AGRONOMY (AGRONOMIA)

Revista Brasileira de Ciências Agrárias
ISSN (on line) 1981-0997
v.14, n.1, e5618, 2019
Recife, PE, UFRPE. www.agraria.pro.br
DOI:10.5039/agraria.v14i1a5618
Protocolo 5618 - 25/02/2018 • Aprovado em 31/10/2018

Organic, mineral and organomineral fertilizer in the growth of wheat and chemical changes of the soil

Gilmar Luiz Mumbach[1], Luciano Colpo Gatiboni[1], Fabiano Daniel de Bona[2],
Djalma Eugênio Schmitt[3], Daniel João Dall'Orsoletta[1], Camila Adaime Gabriel[1], Élcio Bilibio Bonfada[4]

[1] Department of Soil Science and Natural Resources of the Santa Catarina State University, Lages, SC, Brazil. E-mail: gilmarmumbach@hotmail.com (ORCID: 0000-0002-1880-3894); luciano.gatiboni@udesc.br (ORCID: 0000-0001-8724-3600); dani.orsoletta@gmail.com (ORCID: 0000-0003-0882-0073); camilaadaimegabriel@gmail.com (ORCID: 0000-0000-0000-0000)
[2] Brazilian Agricultural Research Corporation (Embrapa Trigo), Passo Fundo, RS, Brazil. E-mail: fabiano.debona@embrapa.br (ORCID: 0000-0000-0000-0000)
[3] Department of Agriculture, Biodiversity and Forests of the Santa Catarina Federal University, Curitibanos, SC, Brazil. E-mail: djalma.schmitt@gmail.com (ORCID: 0000-0001-9665-9704)
[4] Mato Grosso Fundation, Campo Novo do Parecis, MT, Brazil. E-mail: agroebonfada@gmail.com (ORCID: 0000-0002-8760-635X)

ABSTRACT: The organomineral fertilizers can release organic compounds during their solubilization, and those compounds can affect the plant growth. The aim of this study was to evaluate the initial development of wheat, nutrient accumulation in the plant and soil chemical changes, with the use of organic, mineral and organomineral fertilizers. The experiment was conducted in a greenhouse using an Acrisol cultivated with wheat (*Triticum aestivum*). Six treatments were tested: 100% of the nutrient recommendation in organomineral form (OMF 100); broiler litter in the same amount present in the OMF 100 (BL 10); mineral fertilizer in the same quantity present in the OMF 100 (MF 90); 100% of the nutrient recommendation in the form of broiler litter (BL 100); 100% of the nutrient recommendation in mineral form (MF 100); and a control without fertilization (CONT). The treatments were evaluated at six sampling times: 2, 4, 8, 15, 30 and 80 days after implantation. No significant differences were observed between fertilizers in dry matter yield. In the soil, there was a decrease in availability of N, P and K over time. By equivalence, all the sources tested can be used in the supply of nutrients to the wheat crop.

Key words: biofertilizer; broiler litter; fertilization; *Triticum aestivum*

Fertilizante orgânico, mineral e organomineral no crescimento de trigo e alterações químicas do solo

RESUMO: Os fertilizantes organominerais podem liberar compostos orgânicos durante sua dissolução, os quais podem afetar o desenvolvimento das plantas. Objetivou-se avaliar o desenvolvimento inicial de trigo, acúmulo de nutrientes na planta e alterações químicas do solo, com o uso de fertilizantes orgânico, mineral e organomineral. O experimento foi conduzido em casa-de-vegetação, utilizando um Cambissolo Háplico cultivado com trigo (*Triticum aestivum*). Foram testados seis tratamentos: 100% da recomendação de nutrientes na forma de organomineral (FOM 100); cama aviária na mesma quantidade presente no FOM 100 (CA 10); adubo mineral na mesma quantidade presente no FOM 100 (FOM 90); 100% da recomendação de nutrientes na forma de cama aviária (CA 100); 100% da recomendação de nutrientes na forma mineral (FM 100); e uma testemunha sem adubação (CONT). Os tratamentos foram avaliados em seis épocas de amostragem: 2, 4, 8, 15, 30 e 80 dias após a implantação. Não foram observadas diferenças significativas entre os fertilizantes no rendimento de massa seca. No solo houve decréscimo na disponibilidade de N, P e K ao longo do tempo. Pela equivalência, todas as fontes testadas podem ser empregadas no suprimento de nutrientes para a cultura do trigo.

Palavras-chave: biofertilizante; cama aviária; adubação; *Triticum aestivum*

Introduction

The application of fertilizers, mineral or organic, is a recommended practice to supply the nutrients necessary for the plant growth. However, the type of fertilizer may alter the initial development of the plants, since organic fertilizers need to be mineralized for the release of nutrients (Antille et al., 2014b). Regarding cultivated species, among them wheat (*Triticum aestivum*), the nutrient supply is predominantly done in the form of mineral fertilization, which stands out for the high concentration and solubility (Herrera et al., 2016).

Organic fertilization with manure is an alternative to mineral fertilization in sites with large production of animals in a confined system (De Conti et al., 2016). The continuous addition of animal manure can increase the soil contents of macronutrients such as calcium (Ca), magnesium (Mg), potassium (K) and phosphorus (P) (Lourenzi et al., 2016) and of cationic micronutrients (Andreola et al., 2000), as well as the total organic carbon contents (Lourenzi et al., 2016). Furthermore, it can reduce the activity of aluminum in the soil (Brunetto et al., 2012). However, these sources present, in general, low concentration of nutrients, precluding their transport and application in areas far from the place where they are produced.

As an alternative to the combination of the benefits of organic and mineral fertilizers, the so-called organomineral fertilizers are nowadays offered in the market, resulting from the addition of mineral fertilizers to organic waste (Sá et al., 2017). Among the benefits to the soil, it is possible to highlight the possible reduction of the specific adsorption of P, by the presence of labile forms of C, which may block the adsorption sites, or make complex the forms of Al, Fe and Ca (Weng et al., 2012). The use of these fertilizers can also reduce the losses of N by the presence of more recalcitrant forms of this element, which are bounded to organic compounds (Tejada et al., 2005).

Some studies show that organomineral fertilizers present similar potential to that of mineral fertilizers, as regards to the development and yield of agricultural species in the field (Andreola et al., 2000; Deeks et al., 2013). However, there is still a lack of studies evaluating the effect of the application of these fertilizers on the initial development of plants and on changes in soil chemical attributes. In addition, it is necessary to evaluate if the organic fraction present in the organomineral fertilizers results in benefits to the plant and to the soil, or if the response comes only from the mineral fraction, which supplies much of the nutrients present in the organomineral fertilizer.

Thus, the hypotheses of this work are that (1) the organomineral fertilizer, due to the slow release of nutrients and the presence of soluble fractions of C, results in greater initial growth of wheat, and (2) promotes improvements in soil chemical attributes. The objective of this study was to evaluate the efficiency of fertilizer sources in the initial growth of wheat and their effect on the soil chemical attributes and on the plant over time in a greenhouse experiment.

Materials and Methods

Place of study and soil used

The experiment was conducted in a greenhouse at the Santa Catarina State University. An Acrisol, important soil class of Santa Catarina and derived from sedimentary rocks, was collected in the 0.00-0.20 m layer of a land under native pasture (27° 11’ S, 49° 39’ W, and 690 m altitude). The soil was passed through a 5-mm sieve, air dried and incubated with lime to raise the pH in water to 6.0. The chemical characterization of the soil, based on the methodologies described by Tedesco et al. (1995), presented: 217, 345 and 438 g kg^{-1} of clay, silt and sand, respectively; pH-H_2O = 4.9; SMP Index = 5.6; 33.4 g kg^{-1} of organic matter (OM); 5.7 and 138.0 mg dm^{-3} of available P and K (Mehlich 1); 1.9, 1.9 and 2.2 cmolc dm^{-3} of exchangeable Ca, Mg and Al, respectively; 62.8, 0.9, 4.1 and 493.1 mg dm^{-3} of Mn, Cu, Zn and Fe, respectively; 7.1, 4.1, 6.3 and 11.3 cmolc dm^{-3} of potential acidity (H + Al), sum of bases, effective CEC and CEC pH 7; 34 and 37% of aluminum saturation and base saturation, respectively. The OM content and soil P and K contents were classified as medium, low and very high, respectively (CQFS-RS/SC, 2004).

Experimental design and treatments

The experiment was conducted in a completely randomized design in a 6 x 6 factorial scheme, with six treatments, six sampling times, and three replications, totaling 108 experimental units. The treatments were: 1) OMF 100, with 100% of the recommendation of NPK in organomineral form; 2) BL 10 - same amount of broiler litter present in the OMF 100 treatment; 3) MF 90 - the same amount of mineral fertilizer present in the OMF 100 treatment; 4) BL 100: 100% of the NPK recommendation supplied by broiler litter; 5) MF 100: 100% of NPK recommendation in mineral form; 6) CONT: treatment without fertilization. The organomineral fertilizer is composed by 60% of broiler litter and 40% of monoammonium phosphate (MAP) and each is responsible, respectively, by 10 e 90% of N and P contents in the fertilizer. The applied NPK rates were based on the recommendations of the Local Soil Fertility Committee (CQFS-RS/SC, 2004), aiming at a yield of 4 Mg ha^{-1} of wheat grains. The broiler litter, the MAP and the organomineral fertilizer had 2.3, 9.0 and 5.8% of N, 3.7, 48.0 and 21.0% of P_2O_5, and 2,3, 0,0 and 1,6 % of K_2O respectively, in their composition (Tedesco et al., 1995). The following amounts of N, P and K were added, respectively: OMF 100: 31, 22 and 25 mg kg^{-1}; BL 10: 3, 2 and 2.5 mg kg^{-1}; MF 90: 28, 20, 22.5 mg kg^{-1}; BL 100: 31, 22 and 25 mg kg^{-1} and MF 100: 31, 22 and 25 mg kg^{-1}. In the treatments OMF 100, MF 90 and MF 100, urea (45% N) and potassium chloride (58% K_2O) were added to supplement the deficiencies of N and K, respectively.

Wheat, cultivar Tbio Sintonia, was sown in pots containing 2.7 kg of soil. The soil was maintained with moisture at 85% of field capacity, with daily replacement of the lost volume through the addition of distilled water. Fertilization was carried out at the time of sowing. Initially, a cylindrical opening was made in the soil in the central part of the pot, with a diameter of 0.01 m and a depth of 0.04 m, in which the fertilizers were put, they were then covered with soil. Seeding was done later, with the placement of 5 wheat seeds per pot, at a depth of 2 cm. After emergence, 3 plants were maintained per pot.

Collection of material and analyzes carried out

Soil samples were collected at 2, 4, 8, 15, 30 and 80 days after implantation (DAI), and the plants samples at 8, 15, 30 and 80 DAI. In each of the six sampling periods, a set of 18 pots were collected, and the plant and soil samples were collected for subsequent determinations. The soil was sampled in two ways: in the first one a soil sample located at 0.01 m from the fertilization site was collected, for evaluation of: Water Soluble Carbon (WSC), whose extraction followed the methodology of Mendonça & Matos (2006) and determination by Silva & Bohnen (2001), and available P by Mehlich 1 (Tedesco et al., 1995). For the other sample, the remaining soil was homogenized and sampled, analyzing: available levels of P by Mehlich 1, K, NO_3^-, NH_4^+, Mn, Cu and Zn extracted by Mehlich 3 (Mehlich, 1984), as well as the values of pH in water and total organic carbon content (TOC) (Tedesco et al., 1995).

After removal from the pots, the plants were placed in paper bags and oven dried at 60ºC for 72 hours to determine the dry mass. Subsequently the samples were ground and underwent wet digestion with sulfuric acid, hydrogen peroxide and digestion mixture containing sodium sulfate, copper sulfate and selenium (Tedesco et al., 1995). The contents of N, P and K were analyzed according to the methodology of Tedesco et al. (1995), and the amount of each of the nutrients accumulated per pot was calculated.

The obtained data were submitted to the Shapiro Wilk normality test and subsequent analysis of variance. When significant, the qualitative effects (fertilizers) were compared by the Tukey Test ($P<0,05$), while the quantitative (sampling periods) were analyzed by regression. Data analysis was performed using the statistical software SISVAR (Ferreira, 2014).

Results and Discussion

Growth and nutritional parameters of the wheat crop

The total dry matter yield of the wheat crop varied over time and between treatments (Table 1). The OMF 100 and MF 90 treatments presented higher yield than the control in the last sampling period (80 DAI), but were similar to the other sources in all the initial samplings, indicating that there was no superior response of the organomineral in relation to them. The reduced growth of wheat, observed up to the 30 DAI, is mainly due to the restriction of sunlight in that period. Due to their higher solubility, the mineral fertilizers can promote superior growth, especially in the early stages of crop development (Lourenço et al., 2013). In addition, fertilizers of higher solubility may favor nutrient uptake by plants in the early stages of development (Lourenço et al., 2013), where the volume of soil explored is small. However, due to the residual effect of the organic and organomineral fertilizers, with the late release of some nutrients, this response ceases to exist in subsequent crops (Silva et al., 2015).

The concentration of N, P and K in the plants increased in the plant up to the 30 DAI, with subsequent reduction (data not shown), mainly due to the dilution caused by the increase in phytomass accumulation. The amount of nutrients accumulated in the plant increased over time due to plant growth, and the differences between treatments only occurred in the last two harvests for P and N and only in the last one for K (Table 2). In general, the amounts of N, P and K accumulated by the plants were similar in the treatments with 100% fertilization (OMF 100, BL 100 and MF 100) but also in the MF 90. For P, however, fertilization with 100% broiler litter (BL 100) resulted in a lower absorption in relation to the mineral source at the 80 DAI. The higher accumulation of P in treatments with mineral fertilization may be due to the greater solubility in relation to organic fertilization, indicating that part of the P present in the organic fertilizer was not made available to the plant in the period (Antille et al., 2014a).

In general, it was observed that the organomineral fertilizer presented a similar response to mineral and organic fertilization in wheat development, without resulting in a differentiated initial growth, as was expected. In the same way, the nutrient absorption suffered little interference between the sources, except for P, with greater absorption of the element when the mineral fertilization was done, in relation to the organic one. It should be noted that, despite the equivalent response to mineral fertilizers, organomineral

Table 1. Yield of total dry mass of wheat cultivated in greenhouse, evaluated in different periods after implantation, and equations of behavior over time, due to the addition of fertilizer sources.

Treatment	Days after implantation						Equation	R²
	2	4	8	15	30	80		
	(g pot^{-1})							
OMF 100	-	-	0.1^{ns}	0.1^{ns}	0.2^{ns}	6.6 a$^{(1)}$	$y = 0.096**x - 1.426$	0.93
BL 10	-	-	0.1	0.1	0.2	3.2 ab	$y = 0.045**x - 0.609$	0.94
MF 90	-	-	0.1	0.1	0.2	6.7 a	$y = 0.002**x^2 - 0.056x + 0.468$	0.99
BL 100	-	-	0.1	0.1	0.2	5.3 ab	$y = 0.001**x^2 - 0.045x + 0.404$	0.99
MF 100	-	-	0.1	0.1	0.3	6.4 ab	$y = 0.092**x - 1.366$	0.93
CONT	-	-	0.1	0.1	0.2	2.7 b	$y = 0.038**x - 0.488$	0.94
CV, %	-	-	22.1	17.1	13.7	27.5	-	-

OMF 100: 100% of NPK in the form of organomineral fertilizer; BL 10: same amount of broiler litter present in the OMF 100 treatment; MF 90: same amount of mineral fertilizer present in the OMF 100 treatment; BL 100: 100% NPK in the form of broiler litter; MF 100: 100% NPK in mineral form; CONT: control, without fertilization.

(1) Means followed by different letters in the columns differed by Tukey test ($p <0.05$). ns: not statistically significant. CV: coefficient of variation. ** Significant by t test, $P < 0.01$.

Table 2. Accumulated values of phosphorus (P), nitrogen (N) and potassium (K) in wheat plants grown in greenhouse, evaluated at different periods after implantation, and behavioral equations over time, as a function of the addition of fertilizer sources.

Treatment	Days after implantation						Equation	R^2
	2	4	8	15	30	80		
			(P mg pot^{-1})					
OMF 100	-	-	0.3^{ns}	0.2^{ns}	0.9 a$^{(1)}$	10.5 ab	$y = 0.002^{**}x^2 - 0.057x + 0.600$	0.99
BL 10	-	-	0.3	0.3	0.3 b	5.1 cd	$y = 0.001^{**}x^2 - 0.055x + 0.705$	0.99
MF 90	-	-	0.3	0.2	0.7 ab	11.9 ab	$y = 0.003^{**}x^2 - 0.086x + 0.819$	0.99
BL 100	-	-	0.3	0.3	0.3 b	8.7 bc	$y = 0.002^{**}x^2 - 0.093x + 0.997$	0.99
MF 100	-	-	0.3	0.3	0.9 a	13.5 a$^{(1)}$	$y = 0.003^{**}x^2 - 0.095x + 0.918$	0.99
CONT	-	-	0.3	0.3	0.2 b	3.9 d	$y = 0.054^{**}x - 0.609$	0.92
CV, %	-	-	29.0	20.6	37.2	16.9	-	-
			(N mg pot^{-1})					
OMF 100	-	-	3.8^{ns}	4.0^{ns}	9.2 ab	158.9 ab	$y = 0.038^{**}x^2 - 1.221x + 12.151$	0.99
BL 10	-	-	3.9	4.6	6.7 b	83.9 bc	$y = 0.020^{**}x^2 - 0.631x + 8.424$	0.99
MF 90	-	-	2.7	3.9	8.6 ab	163.5 a	$y = 0.039^{**}x^2 - 1.254x + 11.632$	0.99
BL 100	-	-	3.8	4.2	7.2 ab	130.9 abc	$y = 0.032^{**}x^2 - 1.086x + 11.509$	0.99
MF 100	-	-	3.7	3.7	10.7 a	168.9 a$^{(1)}$	$y = 0.040^{*}x^2 - 1.196 + 11.523$	0.99
CONT	-	-	3.7	4.4	6.8 b	72.7 c	$y = 1.011^{**}x - 11.703$	0.94
CV, %	-	-	22.3	16.7	16.7	21.9	-	-
			(K mg pot^{-1})					
OMF 100	-	-	3.4^{ns}	4.5^{ns}	10.8^{ns}	21.9 ab	$y = 0.260^{**}x + 1.518$	0.98
BL 10	-	-	3.3	4.7	8.7	12.6 bc	$y = 0.124^{**}x + 3.213$	0.92
MF 90	-	-	2.3	3.8	10.6	22.8 a$^{(1)}$	$y = 0.285^{**}x + 0.405$	0.98
BL 100	-	-	2.9	4.2	8.3	20.5 abc	$y = 0.246^{**}x + 0.811$	0.99
MF 100	-	-	3.3	4.4	11.5	21.9 ab	$y = -0.002^{**}x^2 + 0.468x - 0.997$	0.99
CONT	-	-	2.9	4.9	8.7	11.7 c	$y = 0.112^{**}x + 3.303$	0.86
CV, %	-	-	22.9	17.2	18.4	19.8	-	-

OMF 100: 100% of NPK in the form of organomineral fertilizer; BL 10: same amount of broiler litter present in the OMF 100 treatment; MF 90: same amount of mineral fertilizer present in the OMF 100 treatment; BL 100: 100% NPK in the form of broiler litter; MF 100: 100% NPK in mineral form; CONT: control, without fertilization.
(1) Means followed by different letters in the columns differed by Tukey test ($p < 0.05$). ns: not statistically significant. CV: coefficient of variation. **Significant by t test, $P < 0.01$.

fertilizers may present positive factors, especially from the environmental point of view, giving adequate destination to residues of animal production (Sá et al., 2017).

Availability of nutrients and soil chemical parameters

The availability of soil P varied significantly over time and between treatments (Table 3). Over time there was a linear reduction of nutrient contents ($y = -0.025^{*}x + 12.759$ $R^2 = 0.66$), possibly due to their absorption by the plant and the adsorption of P to the soil's solid constituents, especially iron and aluminium oxides, becoming unavailable to the plant. The highest availability of P was observed in soil with mineral fertilization (MF 100, MF 90), higher than the other treatments that received equivalent doses of P (OMF 100 and BL 100). The lower P availability in the soil fertilized with organic and organomineral fertilizers may be related to the presence of compounds of lower lability in their constitution, delaying the solubilization (Tejada et al., 2005). In addition, the lower release of P by the organomineral fertilizer in relation to the mineral source may be related to the preparation processes of that fertilizer, with formation of less soluble fractions of the nutrient (Antille et al., 2014a).

The highest contents of P in the soil collected near the fertilizer deposition site (P localized) were observed in treatments with mineral fertilization (MF 100, MF 90), and those were higher than the other treatments (Table 3). The greater solubility of mineral fertilizers may have resulted in increased concentration and consequent saturation of soil adsorption sites at the fertilizer deposition site (Castro et al., 2015), resulting in the displacement of a small fraction of the element. This diffusion of P in the soil usually occurs within a few weeks after fertilization, being restricted, in most cases, to a few millimeters of the application site, varying according to the texture and adsorptive capacity of the soil (Degryse & McLaughlin, 2014).

Table 3. Levels of P available in the total soil (P total soil) and in the fraction collected near the fertilizer deposition site (P localized), in the average of the six samples, as a function of the addition of fertilization sources.

Treatment	P total soil	P localized
	(mg dm^{-3})	
OMF 100	12.8 b	5.7 b
BL 10	8.1 c	5.7 b
MF 90	15.0 a	7.9 a
BL 100	12.2 b	5.6 b
MF 100	16.8 a$^{(1)}$	8.1 a$^{(1)}$
CONT	7.7 c	5.8 b
CV %	16.7	29.8

OMF 100: 100% of NPK in the form of organomineral fertilizer; BL 10: same amount of broiler litter present in the OMF 100 treatment; MF 90: same amount of mineral fertilizer present in the OMF 100 treatment; BL 100: 100% NPK in the form of broiler litter; MF 100: 100% NPK in mineral form; CONT: control, without fertilization.
(1) Means followed by different letters in the columns differed by Tukey test ($p < 0.05$). CV: coefficient of variation.

The availability of K decreased over time (Table 4) as a function of plant growth and consequent absorption of the

Table 4. Potassium (K), ammonium (NH_4^+) and nitrate (NO_3^-) availability, pH H_2O value and water soluble carbon content (WSC), mean of the six samples, and behavioral equations over time, due to the addition of fertilization sources.

Treatment	Variable analyzed	Equation	R^2
-	K. mg dm^{-3}	-	-
OMF 100	119.1 a	$y = -0.559^{**}x+132.07$	0.95
BL 10	103.4 b	$y = -0.344^{*}x+111.40$	0.76
MF 90	125.9 a	$y = -0.019^{**}x^2 + 0.929x + 128.374$	0.82
BL 100	126.4 a	$y = -0.455^{*}x+136.99$	0.43
MF 100	127.0 a$^{(1)}$	$y = -0.017^{**}x^2+0.70x+132.12$	0.98
CONT	107.2 b	$y = -0.346^{**}x+115.23$	0.77
CV, %	9.75	-	-
-	NH_4^+. mg kg^{-1}	-	-
OMF 100	50.6 ab	$y = 0.04^{**}x^2-4.09x+92.33$	0.88
BL 10	36.1 d	$y = 0.03^{**}x^2-3.2x+68.15$	0.78
MF 90	48.2 b	$y = 0.04^{**}x^2-3.96x+89.28$	0.87
BL 100	44.0 bc	$y = 0.03^{**}x^2-3.13x+74.09$	0.76
MF 100	57.2 a$^{(1)}$	$y = 0.05^{**}x^2-4.62x+106.1$	0.80
CONT	36.9 cd	$y = 0.04^{**}x^2-3.65x+74.37$	0.88
CV, %	16.62	-	-
-	NO_3^-. mg kg^{-1}	-	-
OMF 100	105.7 ab	$y = -0.06^{**}x^2+4.67x+67.47$	0.87
BL 10	103.2 ab	$y = -0.04^{**}x^2+3.30x+73.39$	0.72
MF 90	103.0 ab	$y = -0.06^{**}x^2+5.23x+62.56$	0.94
BL 100	110.0 a$^{(1)}$	$y = -0.04^{**}x^2+3.68x+76.33$	0.86
MF 100	108.7 a	$y = -0.06^{**}x^2+5.23x+63.98$	0.96
CONT	97.8 b	$y = -0.04^{**}x^2+3.78x+66.49$	0.86
CV, %	8.3	-	-
-	pH H_2O	-	-
OMF 100	5.6 b	$y = 0.0003^{**}x^2 - 0.034x + 5.972$	0.81
BL 10	5.7 ab	$y = 0.0003^{**}x^2 - 0.026x + 5.906$	0.68
MF 90	5.7 ab	$y = 0.0004^{**}x^2 - 0.034x + 6.007$	0.80
BL 100	5.8 a$^{(1)}$	$y = 0.0002^{**}x^2 - 0.020x + 5.921$	0.53
MF 100	5.7 ab	$y = 0.0004^{**}x^2 - 0.034x + 5.983$	0.78
CONT	5.6 b	$y = 0.0002^{**}x^2 - 0.020x + 5.815$	0.49
CV, %	1.2	-	-
-	WSC. mg dm^{-3}	-	-
OMF 100	227.2$^{(ns)}$	$y = 0.065^{**}x^2 - 6.264x + 290.348$	0.84
BL 10	226.7	$y = 0.052^{**}x^2 - 4.207x + 257.596$	0.44
MF 90	198.7	$y = 0.061^{*}x^2 - 6.061x + 261.737$	0.98
BL 100	225.1	$y = 0.086^{**}x^2 - 8.825x + 319.754$	0.70
MF 100	195.8	$y = -1.169^{**}x + 222.922$	0.84
CONT	203.3	$y = 0.036^{*}x^2 - 4.261x + 255.890$	0.78
CV, %	18.53	-	-

OMF 100: 100% of NPK in the form of organomineral fertilizer; BL 10: same amount of broiler litter present in the OMF 100 treatment; MF 90: same amount of mineral fertilizer present in the OMF 100 treatment; BL 100: 100% NPK in the form of broiler litter; MF 100: 100% NPK in mineral form; CONT: control, without fertilization.

(1) Means followed by different letters in the columns differed by Tukey test ($p < 0.05$). ns: not statistically significant. CV: coefficient of variation. * Significant by t test, $P < 0.05$. ** Significant by t test, $P < 0.01$.

element. All treatments with equivalent doses of K (OMF 100, BL 100 and MF 100) and the MF 90 showed similar availability of the nutrient. This behavior between the sources is related to the fact that the element is in soluble forms, including in the organic fertilizers used (CQFS-RS/SC, 2016). However, the time reduction of K availability in BL100 treatment was lower, much as a function of the increase in nutrient content observed at 80 DAI (data not shown).

The content of NH_4^+ in the soil (Table 4) reduced until the 30 DAI due to the nitrification process. Between the treatments, the lowest values observed for the BL 100, in relation to MF 100, can be attributed to the fact that part of the N present in the broiler litter is linked to more stable organic compounds, which need to be decomposed to make their nutrients available in the soil (Lourenço et al., 2013), as well as to a predominance of the nitric fraction in the broiler litter used in this study, which is not normally observed in this type of material (Rogeri et al., 2016).

The values of NO_3^- (Table 4) increased up to the 30 DAI as a result of nitrification, and subsequently reduced as a function of the increase in nutrient uptake by the plant (Lourenço et al., 2013). The availability of NO_3^- was equivalent for all treatments that received fertilization. Considering the treatments that received equivalent doses of N (OMF 100, BL 100 and MF 100), nitrate concentration peaks in the soil were observed at the 43, 44 and 47 DAI for organomineral, mineral and organic sources, respectively. The tardiest peak for the BL 100 indicates a delay in the nutrient release process, because it is linked to stable organic fractions, thus retarding its solubilization (Rogeri et al., 2016).

The pH in water lowered up to the 30 DAI and subsequently increased (Table 4). The initial reduction of the soil pH can be attributed to the higher rate of absorption of cationic elements by the plant in these initial periods of evaluation and consequent release of H^+ ions in the soil solution (Andreola et al., 2000). In the same sense, the slight pH increase observed in the last sampling may be due to the high NO_3^- values absorbed in this period in comparison to the cationic nutrients, resulting in release of hydroxyls in the soil (Ernani, 2016). In addition, the pH change can be attributed to the soil rewetting, carried out in the implantation of the experiment, and the increase in the decomposition of the soil organic matter in function of the activation of microbial activity of the soil (Lourenzi et al., 2011). The soil pH of the CONT treatment showed less variation in time, possibly due to the non-addition of fertilizers. The pH of the BL100 treatment was higher than that observed for the treatments OMF 100 and CONT, and equivalent to the others. The small increase in pH caused by the application of broiler litter can be attributed to the presence of calcium carbonate in the diet of the birds or by the adsorption of H+ ions caused by the presence of organic compounds in the waste (Lourenzi et al., 2016).

The water-soluble carbon (WSC) reduced until the 30 DAI (Table 4), but showed a small increase in the last sample (80 DAI). The initial reduction of the WSC can be due to the great lability of this fraction, which is rapidly decomposed in the soil, a lot because it is a fraction with a great response to the management (Hue, 1991), to microbial activity, availability of C substrates and sorptivity to soil colloids (Weng et al., 2012). The increase observed at 80 DAI can be attributed to the greater accumulation of phytomass of the plants in the period, resulting in exudation of organic compounds by the roots (Ren et al., 2014). The treatments, considering the average of all the

Table 5. Manganese (Mn), copper (Cu) and zinc (Zn) contents available in the soil, values of total organic carbon (TOC), H + Al, CEC $_{pH7}$ and base saturation (V), in the mean of the six samplings, in function of the addition of fertilizer sources.

Treatment	Mn	Cu	Zn	TOC	H + Al	CEC $_{pH\ 7}$	V
		(mg dm^{-3})		(%)	(cmol$_c$ dm^{-3})		(%)
OMF 100	63.6^{ns}	1.1 b	3.8 ab	1.6^{ns}	2.2 ab	12.7^{ns}	82.4 a
BL 10	63.0	1.1 b	3.4 b	1.6	2.3 ab	12.6	81.8 ab
MF 90	63.4	1.2 ab	3.4 b	1.6	2.3 ab	12.7	81.8 ab
BL 100	66.8	1.3 a(1)	4.2 a(1)	1.6	2.2 b	12.9	82.9 a(1)
MF 100	62.2	1.2 ab	3.4 b	1.6	2.4 ab	12.8	81.8 ab
CONT	62.5	1.2 ab	3.4 b	1.5	2.4 a(1)	12.7	80.9 b
CV %	8.5	6.5	14.13	6.0	9.4	3.5	1.8

OMF 100: 100% of NPK in the form of organomineral fertilizer; BL 10: same amount of broiler litter present in the OMF 100 treatment; MF 90: same amount of mineral fertilizer present in the OMF 100 treatment; BL 100: 100% NPK in the form of broiler litter; MF 100: 100% NPK in mineral form; CONT: control, without fertilization.
(1) Means followed by different letters in the columns differed by Tukey test ($p < 0.05$). ns: not statistically significant. CV: coefficient of variation.

samplings, did not differ statistically, indicating the absence of response of the fertilizers regarding the content of WSC.

The fertilization with broiler litter (BL 100) increased the Zn contents in the soil (Table 5), not differing from the OMF 100 treatment. Cu and Mn contents did not show considerable variations. Considering the critical contents of these nutrients in soils of the states of Rio Grande do Sul and Santa Catarina (CQFS-RS/SC, 2016), that is, 5, 0.4 and 0.5 mg dm^{-3} for Mn, Cu and Zn, respectively, it is observed that the soil used in this study, as it occurs for the soils that predominate in the southern states of Brazil, has values above the critical content, justifying the low influence of the fertilizers. The use of large amounts of organic residues may present significant increases of Cu and Zn in the soil, which may also cause environmental damage due to the accumulation of these metals (De Conti et al., 2016). There was variation over time only for Mn ($y = 0.003^{*}x^2 - 0.27x + 66.59$, $R^2 = 0.54$) and Cu ($y = 0.008^{**}x + 0.99$, $R^2 = 0.74$), without interaction of the treatments and the time.

There were small increases in the values of H + Al ($y = -0.0001^{**}x^2 + 0.03x + 1.91$, $R^2 = 0.96$), CEC pH 7 ($y = -0.0004^{**}x + 0.05x + 12.02$, $R^2 = 0.84$) and reduction of base saturation ($y = 0.0008^{**}x^2 - 0.14x + 84.1$, $R^2 = 0.92$) (Table 5). The values of TOC did not vary over time or between treatments. This was already expected since the amount of C added by organomineral and organic fertilizers is small, relative to the amount of C native of the soil.

The results showed that there were few changes in the soil between the tested fertilizers. Fertilization with organomineral and broiler litter resulted in slower P release, but did not significantly affect the availability of the other nutrients in the soil. Other chemical attributes of the soil were also not influenced by the fertilizer sources. Thus, the choice of fertilizer source should follow criteria such as availability and transportation, storage and application costs.

Conclusions

The yield of wheat dry matter does not vary in function of the tested fertilizers.

Organic and organomineral fertilizers present slow release of P, while the dynamics of release of N and K and other soil chemical attributes do not suffer significant variation as a function of the source of nutrients used.

The organomineral fertilizer can be used as a substitute for mineral fertilization, but it does not present any additional improvements in relation to the other sources when it comes to wheat growth.

Literature Cited

Andreola, F.; Costa, L. M.; Mendonça, E. S.; Olszevski, N. Propriedades químicas de uma terra roxa estruturada influenciadas pela cobertura vegetal de inverno e pela adubação orgânica e mineral. Revista Brasileira de Ciência do Solo, v.24, n.3, p.609-620, 2000. https://doi.org/10.1590/S0100-06832000000300014.

Antille, D. L.; Sakrabani, R.; Godwin, J. Effects of biosolids-derived organomineral fertilizers, urea, and biosolids granules on crop and soil established with Riegrass (*Lolium perenne* L.). Communications in soil science and plant analisys, v.45, n.12, p.1605-1621, 2014b. https://doi.org/10.1080/00103624.2013.875205.

Antille, D. L.; Sakrabani, R.; Godwin, J. Phosphorus release characteristics from biosolids-derived organomineral fertilizers. Communications in soil science and plant analisys, v.45, n.19, p.2565-2576, 2014a. https://doi.org/10.1080/00103624.2014.912300.

Brunetto, G.; Comin, J. J.; Schmitt, D. E.; Guardini, R.; Mezzari, C. P.; Oliveira, B. S.; Moraes, M. P.; Gatiboni, L. C.; Lovato, P. E.; Ceretta, C. A. Changes in soil acidity and organic carbon in a sandy typic hapludalf after médium-term pig-slurry and deep-litter application. Revista Brasileira de Ciência do Solo, v.36, n.5, p.1620-1628, 2012. https://doi.org/10.1590/S0100-06832012000500026.

Castro, R. C.; Benites, V. M.; Teixeira, P. C.; Anjos, M. J.; Oliveira, L. F. Phosphorus migration analysis using synchrotron radiation in soil treated with Brazilian granular fertilizers. Applied Radiation and Isotopes, v.150, p.233-237, 2015. https://doi.org/10.1016/j.apradiso.2015.08.036.

Comissão de Química e Fertilidade do Solo - CQFS-RS/SC. Manual de calagem e adubação para os Estados do Rio Grande do Sul e Santa Catarina. 11.ed. Porto Alegre: SBCS/NRS, 2016. 376 p.

Comissão de Química e Fertilidade do Solo - CQFS-RS/SC. Manual de recomendação de adubação e de calagem para os Estados do Rio Grande do Sul e Santa Catarina. 10.ed. Porto Alegre: SBCS/NRS, 2004. 400p.

De Conti, L.; Ceretta, C. A.; Ferreira, P. A. A.; Lourenzi, C. R.; Girotto, E.; Lorensini, F.; Tiecher, T. L.; Marchezan, C.; Anchieta, M. G.; Brunetto, G. Soil solution concentrations and chemical species of copper and zinc in a soil with a history of pig slurry application and plant cultivation. Agriculture, Ecosystems & Environment, v.216, p.374-386, 2016. https://doi.org/10.1016/j.agee.2015.09.040.

Deeks, L.; Chaney, K.; Murray, C.; Sakrabani, R.; Gedara, S.; Le, M.; Tyrrel, S.; Pawlett, M.; Read, R.; Smith, G. A new sludge-derived organo-mineral fertilizer gives similar crop yields as conventional fertilizers. Agronomy for Sustainable Development, v.33, n.3, p.539-549, 2013. https://doi.org/10.1007/s13593-013-0135-z.

Degryse, F.; Mclaughlin, M. J. Phosphorus diffusion from fertilizer: visualization, chemical measurements, and modeling. Soil Science Society of America Journal, v.78, n.3, p.832-842, 2014. https://doi.org/10.2136/sssaj2013.07.0293.

Ernani, P. R. Química do solo e disponibilidade de nutrientes. 2.ed. Lages: O Autor, 2016. 254 p.

Ferreira, D. F. Sisvar: a Guide for its Bootstrap procedures in multiple comparisons. Ciência e Agrotecnologia, v.38, n.2, p.109-112, 2014. https://doi.org/10.1590/S1413-70542014000200001.

Herrera, W. F. B.; Rodrigues, M.; Teles, A. P. B.; Barth, G.; Pavinato, P. S. Crop yields and soil phosphorus lability under soluble and humic-complexed phosphate fertilizers. Soil Fertility & Crop Nutrition, v.108, n.4, p.1-11, 2016. https://doi.org/10.2134/agronj2015.0561.

Hue, N. Effects of organic acids/anions on P sorption and phytoavailability in soils with different mineralogies. Soil Science, v.152, n.6, p.463-471, 1991. https://doi.org/10.1097/00010694-199112000-00009.

Lourenço, K.S.; Corrêa, J.C.; Ernani P.R.; Lopes, L.S.; Nicoloso R.S. Crescimento e absorção de nutrientes pelo feijoeiro adubado com cama de aves e fertilizantes minerais. Revista Brasileira de Ciência do Solo, v.37, n.2, p.462-471, 2013. https://doi.org/10.1590/S0100-06832013000200017.

Lourenzi, C. R.; Scherer, E. E.; Ceretta, C. A.; Tiecher, T. L.; Cancian, A.; Ferreira, A. A.; Brunetto, G. Atributos químicos de Latossolo após sucessivas aplicações de composto orgânico de dejeto líquido de suínos. Pesquisa Agropecuária Brasileira, v.51, n.3, p.233-242, 2016. https://doi.org/10.1590/S0100-204X2016000300005.

Lourenzi, C.R.; Ceretta, C.A.; Silva, L.S. Da, Trentin, G.; Girotto, E.; Lorensini, F.; Tiecher, T.L.; Brunetto, G. Soil chemical properties related to acidity under successive pig slurry applications. Revista Brasileira de Ciência do Solo, v.35, n.5, p.1827-1836, 2011. https://doi.org/10.1590/S0100-06832011000500037.

Mehlich, A. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. Communications in Soil Science and Plant Analysis, v.15, n.12, p.1409-1416, 1984. https://doi.org/10.1080/00103628409367568.

Mendonça, E.; Matos, E. Matéria orgânica do solo: métodos de analises. Viçosa: UFV, 2006. 107 p.

Ren, T.; Wang, J.; Chen, Q.; Zhang, F.; Lu, S. Effects of Manure and Nitrogen Fertilizer Applications on Soil Organic Carbon and Nitrogen in a High-Input Cropping System. Plos One, v.9, n.5, e97732, 2014. https://doi.org/10.1371/journal.pone.0097732.

Rogeri, D. A.; Ernani, P. R.; Mantovani, A.; Lourenço, K. S. Composition of poultry litter in Southern Brazil. Revista Brasileira de Ciência do Solo, v.40, e0140697, 2016. https://doi.org/10.1590/18069657rbcs20140697.

Sá, J. M.; Jantalia, C. P.; Teixeira, P. C.; Polidoro, J. C.; Benites, V. M.; Araújo, A. P. Agronomic and P recovery efficiency of organomineral phosphate fertilizer from poultry litter in sandy and clayey soils. Pesquisa Agropecuária Brasileira, v.52, n.9, p.786-793, 2017. https://doi.org/10.1590/S0100-204X2017000900011.

Silva, A. A.; Lana, A. M. Q.; Lana, R. M. Q.; Costa, A. M. Fertilização com dejetos suínos: influência nas características bromatológicas da *Brachiaria decumbens* e alterações no solo. Engenharia Agrícola, v.35, n.2, p.254-265, 2015. https://doi.org/10.1590/1809-4430-Eng.Agric.v35n2p254-265/2015.

Silva, L. S.; Bohnen, H. Mineralização de palha de milho e adsorção de carbono, cálcio, magnésio, e potássio em substratos com caulinita natural e goethita sintética. Revista Brasileira de Ciência do Solo, v.25, n.2, p.289-296, 2001. https://doi.org/10.1590/S0100-06832001000200005.

Tedesco, M. J.; Gianello, C.; Bissani, C. A.; Bohnen, H.; Volkweiss, S. J. Análise de solo, plantas e outros materiais. Porto Alegre: Universidade Federal do Rio Grande do Sul, 1995. 174 p.

Tejada, M.; Benitez, C.; Gonzalez, J. L. Effects of Application of Two Organomineral Fertilizers on Nutrient Leaching Losses and Wheat Crop. Agronomy Journal, v.97, n.3, p.960-967, 2005. https://doi.org/10.2134/agronj2004.0092.

Weng, L.; Van Riemsdijk, W.; Hiemstra, T. Factors Controlling Phosphate Interaction with Iron Oxides. Journal of Environmental Quality, v.41, n.3, p.628-635, 2012. https://doi.org/10.2134/jeq2011.0250.