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SOIL SOLUTION CONCENTRATION RELATED WITH CORN YIELD IN OXISOL FERTILIZED WITH SLURRY

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ABSTRACT

The pig slurry (PS) use as fertilizer for a long time can increase the nutrient content in the soil solution and its uptake by plants. Thus, the aims of this research was to evaluate the effects of 12 year of soil fertilization with PS compared to mineral fertilizer (MF) and combination of these two sources, on the nutrient contents in soil solution and its correlation with the leaf content and yield of corn. A field experiment was conducted in a southern Brazil Oxisol treated with PS at the annual doses 50 and 100 m^3 ha^{-1} (PS50 and PS100); soluble mineral fertilizer (MF); and 25 m^3 ha^{-1} of PS plus MF (PS+MF). Treatments were applied once a year to corn (*Zea mays*) cultivated in succession with oats (*Avena strigosa*) under no-tillage. Soil solution was sampled with ceramic capsule extractors at the depth 0.40 m, on six dates after the last application of fertilizer (DAAF). PS50 provide contents of NO_3^--N, P and K in the soil solution similar to those supplied by MF or PS+MF. The nitrate (NO_3^--N) and K contents in the soil solution measured at 40, 108 and 135 DAAF were correlated with corn yield. PS100 promotes soil solution NO_3^--N contents greater than 10 mg L^{-1} at 75 % of the sampling date, but this can also occur with MF.

KEYWORDS

manure; leaching; organic fertilizer

INTRODUCTION

The pig farming in Brazil has been growing and thereby increasing the waste pig slurry (PS) generated which is usually applied as fertilizer on farmlands, mainly in maize crops (Cassol et al., 2012). However, this use demand technology that enable it favorable effects on soil and agricultural production. When applied to the soil, PS changes the contents and forms of mineral nutrients, mainly nitrogen (N), phosphorus (P) and potassium (K) (Cassol et al., 2012, Grohskopf et al., 2015).

Most of the N content in PS is NH_4^+ and when applied on the soil surface, part is lost as ammonia and another part is transformed to nitrate (NO_3^-) which is not adsorbed in the soil, resulting in N leaching (Payet et al., 2009). Despite the low mobility of P in the soil, successive applications of mineral and mostly organic fertilizers can increase it content in soil solution, allowing it movement along the soil profile (Basso et al., 2005). In contrast, the K content in PS is in soluble mineral form, but after application a largest share is adsorbed to negative charges in the soil, although this form is easily exchanged and became available in the solution to leach. Thus, the mineral and organic fertilizers increases the nutrients contents in the soil solution, which increases its absorption by plants. Another consequence may be the fact that NO_3^- groundwater contents can raise to values higher than considered safe to environmental quality.

The objective of this study was to determine the soil solution N, P and K contents at depth of 0.4 m of a Typic Hapludox with no-tillage corn-oat crop succession and under 12 years of annual fertilizations with pig slurry, soluble mineral fertilizer and with these two sources together, and relating these data with leaf tissue content and grain yield.

MATERIALS AND METHODS

A field experiment was carried out during 12 years at the geographical coordinates: 51° 2' 47” west longitude and 27º 23' 34.5'' south latitude. Local climate is Cfb, according Köppen. The soil is a Typic Hapludox which had on the experiment starting in the 0 to 20 cm layer the following chemical characteristics: water pH 6.1; exchangeable Al, Ca and Mg 0.01, 8.2 and 4.6 $cmol_c\ dm^{-3}$; available (Mehlich) P 6.4 and K 97 mg dm^{-3}; clay 680 g kg^{-1} and 25 g kg^{-1} of total organic carbon.

The treatments: pig slurry (PS) at doses 50 (PS50) and 100 (PS100) $m^3\ ha^{-1}$; mineral fertilizer (MF); and 25 $m^3\ ha^{-1}$ of PS complemented with MF (PS+MF) were arranged in randomized block with four replicates in plots with 12 x 6.3 m. The MF comprised 170, 57 and 66 kg ha^{-1} $year^{-1}$ of N, P and K, with urea, triple superphosphate and potassium chloride, respectively. The PS+MF was the PS added by MF to provide the similar amounts of N, P and K supplied by MF. The MF N was applied 20% at sowing and the rest by topdressing in the 10 leaves corn stage, where was also applied the mineral N of PS+MF. The slurry was from growing pigs and remained about four months in open dunghills on anaerobic digestion process. The mean of the 12 PS used were: pH 7.2, and 58, 23, 3.6, 1.5 and 1.6 kg m^{-3} of dry matter and totals contents of organic carbon, N, P and K, respectively.

Corn (*Zea mays*) and oat (*Avena strigosa*) were grown yearly under no-tillage system. The corn was a simple hybrid sown a week after treatments application with seven plants per square meter and oat were the “comum” cultivar sown with 60 kg ha^{-1} of seeds. The corn harvest was carried out by manual collection of cobs that were mechanically threshed. Corn leaves were sampled at the flowering stage to determine the N, P and K contents through sulfuric acid digestion.

The soil solution was collected on six dates after the last application of fertilizer (DAAF), always at three days after high-intensity rains, through ceramic capsule extractors placed at 0.4 m depth in the middle of each plot. Around 80 mL of soil solution were collected from each sample and a little amount of toluene was dropped and next the samples were frozen and kept at -10 °C until analysis. Soil solution contents of NH_4^+, NO_3^- (NO_2^-+NO_3^-), P and K, was determined as in Rice et al. (2012).

The variance analysis was performed by the F-test and the effect of treatments and sampling dates were compared using LSD test ($p < 0.05$). Nutrient contents within the soil solution were correlated to respective leaves content and corn grain yields by Pearson correlation ($p < 0.05$).

RESULTS AND DISCUSSION

The soil solution NH_4^+-N content was below the lower detection limit on all sampling dates, which may be related to it fast transformation from NH_4^+-N to NO_3^--N, through nitrification process in oxidizing environment, which is favored by high drainage and aeration (Payet et al., 2009) as occurs in the Typic Hapludox. The soil solution contents of NO_3^--N varied with sampling times as well as type of fertilizers (Table 1). The PS100 had NO_3^--N content greater than others treatments on 40, 108, 135 and 230 DAAF that can be justified by the 350 kg ha^{-1} of N supply with this PS applications, twice the dose applied in PS50 and MF. The lowest soil solution contents of NO_3^--N were observed on all evaluated dates for PS50. Basso et al. (2005) also reported absence of groundwater NO_3^--N contamination by pig slurry at dose of up to 40 m^3 ha^{-1}. The NO_3^--N content differences in soil solution between sampling dates can be also explained by variation in the rate of N uptake by crops. The PS100 treatment exceeded the limit of 10 mg L^{-1} for NO_3^--N in soil solution on 40, 108, 135 and 230 DAAF. This also happened with the MF on 108 and 230 DAAF. Thus, higher doses of both organic and mineral fertilizers can promote NO_3^--N content above the insured amount for water potability, although, further studies with methods of soil solution extraction are needs to conclude about it.

The soil solution P content ranged with sampling dates and fertilizer type (Table 1), with little variation among treatments. The PS100 provided contents higher than PS+MF at 40, 108 and 135 DAAF, as well as than MF and PS50 at 108 and 135 DAAF, that is explained by the 140 kg ha^{-1} yr^{-1} of P supplied by PS100, compared to 57 kg ha^{-1} supplied by MF and PS+MF and, to 70 kg ha^{-1} by PS50. The soil solution P content on 230 and 320 DAAF was below those on 40, 108 and 135 DAAF, which results by the high adsorption of P in soils as the Typic Hapludox.

The largest amounts of K in soil solution were also found at the PS100, on 40, 108, 135 and 230 DAAF (Table 1). These results highlighted the potential of loss of K with the high dose of PS, as 100 m^3 ha^{-1} yr^{-1}, which provided 180 kg ha^{-1} against the application of 66 kg ha^{-1} K in MF and PS+MF and, 90 by PS50. However, the K in solution usually does not cause risk of water pollution.

Table 1. Soil solution content of NO_3^--N, P and K (mg L^{-1}) in a Typic Hapludox under 12 years of no-tillage corn-oat crop succession and yearly fertilized with pig slurry (PS), mineral fertilizer (MF) and pig slurry complemented with mineral fertilizer (PS+MF), at depth 0.4 m, over time in days after fertilizer application (DAAF).

Treatment (1)	DAAF					
	40	90	108	135	230	320
	N-NO_3^- (mg L^{-1})					
MF	4.7 Bc	2.6c^{ns}	10.3 Bb	9.8 Bb	23.6 Ba	1.8 c^{ns}
PS+MF	2.8 Bc	2.3 c	9.0 Bb	8.5 Bb	15.4 Ca	1.7 c
PS50	3.3 Bb	1.8 bc	9.7 Ba	9.2 Ba	4.0 Db	0.6 c
PS100	16.4 Ac	2.2 d	20.6 Ab	20.2 Ab	25.6 Aa	1.0 d
	P (mg L^{-1})					
MF	2.2 ABbc	1.0 d	3.0 Ba	2.7 Bab	0.4 cd	0.7 d
PS+MF	1.8 Bb	0.5 c	3.1 Ba	2.7 Ba	0.5 c	0.4 c
PS50	2.2 ABb	0.7 c	3.1 Ba	2.7 Bab	0.4 c	0.5 c
PS100	2.5 Ab	0.6 c	3.8 Aa	3.7 Aa	0.6 c	0.4 c
	K (mg L^{-1})					
MF	2.0 B^{ns}	2.9^{ns}	2.1 B	1.6 B	3.0 B	2.0
PS+MF	1.4 Bb	3.8 ab	2.3 Bab	1.8 Bb	5.1 Ba	3.1 ab
PS50	3.5 B^{ns}	2.1	2.4 B	1.9 B	3.0 B	1.2
PS100	16.3 Aa	2.7 d	13.4 Ab	13.0 Ab	10.7 Ac	1.8 d

(1) Pig slurry (PS) in annual doses of 50 (PS50) and 100 m^3 ha^{-1} (PS100); soluble mineral fertilizer (MF); and PS at a dose of 25 m^3 ha^{-1} complemented by MF (PD+MF). Means with different letters (lowercase horizontally and uppercase vertically) differ by LSD test ($p \leq 0.05$).

The soil solution NO_3^--N content had no correlation with the N content in corn plant tissue in all evaluation dates, however it had correlation with crop yield for the dates samples of 40, 108 and 135 DAAF, during the corn cycle (Table 2). It is highlighted that low levels of N in plant tissue were observed, influenced by droughts occurred from November to January when plants have high demand for water, reducing thus the levels of N in plant tissue.

There was no correlation between P content in the soil solution with its content in plant tissue or with crop yield (Table 2). The average content of P in the tissue of corn plants was within the range considered adequate for the corn crop, between 1.9 to 3.5 g kg^{-1}. The soil solution K content in all samples was not correlated with the content of this element in corn leaves, although the content at 40, 108 and 135 DAAF were correlated with grain yields.

Table 2. Correlation of nitrate (NO_3^{-}—N), P and K contents in the soil solution at 0.4 m depth with the N, P and K content in leaf tissue and with grain yields in a Typic Hapludox subjected to 12 years of fertilization with pig slurry, mineral fertilizer and association of both, and on different days after the application of fertilizers (DAAF).

Parameters and coefficient.(1)	DAAF							
	40		90		108		135	
	Content(2)	Yield(3)	Content(2)	Yield(3)	Content(2)	Yield(3)	Content(2)	Yield(3)
				nitrate-N				
a	n.s.	8050	n.s.	n.s.	n.s.	7321	n.s.	7391
b		95				112		110
r	0.32	0.66	0.33	-0.2	0.28	0.65	0.26	0.66
				phosphorus				
a	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
b								
r	0.05	0.33	-0.03	-0.43	-0.25	0.28	-0.01	0.43
				potassium				
a	n.s.	8136	n.s.	n.s.	n.s.	8197	n.s.	8245
b		98				100		100
r	0.28	0.73	0.46	-0.34	0.30	0.64	0.31	0.64

(1) Parameters a and b of the linear model and Pearson correlation coefficient r; (2) Content of the respective element in the corn leaf; (3) Corn yield (kg ha^{-1}); n.s - non-significant correlations (P<0.05).

CONCLUSION

The pig slurry applied at the rate 100 m^3 ha^{-1} yiear^{-1} in a Typic Hapludox under no-tillage corn-oat crop succession increases the nitrate-N and K content in the soil solution at depth of 0.4 m, but at the rate 50 m^3 ha^{-1} yiear^{-1} provides nitrate-N, P and K contents in that solution similar to the recommended dosage of mineral fertilizer alone or supplemented with pig slurry.

The nitrate-N and potassium contents in the soil solution are positively correlated with corn yield.

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