tropical soils (Silva et al., 2014).

The substitution of chemical fertilization by organic fertilization does not interfere with P contents, and also presents similar behaviour for K. The highest dose (T4) provided the highest levels of this element to the soil (Table 1). There was a higher increase of this element when 7,600 kg ha⁻¹ turkey litter (3.1 mmol_c dm⁻³) applied compared to the control (2.2 mmol_c dm⁻³), representing an elevation of approximately 41%. Regardless of any amount replaced by turkey litter compared to chemical fertilizer, the K contents were not influenced. Therefore, it seems that the use of organic residue does not negatively affect the grain yield of maize and available K content in the soil, which means that turkey litter can replace total or partially conventional chemical fertilization.

Table 1. Soil chemical attributes after two cropping seasons of maize in organic and chemical fertilization systems.

Treatments	pH	P mg dm ⁻³	K -----mmolc dm ⁻³ -----	CEC	OM g dm ⁻³	V% %
Controle	5.3 ^{ns}	13 b	2.2 b	75.2 ^{ns}	45.2 ^{ns}	60.7 ^{ns}
AQ450	5.2	14 b	2.4 ab	78.6	47.6	55.7
CP3.800	5.3	21 ab	2.6 ab	78.8	50.6	64.6
CP7.600	5.3	24 a	3.1 a	81.5	50	63
AQ225+CP1.900	5.2	19 ab	2.6 ab	82.2	47.4	59.8
AQ225+CP3.800	5.2	16 ab	2.8 ab	80	48.6	58.6

^{ns} Not Significant. * Treatments followed by the same letter do not differ statistically by the test of Tukey with 5% probability level. P – phosphorus; K – potassium; CEC – cation exchange capacity; OM – organic matter; V% – base saturation. T1 – Control; T2 – Chemical fertilization with 450 kg ha⁻¹ from 10-27-10; T3 – Application of 3,800 kg ha⁻¹ of turkey litter; T4 – Application of 7,600 kg ha⁻¹ of turkey litter; T5 – Application of 225 kg ha⁻¹ from 10-27-10 + 1,900 kg ha⁻¹ of turkey litter; T6 – Application of 225 kg ha⁻¹ from 10-27-10 + 3,800 kg ha⁻¹ of turkey litter.

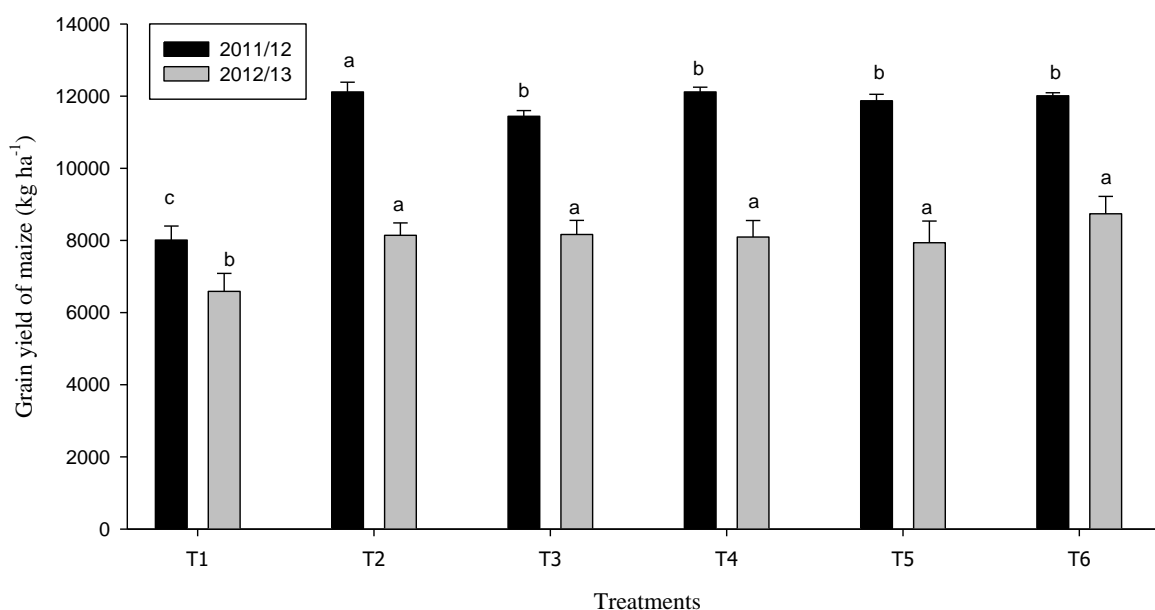


Fig 1. Grain yield of maize cultivated in a dystroferic red Oxisol and submitted to a full or partial chemical fertilization replacement by organic fertilization with turkey litter. Mineiros, GO, Brazil. * Treatments followed by the same letter in each year do not differ statistically by the Tukey test at level of 5% probability. T1 – Control; T2 – Chemical fertilization with 450 kg ha⁻¹ from 10-27-10; T3 – Application of 3,800 kg ha⁻¹ of turkey litter; T4 – Application of 7,600 kg ha⁻¹ of turkey litter; T5 – Application of 225 Kg ha⁻¹ from 10-27-10 + 1,900 kg ha⁻¹ of turkey litter; T6 – Application of 225 kg ha⁻¹ from 10-27-10 + 3,800 kg ha⁻¹ of turkey litter.

Table 2. Soil chemical and granulometric analysis, in the depth of 0-0.2 m, performed previously to the experiment implementation, in 2012. Mineiros, GO, Brazil.

OM	pH	P Resin	K	Ca	Mg	Al	H+Al	Sb	CEC	V	Clay	Silte	Sand
g dm ⁻³	CaCl ₂	mg dm ⁻³	-----	-----	-----	-----	-----	-----	-----	%	-----	-----	-----
36.0	4.8	12.0	2.1	36.0	14.0	1.0	38.0	52.0	90.0	57.0	500.0	200.0	300.0

OM – organic matter; Pres – phosphorus resin; SB – sum of bases; CEC – cation exchange capacity; V% – base saturation.

Table 3. Nutrient contents in the turkey litter used in the maize fertilization.

N	P ₂ O ₅	K ₂ O	Ca	Mg	S	Moisture content
-----%-----						
4	4.6	3.5	3.2	0.46	0.2	29

Table 4. Amounts of nutrients (N, P and K) available in the soil as a function of doses of turkey litter and chemical fertilizer applied.

Treatments	Fertilization kg ha ⁻¹	N	P ₂ O ₅ kg ha ⁻¹	K ₂ O
T1	-	180	00	00
T2	450 in (10-27-10)	45 + 180	121.5	45
T3	3,800 of turkey litter	107.9 + 180	124.1	94.4
T4	7,600 of turkey litter	215.8 + 180	248.2	188.8
T5	225 (10-27-10) + 1,900 turkey litter	76.46 + 180	122.8	69.7
T6	225 (10-27-10) + 3,800 turkey litter	130.4 + 180	184.9	116.9

Corroborating the results of this study, Silva et al. (2018) did not verify alterations on K levels in the soil when turkey litter replaced by chemical fertilizers in pasture of *Urochloa decumbens*. Ribeiro et al. (2017), did not observe alterations in K element in soybean by application of turkey litter instead of chemical fertilizers. Base saturation values, pH and organic matter content, as well as CEC, were not significantly influenced by the treatments (Table 1). Probably this was related to the short time space between the application of organic residues to the soil and the evaluation. These results corroborate the results obtained in a Quartzarenic Neosol by Silva et al. (2018), in pastures in a clayey Oxisol by Ribeiro et al. (2017) in soybean crop. However, contrasting results were found in a clayey Oxisol when subjected to increasing doses of turkey litter in pasture, where increasing in pH, V%, and carbon and nitrogen stocks in the soil was observed (Pinto et al., 2012). This may be related to the higher doses of turkey litter and the longer time of implementation of the experiment.

Materials and Methods

Site and soil

The experiment was carried out in the county of Mineiros, in Goiás state (Brazil), in a research field belonging to the Association of Grain Producers of Mineiros, located at the following geographic coordinates: 17° 30' 081"S and 52° 44' 299" W. The region has an annual mean temperature of 24.2 °C and a mean rainfall of 1,700 mm. The predominant climate is warm, semi-humid and remarkably seasonal, with rainy summer and dry winter, being classified as "Aw", according to the classification of Köppen. The soil was classified as Dystroferic Red Oxisol with clayey texture (Embrapa, 2018). The chemical and granulometric characteristics are presented on Table 2. Previously to the implantation of the experiment, the field had been cultivated for more than 20 years with the soybean crop in the summer, and the alternation of corn, millet and sorghum in the winter.

Experimental design, treatments and implementation

The experiment was carried out in the 2011/12 and 2012/13 crop seasons. The experimental design was a randomized blocks, with six treatments and five replicates. Each experimental plot unit consisted of 10 rows with eight meters in length of maize plant and the rows was 0.45 m spaced from each other, totalling 36 m² per plot. In the crop season 2011/12 the maize hybrid P3862H was used, and in the crop season 2012/13 the hybrid 2B707 PW seeded

mechanically with the stand of 67,000 and 73,333 plants ha⁻¹, respectively. The doses of P and K were based on recommended doses for the central region of Brazil (Sousa and Lobato, 2004). All plots received top dressing nitrogen fertilization, with the application of 400 kg ha⁻¹ of urea, split into two applications: V4 and V8 phases.

The treatments were applied over soil surface, previously to the maize sowing, which occurred on Nov. 06, 2011 (2011/12 crop season) and Nov. 05, 2012 (2012/13 crop season).

The treatments consisted of different proportions of replacement of chemical fertilization by organic fertilization with turkey litter. For chemical fertilizer substitution by the turkey litter, the treatments were based on the P contents present in the turkey residue (Table 3): T1 – Control treatment (without any fertilization); T2 – AQ450 – Chemical fertilization with 450 kg ha⁻¹ of the formulated 10-27-10 (45 kg ha⁻¹ of N, 121.5 kg ha⁻¹ P₂O₅ and 45 kg ha⁻¹ of K₂O); T3 – CP 3800 – Application of 3800 kg ha⁻¹ of turkey litter; T4 – CP 7600 – Application of 7,600 Kg ha⁻¹ of turkey litter; T5 – AQ225+CP1900 – 50% of the chemical fertilization (225 kg ha⁻¹) + 50% of organic fertilization (1900 kg ha⁻¹ of turkey litter); T6 – AQ225+CP3800 – 50% of the chemical fertilization + 100% of the organic fertilization (3800 kg ha⁻¹ turkey litter). The amount of nutrients available for each treatment is presented on Table 4.

Grain yield and soil chemical attributes determination

The determination of maize yield was performed on the harvest, around 150 days after sowing, when the 4 centre rows of each plot were manually harvested, with 4 meters of length each. The maize ears were threshed, and the moisture of the grains was determined, adjusting the humidity to 13% for grain yield calculation.

Soil sampling for assessment of soil chemical attributes was performed after harvesting 2012/13 crop season. The samples were collected with aid of a Dutch type auger, in the superficial layer of the soil (0.0-0.1 m) depth, whereas 4 simple samples in the interrow and one in the planting row were collected. These samples were air-dried and sifted in 2 mm mesh, and then analysed for the contents of organic matter, pH, P, K, Ca and Mg (Raj et al., 2001).

Statistical analysis

Data were submitted to analysis of variance. Once a significant effect within treatments was detected by the F test, the Tukey's test for mean comparison was used to examine differences between treatments, using Sisvar statistical software (Ferreira, 2008).

Conclusion

The absence of fertilization, both organic and chemical, resulted in reduced of maize grain yield in Oxisol with medium levels of P. The organic fertilization using turkey litter presented potential for total or partial replacement of chemicals fertilization for maize cultivation. The organic fertilization with 7,600 kg ha⁻¹ turkey litter provided an increase in P and K levels available in the soil after two crop seasons. The use of turkey litter increased the sustainability of agricultural systems of intensive animal protein production because it allows the reduction of dependency for conventional chemical fertilizers for large crop production such as maize.

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References

- Companhia Nacional de Abastecimento - CONAB (2019) Acompanhamento da safra brasileira: grãos, safra 2018/19, quarto levantamento. Brasília: CONAB, 126p.
- Conte AN, Sato O, Rando EM, Zucarelli C, Santos KH (2014) Parâmetros fitométricos e produtividade da cultura do milho com aplicação de cama de aviário em sistema de preparo convencional do solo e plantio direto. *Revista Agrarian*. 25: 401-412.
- Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA (2018) Sistema brasileiro de classificação do solo. 5 ed. Brasília: Empresa Brasileira de Pesquisa Agropecuária, 590p.
- Ferreira DF (2008) SISVAR: um programa para análises e ensino de estatística. *Rev Symposium*. 6: 36-41.
- Gomides JN, Borges EM (2014) Atributos físicos de Latossolo cultivado com cana-de-açúcar e adubado com dejetos de animais de criação intensiva. *Rev Agrotecnologia*. 5(1): 33-49.
- Magalhães PC, Durães FOM, Carneiro NP, Paiva E (2002) Fisiologia do milho. Sete Lagoas: Embrapa, 23p.
- Meurer EJ (2012) Fundamentos de Química do Solo. 5. ed. Porto Alegre-RS: EVANGRAF, 275 p.
- Pinto FA, Santos FL, Terra FD, Ribeiro DO, Sousa RRJ, Souza ED, Carneiro MAC, Paulino HB (2012) Atributos de solo sob pastejo rotacionado em função da aplicação cama de peru. *Pesqui Agropecu Trop*. 42: 254-262.
- Raij BV, Andrade JC, Cantarella H, Quaggio JA (2001). Análise química para avaliação da fertilidade de solos tropicais. 1 ed. Campinas: Instituto Agrônomo, 285p.
- Ribeiro DO, Carballal MR, Silva AJ, Leal AJF, Caetano JO, Rodrigues AA, Vital RG, Prado RLF, Silva HD, Filho MBM (2017) Organic fertilization in soy farming in a tropical region. *Australian Journal of Basic and Applied Sciences*. 11(7): 18-22.
- Rondón EOO (2008) Tecnologias para mitigar o impacto ambiental da produção de frango de corte. *Rev Bras Zootec*. 37: 239-252.
- Silva AJ, Cunha FF, Roque CC, Silva MDT, Ribeiro DO, Carballal MR (2018) Replacement of liming and NPK fertilization with turkey litter in degraded areas grown with *Urochloa decumbens*. *Semina*. 39(2): 467-476.
- Silva VB, Silva AP, Dias BO, Araújo JL, Santos D, Franco RP (2014) Decomposição e liberação de N, P, e K de esterco bovino e cama de frango isolados ou misturados. *Rev Bras Cienc Solo*. 38: 1537-1546.
- Sousa DMG, Lobato E (2004) Cerrado: correção do solo e adubação. 2. ed. Planaltina: Empresa Brasileira de Pesquisa Agropecuária Cerrados, 416p.