

Organic, organomineral, and mineral fertilizers with urease and nitrification inhibitors for wheat and corn under no-tillage

Juliano Corulli Corrêa⁽¹⁾, Marco André Grohskopf⁽²⁾, Rodrigo da Silveira Nicoloso⁽¹⁾,
Késia Silva Lourenço⁽³⁾ and Rosemari Martini⁽¹⁾

⁽¹⁾Embrapa Suínos e Aves, BR-153, Km 110, Distrito de Tamanduá, Caixa Postal 321, CEP 89715-899 Concórdia, SC, Brazil. E-mail: juliano.correa@embrapa.br, rodrigo.nicoloso@embrapa.br, rosemari.martini@embrapa.br ⁽²⁾Universidade Estadual Paulista Júlio de Mesquita Filho, Faculdade de Ciências Agrônomicas, Campus de Botucatu, Fazenda Lageado, Rua José Barbosa de Barros, nº 1.780, CEP 18610-307 Botucatu, SP, Brazil. E-mail: marcogrohskopf@gmail.com ⁽³⁾Instituto Agronômico, Avenida Barão de Itapura, nº 1.481, CEP 13012-970 Campinas, SP, Brazil. E-mail: silkesia@hotmail.com

Abstract – The objective of this work was to evaluate soil chemical attributes, leaf nitrogen content, and corn and wheat yields under a no-tillage system in response to the application of organic, organomineral, and mineral fertilizers with or without urease and nitrification inhibitors. The experiment was carried out on the field, with one wheat and two corn crops, on a Rhodic Kandiodox, in a randomized complete block design with six replicates. The evaluated treatments were: control, without fertilization; O, poultry litter as an organic fertilizer; O+I, poultry litter and inhibitors; OM, organomineral fertilizer; OM+I, organomineral fertilizer and inhibitors; U, urea as a mineral fertilizer; and U+I, super urea with the urease inhibitor alone. The use of organic, organomineral, and mineral fertilizers, with or without inhibitors, increased available N content in the 0.00–0.05-m soil layer. In deeper layers, only OM+I in the 0.05–0.10-m layer and U+I in the 0.10–0.20-m layer provided higher contents than the control treatment. Leaf N contents were adequate, regardless of the fertilizer used. The O, O+I, OM, and OM+I treatments increase available P content and base saturation, and decrease H+Al on soil surface. Moreover, all fertilizers increase total grain yield of the two studied crops, in the following order: OM+I > U+I ≥ U > OM ≥ O+I ≥ O.

Index terms: *Triticum aestivum*, *Zea mays*, agronomic efficiency, poultry litter, nitrogen fertilization, volatilization losses.

Fertilizantes orgânicos, organominerais e minerais com inibidores de urease e de nitrificação para trigo e milho em plantio direto

Resumo – O objetivo deste trabalho foi avaliar os atributos químicos do solo, o teor de nitrogênio foliar e a produtividade de milho e trigo, em sistema plantio direto, em resposta à aplicação de fertilizantes orgânicos, organominerais e minerais, com ou sem inibidores da urease e da nitrificação. O experimento foi realizado em campo, com um cultivo de trigo e dois de milho, em Nitossolo Vermelho distroférrico, em delineamento de blocos ao acaso, com seis repetições. Os tratamentos avaliados foram: controle, sem adubação; O, fertilizante orgânico de cama de aves; O+I, cama de aves e inibidores; OM, fertilizante organomineral; OM+I, fertilizante organomineral e inibidores; U, ureia como fertilizante mineral; e U+I, superureia com inibidor da urease apenas. O uso de fertilizantes orgânicos, organominerais e minerais, com ou sem inibidores, aumentou o teor de N disponível na camada de 0,00–0,05 m do solo. Nas camadas mais profundas, apenas OM+I, na camada de 0,05–0,10 m, e U+I, na de 0,10–0,20 m, proporcionaram maiores teores do que o tratamento-controle. Os teores foliares de N foram adequados, independentemente do fertilizante utilizado. Os tratamentos O, O+I, OM e OM+I aumentam o teor de P disponível e a saturação por bases, e reduzem H+Al na camada superficial do solo. Além disso, todos os fertilizantes aumentam a produtividade total de grãos das duas culturas estudadas, na seguinte ordem: OM+I > U+I ≥ U > OM ≥ O+I ≥ O.

Termos para indexação: *Triticum aestivum*, *Zea mays*, eficiência agrônômica, cama de frango, adubação nitrogenada, perdas por volatilização.

Introduction

Strategic actions are needed in Brazil to develop technologies that enable the reuse of poultry litter

as organic or organomineral fertilizers, since about 5.5 billion broiler poultry were slaughtered in 2015/2016 and there is a growth forecast up to 2020 (Brasil, 2010). Poultry litter is the most widely used organic fertilizer

in South Brazil due to its abundance, price, and ease of handling. It is estimated that 16,243,286 tons of poultry litter are produced annually in the country (Schneider et al., 2012), which can provide numerous benefits to soil physical, chemical, and biological properties if used accordingly to technical criteria (Hirzel et al., 2007; Cassity-Duffey et al., 2015; Mafra et al., 2015).

Using N fertilizers with urease and nitrification inhibitors could also boost the content of available N in the soil and, consequently, increase nutrient recovery efficiency by providing a better balance between the N mineralization and nitrification processes (Muller et al., 2011).

Despite this, few studies have compared the efficiency of organomineral fertilizers with that of mineral ones. Morais & Gatiboni (2015) found that both types of fertilizer take about 30 days to provide to the plants the P present in their chemical composition. Other studies have evaluated the association between organic and mineral fertilization in topdressing to increase soil fertility (Cassol et al., 2012). However, researches on technologies using urease and nitrification inhibitors in the formulation of organomineral fertilizers from poultry litter are still scarce.

It should be noted that N losses by volatilization and leaching decrease N fertilization efficiency and limit crop yields (Viero et al., 2015). Therefore, urease and nitrification inhibitors may enhance the use efficiency of N sources during crop fertilization by reducing losses due to ammonia emission (N-NH_3) and nitrate leaching (N-NO_3^-) (Zaman et al., 2008; Soares et al., 2012).

In recent studies with inhibitors, urea has been commonly used as a N source. This technology is responsible for 5 to 10% of the total N applied as a fertilizer worldwide (Trenkel, 2010). Among the adopted inhibitors, stand out the molecules of dicyandiamide (DCD), which retard N-NO_3^- formation in the soil, and of N-(n-butyl) thiophosphoric triamide (NBPT), which block the active sites of the urease enzyme.

The objective of this work was to evaluate soil chemical attributes, leaf N content, and corn and wheat yields under no-tillage system in response to the application of organic, organomineral, and mineral fertilizers with or without urease and nitrification inhibitors.

Materials and Methods

The experiment was carried out on the field, from 2011 to 2013, at the experimental station of Embrapa Suínos e Aves, located in the municipality of Concórdia, in the state of Santa Catarina, Brazil ($27^\circ 14' 2''\text{S}$, $52^\circ 1' 40''\text{W}$, at 569 m of altitude). The climate of the region is classified as humid subtropical, Cfa according to the Köppen-Geiger classification. Monthly data of temperature and rainfall were gathered at the meteorological station of Embrapa Suínos e Aves, about 300 m from the experimental area (Table 1).

The soil of the experimental area is derived from basalt rocks and is classified as a Nitossolo Vermelho distroférrico (Santos et al., 2013), i.e., a Rhodic Kandiodox. Previous chemical analysis showed the following characteristics in the 0–0.20-m soil layer: pH (H_2O) of 5.0; 32.7 g dm^{-3} soil organic matter; 1.9 g dm^{-3} total N; 60, 35, 15, and 40 $\text{mmol}_c \text{ dm}^{-3}$ Ca, Mg, K, and H+Al, respectively; 35 mg dm^{-3} P; base saturation of 73%; and soil bulk density of 1.2 g cm^{-3} .

The treatments consisted of the application of the following fertilizers, with or without urease and nitrification inhibitors (NBPT and DCD, respectively): O, poultry litter as an organic fertilizer; O+I, poultry litter and both inhibitors; OM, organomineral fertilizer; OM+I, organomineral fertilizer and both inhibitors; U, urea as a mineral fertilizer; and U+I, super urea with the urease inhibitor alone; besides a control, without the application of N in the soil. The treatments were applied on 35-m^2 ($5 \times 7 \text{ m}$) plots, with a net area of 15 m^2 , in which the treatments were arranged in a randomized complete block design with six replicates.

The organic fertilizer used was poultry litter composed of 20, 40, and 22 g kg^{-1} total N, P_2O_5 , and K_2O , respectively. The litter was removed from aviary after six rotations. For granulation, poultry litter was micronized and received 0.5% of cassava starch as a conditioner for aggregation and 0.5% of calcium silicate to give hardness to the granule, with or without Agrotain Plus (Koch Agronomic Services, LLC, Wichita, KS, USA), which is a product that provides both urease and nitrification inhibitors. This product was used in the proportion of 4 kg Mg^{-1} in the poultry litter.

The $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$ formulation of the organomineral fertilizer, with or without inhibitors, was 06-16-16. The poultry litter was micronized and added to the diammonium phosphate (DAP) and potassium chloride (KCl) mineral fertilizers in the form of powder, along

with 0.5% of cassava starch for aggregation and 0.5% of calcium silicate for hardness. The proportion of the Agrotain Plus (Koch Agronomic Services, LLC, Wichita, KS, USA) inhibitor added to this formulation was also 4 kg Mg⁻¹.

Two corn (*Zea mays* L.) crops were sown in the first half of November, whereas one wheat crop (*Triticum aestivum* L.) was sown in the second half of May. The sowing of all crops was carried out with a drag-type no-tillage seed drill, with a disk coulter in front of the lagged double disks, with depth-limiter wheels, shank, and V-shaped compactors with two rubber wheels.

In the summer crops with corn, in 2012 and 2013, an early simple hybrid was sown: DKB 240 YieldGard (Monsanto do Brasil Ltda., São Paulo, SP, Brazil), with a cycle of 130 days, a density of 5.8 seeds per meter, and a row spacing of 0.60 m, to obtain a stand of 70,000 plants per hectare. The wheat crop was sown in the winter of 2011 with the cultivar BRS Parrudo – which has an early cycle of 135 days – at a density of 300 to 350 viable seeds per square meter, with row spacing of 0.20 m.

The agronomic efficiency of the different fertilizers was evaluated according to the wheat and corn crop demands to reach high yields. A dose of 100 kg ha⁻¹ N was applied to the wheat crop and of 140 kg ha⁻¹ N to the corn crops, corresponding, respectively, to 5 and 7 Mg ha⁻¹ of organic fertilizer, 1.7 and 2.3 Mg ha⁻¹ of organomineral fertilizer, and 217 and 304 kg ha⁻¹ of urea. In addition, for the wheat and corn crops, respectively, the doses of P₂O₅ and K₂O applied with the organomineral fertilizer corresponded to 272 and

368 kg ha⁻¹, whereas those with the organic fertilizer were 200 and 280 kg ha⁻¹ P₂O₅ and 110 and 154 kg ha⁻¹ K₂O. For the mineral fertilizer to provide similar amounts of P₂O₅ and K₂O as those obtained with the organomineral fertilizer, triple superphosphate and potassium chloride were added to the urea.

Organic, organomineral, and mineral fertilizers, with or without inhibitors, were applied to soil surface, next to the planting row, manually and in a single dose, immediately after sowing and without incorporation. The desiccation of weeds was done 14 days before sowing, with manual control during the initial period of plant development.

The stratified soil sampling was performed at the end of the second corn crop, in 2013, when samples were collected at the depths of 0.00–0.05, 0.05–0.10, and 0.10–0.20 m. Three simple samples were taken from the useful area of the plots using a cutting shovel: two from the interrows and one from the row, close to the point sampled in the interrows. The single samples were homogenized to form the composite sample. After collection, the soil was dried in a forced-air circulation oven at 65°C, milled, sieved in a 2.0-mm mesh sieve, and stored in plastic bags.

In each experimental plot, total N content, P, K, Ca, Mg, and H+Al in the soil, as well as total N in corn and wheat leaves were determined according to the methodologies described by Tedesco et al. (1995). For leaf sampling, 30 leaves were collected from the middle third of the plant, opposite and below the corn spike, in the corn tasseling stage; and 50 flag leaves were collected at the beginning of wheat flowering, as

Table 1. Averages of the maximum and minimum air temperatures and of rainfall during the experimental period, in the municipality of Concórdia, in the state of Santa Catarina, Brazil.

Month	2011			2012			2013		
	Maximum (°C)	Minimum (°C)	Rainfall (mm)	Maximum (°C)	Minimum (°C)	Rainfall (mm)	Maximum (°C)	Minimum (°C)	Rainfall (mm)
January	-	-	-	30.4	19.3	176	30.6	15.9	117
February	-	-	-	31.8	21.1	161	30.0	17.3	134
March	-	-	-	29.2	17.6	74	27.0	15.5	237
April	-	-	-	25.6	15.4	136	-	-	-
May	21.1	11.6	87	24.5	11.8	46	-	-	-
June	18.0	9.2	209	21.2	9.8	153	-	-	-
July	19.7	9.8	212	19.6	9.2	212	-	-	-
August	20.8	11.8	208	24.7	13.2	0	-	-	-
September	23.3	12.0	164	25.6	13.4	110	-	-	-
October	26.7	16.1	258	25.2	16.4	246	-	-	-
November	27.5	17.0	123	31.1	16.4	39	-	-	-
December	29.3	18.1	65	31.5	18.9	159	-	-	-

recommend in the manual of Comissão de Química e Fertilidade do Solo (Tedesco et al., 2004). The leaf samples were placed in paper bags and dried in a forced-air circulation oven at 65°C, for 72 hours or until achieving constant weight, and then were milled.

In order to estimate grain yield, harvest was carried out manually. For corn, spikes were harvested from the two central rows – with 2 m length and 0.8 m width – of the experimental plot, totaling 3.2 m²; and, for wheat, spikes were harvested from the three 0.25-m² micro-plots in each experimental unit. In all crops, grains were manually threshed, weighed, and dried, and grain yield was corrected to 13% moisture.

The results were subjected to the analysis of homogeneity of variances and normality. There was no need for data transformation. Means were compared by the LSD test, at 5% probability.

Results and Discussion

N content in the 0.00–0.05-m soil layer was higher, when compared with the control, in the treatments that received fertilization with organic, organomineral, and mineral fertilizers, with or without urease and nitrification inhibitors, after the three evaluated crop seasons. However, in the 0.05–0.10-m layer only the OM+I treatment differed from the control, and in the 0.10–0.20-m layer, only the U+I treatment was significant (Figure 1). The mineral fertilizers caused greater N movement in the soil profile than the organomineral ones due to the increased physicochemical solubility of their granules, which provide N more quickly to soil regardless of the use of inhibitors. It should be pointed out that, although the OM+I and OM treatments did not differ significantly, the first one showed higher values of available N after two years of cultivation under no-tillage. This result, despite the lack of statistical significance, is an indicative that the presence of inhibitors in the organomineral fertilizer (OM+I) may reduce N losses in the soil.

The granulated organic fertilizer (O and O+I) provides gradual N release. When there is an increase in the soil labile organic carbon, biomass and microbial activity are stimulated and may lead to increased N mineralization efficiency in the soil (Gong et al., 2009). This would explain the absence of significant differences between fertilizers regarding available N

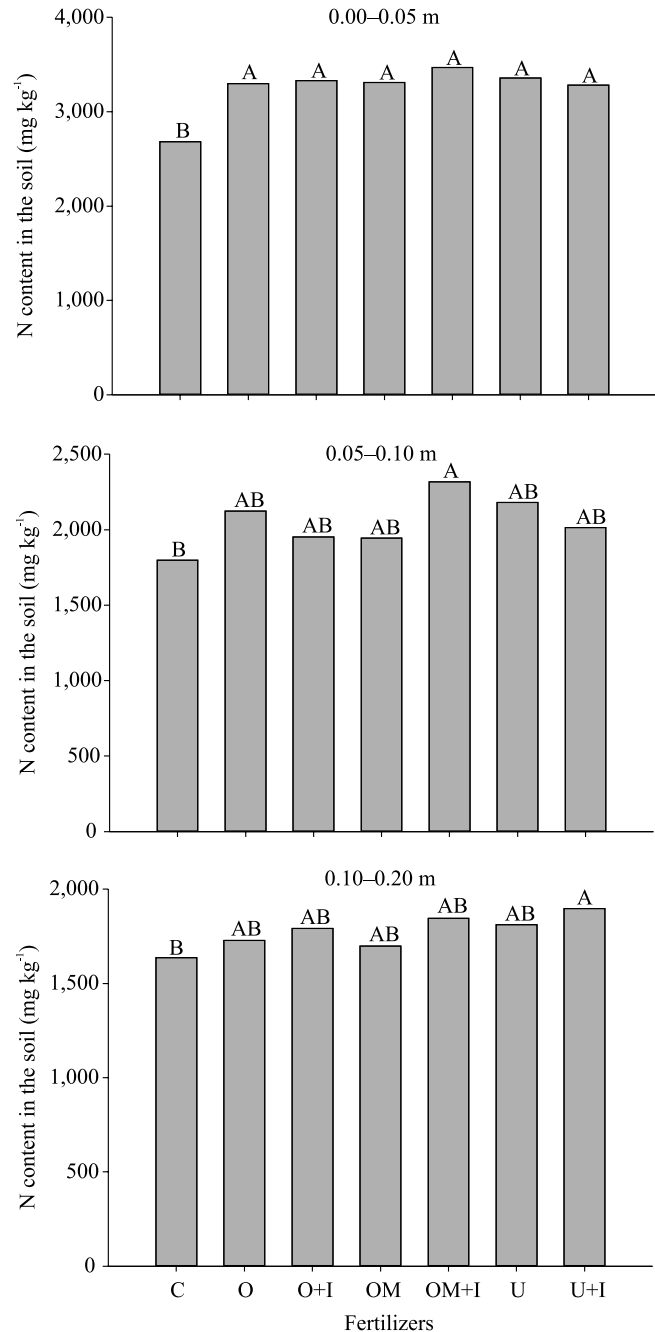


Figure 1. Soil nitrogen content after one wheat (*Triticum aestivum*) and two corn (*Zea mays*) crops with the evaluated organic, organomineral, and mineral nitrogen fertilizers, in the 0.00–0.05, 0.05–0.10, and 0.10–0.20-m soil layers. Means followed by equal letters do not differ by the LSD test, at 5% probability. C, control; O, poultry litter as an organic fertilizer; O+I, organic fertilizer + urease and nitrification inhibitors; OM, organomineral fertilizer; OM+I, organomineral fertilizer + urease and nitrification inhibitors; U, urea as a mineral fertilizer; and U+I, super urea + urease inhibitor.

contents in the soil. Depending on the type of organic chain in which it is inserted, soil organic N may have high or low lability (Grohskopf et al., 2015).

The statistical similarity observed between treatments for soil N availability is related, among other factors, to the buffering power of the cultivation environment given by soil organic matter, in which nutrient contents – classified as medium, but close to high (Tedesco et al., 2004) – may be stabilized in soils at adequate levels for plant growth and production.

After the three crops, the fertilizers provided 393, 264, and 260 kg ha⁻¹ N in the 0.00–0.05, 0.5–0.10, and 0.10–0.20-m layers, respectively. These values were obtained by the difference between the control and the treatments with N fertilizers that enabled increased nutrient contents in the soil, such as OM+I in the first two layers and U+I in the last one (Figure 1). These results indicate that the production system has provided the stabilization of labile forms of N in the soil and also that, over the years, new assessments will be needed to guide the decision-making process and to increase the efficiency of N fertilization.

In the first wheat crop, in 2011, the fertilizers showed similar efficiency regarding the increased leaf N contents, but only the O, O+I, and U treatments were significantly superior to the control (Figure 2). The N sufficiency range for the wheat crop is between 20–34 g kg⁻¹ N (Malavolta et al., 1997); therefore, the treatments with fertilizers provided N contents higher than those recommended by the literature, which evidences that the plants were well supplied with this nutrient.

Still regarding wheat, the efficiency of the organic fertilizers was similar to that of the mineral ones. A possible explanation is the superficial wheat root system, which increases plant capacity to exploit the area of the soil with the highest N concentration, probably favoring the similar results obtained among fertilizers.

In the second crop season, with corn cultivation in 2012, the treatments differed regarding leaf N contents; the highest values were observed with the use of soluble mineral sources, especially U+I (Figure 2). Considering that the sufficiency range for the corn crop is between 27 and 35 g kg⁻¹ N, only the control and the treatments with organic fertilization (O and O+I) resulted in lower leaf N contents than those recommended by the literature.

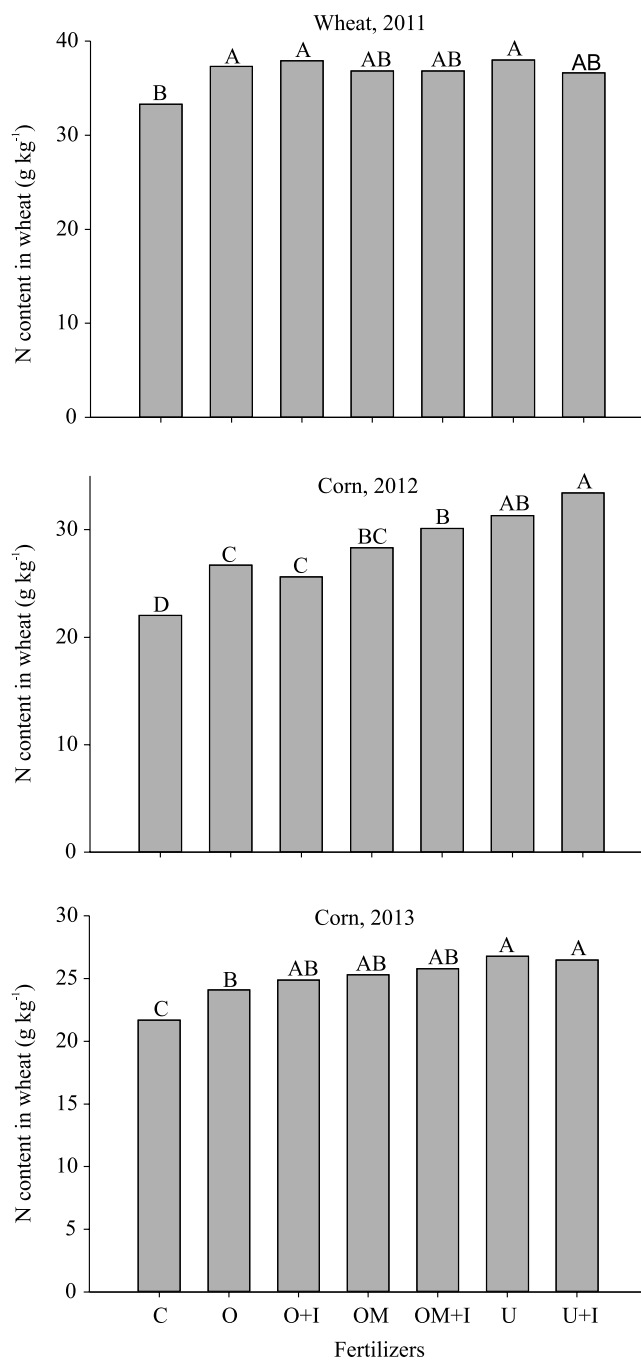


Figure 2. Nitrogen content in wheat (*Triticum aestivum*) and corn (*Zea mays*) plants treated with the evaluated organic, organomineral, and mineral nitrogen fertilizers, in 2011, 2012, and 2013. Means followed by equal letters do not differ by the LSD test, at 5% probability. C, control; O, poultry litter as an organic fertilizer; O+I, organic fertilizer + urease and nitrification inhibitors; OM, organomineral fertilizer; OM+I, organomineral fertilizer + urease and nitrification inhibitors; U, urea as a mineral fertilizer; and U+I, super urea + urease inhibitor.

In the treatments with the same fertilizer, the inclusion of inhibitors did not significantly increase leaf N content; however, the highest numerical values were found in the treatments with inhibitors. It is interesting to note that the lowest rainfall during the crop cycle (Table 1), in this same crop season, may have contributed to reduce N losses, which most likely approximated the results of the treatments with and without inhibitors.

In the third crop season, with corn cultivation in 2013, N content in the plant tissue was higher in the treatments with fertilizers (Figure 2). Only the O treatment presented results lower than those obtained with urea, with or without the presence of the urease inhibitor (U and U+I, respectively); in addition, this was the only treatment, together with the control, in which leaf N content was below the critical level of 27 g kg⁻¹ N (Malavolta et al., 1997).

In the 2013 crop season, rainfall was uniform throughout the crop cycle (Table 1), a condition that favors greater nutrient absorption by plant roots.

The organic, organomineral, and mineral fertilizers, with or without inhibitors, caused significant differences in P, K, Ca, Mg, and H+Al contents, as well as in base saturation, in different soil layers after two crop years (Table 2). Only the O, O+I, OM, and OM+I treatments increased available P content in the 0.00–0.05-m layer. It should be highlighted that the presence of organic matter in organic and organomineral fertilizers may reduce P fixation in crystalline forms of iron and aluminum oxides, since organic matter competes with the anion phosphate for adsorption at these sites (Shuai & Zinati, 2009).

Although soil K content was classified as very high in the control treatment (Tedesco et al., 2004), it was lower than that obtained with O, O+I, and OM+I in the 0.05–0.10-m layer, and with OM+I, U, and U+I in the 0.10–0.20-m layer (Table 2), which shows the effect of the non-restitution of the nutrient on soil fertility. However, when compared with the control, the organic fertilizer decreased H+Al contents and

Table 2. Soil chemical properties at different depths after one wheat (*Triticum aestivum*) and two corn (*Zea mays*) crops, under the evaluated organic, organomineral, and mineral nitrogen fertilizers⁽¹⁾.

Fertilizer	pH (H ₂ O)	P (mg dm ⁻³)	K	Ca	Mg	H+Al	CEC	Base saturation (%)
0.00–0.05-m soil layer								
C	5.6	19c	11.5	71b	49b	39	177	77
O	5.7	45a	11.9	84a	57a	33	185	82
O+I	5.6	41ab	14.3	81ab	57a	37	188	80
OM	5.5	42ab	12.9	73b	53b	42	178	77
OM+I	5.5	41ab	12.2	72b	52b	36	172	79
U	5.5	35b	11.5	75b	53b	41	181	79
U+I	5.6	35b	13.6	70b	49b	41	177	76
0.05–0.10-m soil layer								
C	5.4	4.8b	5.9b	55ab	37	47a	145ab	67b
O	5.4	8.3a	9.9a	61a	38	38b	142b	76a
O+I	5.5	10.1a	10.8a	60a	41	42ab	154a	72ab
OM	5.3	9.5a	8.8ab	56ab	39	44ab	148ab	70ab
OM+I	5.3	9.5a	10.6a	60a	40	47a	158a	70ab
U	5.3	10.0a	9.1ab	60a	39	48a	156a	69ab
U+I	5.2	9.2a	8.2ab	50b	35	45ab	138b	67b
0.10–0.20-m soil layer								
C	5.4	2.5	6.0b	47	36	45	134	66
O	5.4	5.0	6.9ab	55	37	44	142	69
O+I	5.3	6.0	8.3a	55	35	43	142	70
OM	5.4	5.5	7.8ab	57	37	42	144	70
OM+I	5.3	7.0	7.3ab	52	35	42	140	69
U	5.3	7.5	8.4a	54	36	43	139	69
U+I	5.3	6.0	8.5a	55	38	44	143	70

⁽¹⁾Means followed by equal letters do not differ by the LSD test, at 5% probability. C, control; O, poultry litter as an organic fertilizer; O+I, organic fertilizer + urease and nitrification inhibitors; OM, organomineral fertilizer; OM+I, organomineral fertilizer + urease and nitrification inhibitors; U, urea as a mineral fertilizer; U+I, super urea + urease inhibitor; and CEC, cation exchange capacity.

increased base saturation; OM+I and U increased H+Al; and U+I increased base saturation in the 0.05–0.10-m layer. These results may be attributed to the fact that the organic matter present in the organic fertilizer is able to complex aluminum and provide negative charges for the retention of basic cations, when applied in large amounts in the soil-plant system.

Regarding wheat grain yield, only the OM+I and U treatments were superior to the control, and the highest yield was obtained with OM+I, which presented an increase of 916 kg ha⁻¹ in comparison with the control (Figure 3). It should be pointed out that, at the beginning of the experiment, the soil already presented 1.25, 1.00, and 1.60 Mg ha⁻¹ N in the 0.00–0.05, 0.05–0.10, and 0.10–0.20-m layers, respectively.

In the 2012 corn crop season, the OM+I and U+I treatments with inhibitors stood out compared with the other ones (Figure 3). This shows that the slower N release enabled the longer preservation of the nutrient in the soil, with positive effects on yield. In this crop season, the yield gains were of 1,724 kg ha⁻¹ with the OM+I treatment, in comparison with the control.

In the 2013 crop season, with a uniform rainfall distribution, the treatments with fertilizers did not differ from each other, but were superior to the control (Figure 3). However, there was a significant yield gain of 1,656 kg ha⁻¹ in the U+I treatment, when compared with the control.

Even when N content in the soil was adequate (Figure 2), the contribution of the nutrient to the system allowed gains in the total grain yield of the three crop

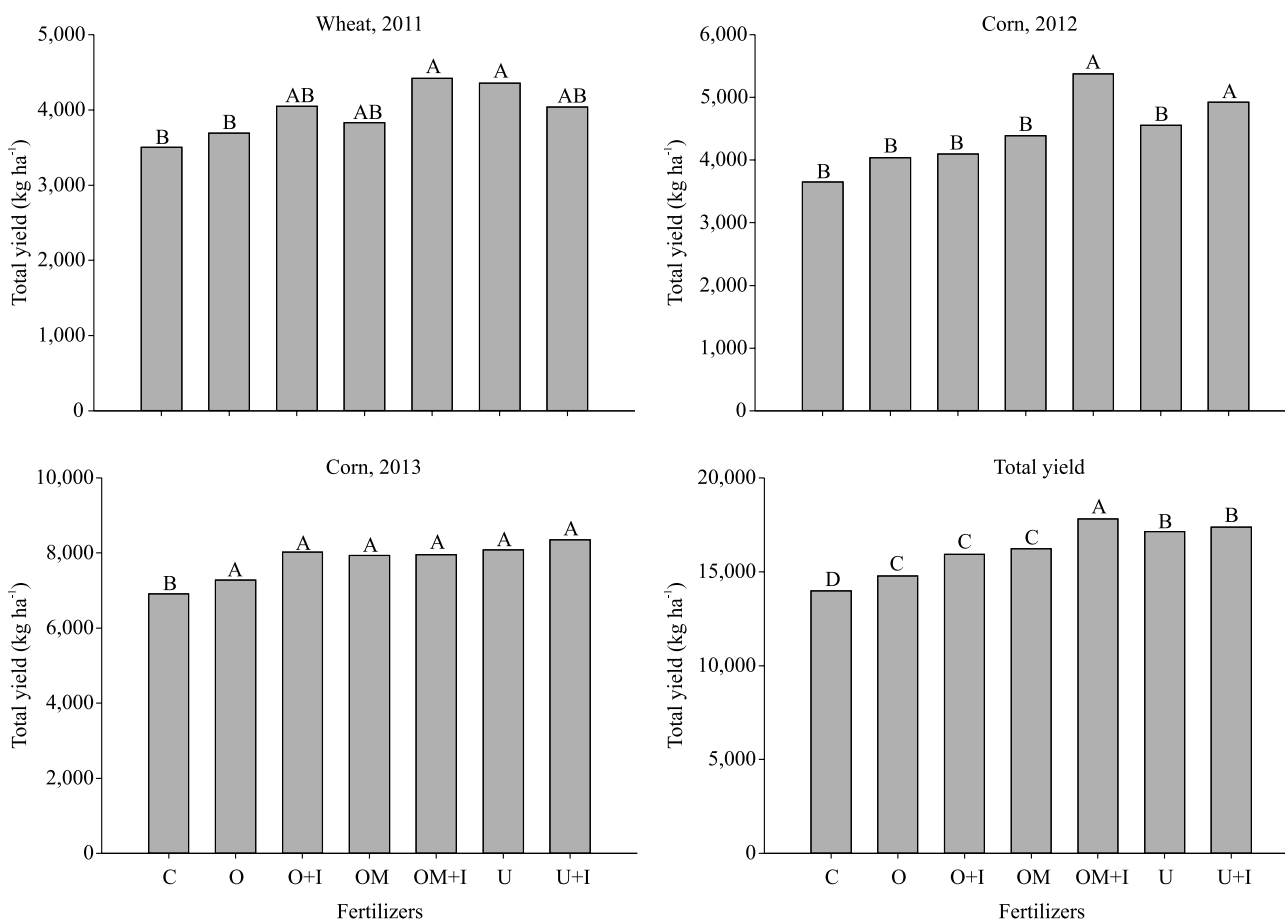


Figure 3. Wheat (*Triticum aestivum*), corn (*Zea mays*), and total grain yields after the application of the evaluated organic, organomineral, and mineral nitrogen fertilizers, in 2011, 2012, and 2013. Means followed by equal letters do not differ by the LSD test, at 5% probability. C, control; O, poultry litter as an organic fertilizer; O+I, organic fertilizer + urease and nitrification inhibitors; OM, organomineral fertilizer; OM+I, organomineral fertilizer + urease and nitrification inhibitors; U, urea as a mineral fertilizer; and U+I, super urea + urease inhibitor.

seasons. During this period, the OM+I treatment stood out and was superior to the U and U+I mineral sources, which, in turn, were superior to OM, O+I, and O (Figure 3).

Other studies have shown similar or greater yield with the use of organic fertilizers, such as swine manure or poultry litter, in comparison with that of mineral fertilizer under no-tillage (Cassol et al., 2012). In a Latossolo Vermelho-Amarelo, i.e., a Rhodic Hapludox, with a sandy texture, Fernandes et al. (2007) found no significant differences in coffee (*Coffea arabica* L.) yield in response to the use of organominerals in solid form and poultry litter-based, when compared with conventional chemical sources. Similarities in crop yield have also been observed between other organic materials and mineral sources in fertilizer formulation (Tejada et al., 2004; Babalola et al., 2007). However, the lack of scientific information and research results does not yet allow the confirmation of the potential and of the risks of using these fertilizers, especially with inhibitors in their formulation.

Conclusions

1. The use of organic, organomineral, and mineral fertilizers, with or without urease and nitrification inhibitors, increases available N content in the 0.00–0.05-m soil layer; however, in deeper layers, only the organomineral fertilizer + inhibitors, in the 0.05–0.10-m layer, and super urea + urease inhibitor, in the 0.10–0.20-m layer, are superior to the control.

2. The used fertilizers increase total grain yield of the evaluated corn (*Zea mays*) and wheat (*Triticum aestivum*) crops in the following order: organomineral fertilizer + inhibitors > urea + urease inhibitor ≥ urea > organomineral fertilizer ≥ organic fertilizer + inhibitors ≥ organic fertilizer.

3. The organic fertilizer, organic fertilizer + inhibitors, organomineral fertilizer, and organomineral fertilizer + inhibitors increase available P content and base saturation, besides decreasing H+Al in the soil surface layer.

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