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Soil chemical properties after surface application of swine wastewater in the cultivation of jatropha

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This work aims to evaluate the behavior of macronutrients and micronutrients in the soil when there is successive application of swine wastewater in growing jatropha (*Jatropha curcas* L.). The experiment was conducted in Palotina – PR, Brazil. The experimental parcels were designed and built in an area of 900 m^2, in a completely randomized design with six treatments and three replications. The doses of swine wastewater (SW) were set in proportions of 0, 40, 80, 120, 160 and 200 m^3 ha^{-1}. Soil attributes related to acidity did not suffer influence of successive applications of SW. In the first application none of the parameters evaluated suffered interference of the doses. Macronutrients K and Ca presented quadratic behavior in the second application. There was an increase in micronutrient Cu in function of the dose of SW in the second and third applications. Fe increased only in the third application of SW.

Key words: Organic fertilization, macronutrients, micronutrients, mobility in soil.

INTRODUCTION

The Brazilian swine production, like other agribusiness production chains, has grown significantly in recent years. Such growth is noticed when analyzing the various economic and social indicators, as export volume, global market share, number of direct and indirect jobs, and others. Among the relevant aspects of the development of this sector one can also highlight the generation of employment and income, especially in the context of family labor, the possibility of increased food production and the decrease in rural exodus (ABIPECS, 2011).

Jatropha (*Jatropha curcas* L.) is a perennial, shrubby species which belongs to the Euphorbia family and can reach up to five meters in height. It develops well, both in dry tropical areas and in equatorial humid zones and also in arid and rocky soils, being able to endure long periods of drought. It can be found from sea level to 1200 m of altitude (Drummond et al., 2009). According to Cabral et al. (2013), the culture of jatropha presents great energetic potential and aims to upgrade the generation of energy and clean fuels.

The inefficient management and practice of releasing wastes indiscriminately in nature has propitiated serious imbalances. According to Scherer et al. (2010) by knowing the dynamic elements in the soil where swine manure is being used as fertilizer, it is possible to establish strategies to correct distortions in production systems, seeking environmental sustainability.

Meneghetti (2010) observed that high doses of swine

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Table 1. Soil density, microporosity, macroporosity and total soil porosity (TP).

Sample	Density (g cm^{-3})	Macroporosity (%)	Microporosity (%)	TP (%)
1	1.16	35.90	10.52	45.87
2	1.19	36.27	8.89	46.92
3	1.18	42.56	8.87	46.26
Mean	1.17	38.24	9.42	46.35

Table 2. Chemical characterization of the soil in the experimental area before successive applications of SW.

Parameter	pH	H+Al	K	Ca	Mg	Al	NH_4^+	NO_3	Cu
	Water	mmol$_c$ dm^{-3}						mg.dm^{-3}	
1	6.44	38	4.0	44	18	0.4	14.0	19.6	23.2
2	6.35	42	4.0	52	21	0.0	14.0	8.4	18.2
3	6.29	29	3.5	39	17	0.0	8.4	5.6	18.9
Mean	6.36	36.36	3.83	45	18.66	0.13	12.6	12.6	20.1
	Fe	**Mn**	**Zn**	**B**	**P**	**MO**	**V**	**CTC**	**SB**
	mg.dm^{-3}					g.dm^{-3}	%	cmol$_c$/dm³	
1	11	150	5.6	0.31	19.2	66	63.46	10.4	6.6
2	5	148	6.8	0.41	29.6	77	64.70	11.9	7.7
3	17	107	4.0	0.25	20.1	59	67.71	8.8	5.95
Mean	11	110	3.9	0.36	14.0	67.33	65.29	10.3	6.74

wastewater, combined with chemical fertilization showed unwanted performance because it contributed to the leaching of NO_3^-, also causing an increase in the concentrations of the potential contaminant metals such as copper and zinc in the soil and accumulation of available phosphorus. Scherer et al. (2010) observed that the continued use of swine manure as fertilizer in areas with annual crops provides greater accumulation of nutrients (P, K, Cu and Zn) in the topsoil than the use of mineral fertilizers. Intensive provision of swine manure can promote accumulation of nutrients in the topsoil (P, Cu and Zn), especially of less mobile elements (Gräber et al., 2005; Scherer et al., 2007).

In this study, the effect of continued application of SW on the chemical properties of the soil cultivated with jatropha was evaluated.

MATERIALS AND METHODS

The study was conducted in the experimental area of Adroaldo Augusto Colombo Agriculture High School - CAEAAC, Palotina - PR, from December 2011 to June 2012. The region is geographically located at 24° 12' 00'' south latitude, 53° 50' 30'' west longitude (Greenwich), with an average elevation of 332 m. The regional climate is defined according to the Köppen classification as humid subtropical (Cfa), with average annual rainfall of 1800 mm, with hot summers and cold or mild winters, with average temperature of 20°C and relative humidity (RH) of the air of 75% (IAPAR, 2013) (Table 4).

The area used for the implementation of the experiment was determined by its density, macroporosity, microporosity and total soil porosity (Table 1) in the layer 0-20 cm of distinct points of the area prior to the experiment, according to the volumetric ring method (Embrapa, 1997). The chemical characterization of the soil was performed prior to experiment installation in the layer 0-20 cm according to the methods described by Raij et al. (2001), Tedesco et al. (1995) and Embrapa (1997). Results are shown in Tables 2 and 3).

The experimental parcels were designed and built in a 900 m^2 area of cultivation of Jatropha located in the premises of the Adroaldo Augusto Colombo Agriculture High School - CAEAAC, Palotina - PR. The Jatropha crop used in the experiment has been cultivated for five years. The treatments used in the experiment consisted of swine wastewater (SW), six treatments with three replications, totaling 18 experimental parcels spaced 4 x 3 m and four plants of jatropha each. The doses of swine wastewater were set in the proportions of 0, 40, 80, 120, 160 and 200 m^3 ha^{-1}. The applications were performed on December 3rd 2011, March 3rd 2011 and June 1st 2012.

After each application of SW, the collection and analysis of soil of each parcel were carried out in order to determine the chemical characteristics of the soil. Three collections were made, totaling 54 soil samples at a depth of 0-20 cm. The collected samples were placed in individual identified plastic bags and then sent to the laboratory and subjected to the determination of pH, organic matter (OM), aluminum (Al), boron (B), calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), potential acidity (H + Al^{+3}), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), total nitrogen TKN and organic N+ ammonium (NH_4^+ and NH_3). The analyzes were performed at the Laboratory of Agricultural and Environmental Analyses - AGRILAB/UNESP, in accordance with the methodologies of Tedesco et al. (1995) and Raij et al. (2001).

The data were analyzed by means of Tukey's test and regression

Table 3. Characterization of SW.

Parameter	pH	CE	C. Org	$NO^{-3} + NO^{2}$	P	K	Ca
1st	8.40	5170	12.19	71.1	25.82	1160.0	837.0
2nd	7.97	3270	2.12	2.8	29.55	581.1	9.2
3rd	7.60	4060	2.55	26.3	14.47	410.0	13.7
	Mg	**Na**	**Cu**	**Mn**	**Zn**	**Fe**	**N Total**
1st	630.0	152.1	12.70	24.82	75.00	177	2151.3
2nd	14.1	95.0	0.13	0.04	0.40	5.62	582.4
3rd	19.3	83.0	0.05	0.05	0.03	1.79	413.0

*All units in (mg L^{-1}), except for CE (dSm^{-1}).

Table 4. Rainfall and mean temperature recorded during the experiment.

Month	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Rainfall (mm^{-1})	60.4	136.8	104.4	63.2	358.4	30.6	265.4	44.4
Mean Temperature (°C)	25.1	25.6	27.1	24.8	21.8	19	17.5	17.6

analysis at 5%, with Assistat computer program, version 7.6 beta.

RESULTS AND DISCUSSION

One may observe in Tables 5 and 6 that the first surface application of SW did not affect the soil chemical properties. In the second application, the content of K presented quadratic behavior and that of Cu followed linearly. Successive applications of SW interfered linearly in the third application on the levels of NH_4^+, Cu and Fe in the soil and quadratically on the content of NO_3^-/NO_2^-.

Basso (2003) points out that the continuous application of SW may cause imbalance of nutrients in the soil. The severity of the problem might vary according to the application time, composition and quantity of SW applied. The soil type and extraction capacity of the plants are also factors that influence the consequences of the application of SW.

The mean values found for ammonia (NH_4^+), nitrate/nitrite (NO_3^-/NO_2^-) and macronutrients phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca), in the first application did not suffer influence of SW variation. In successive application K and Ca presented quadratic behavior, but the third application did not provide significant results. The levels of ammonia (NH_4^+) and nitrate/nitrite (NO_3^-/NO_2^-) were only influenced by the levels of SW in the third application, presenting a negative linear decrease and quadratic behavior, for ammonia (NH_4^+) and nitrate/nitrite (NO_3^-/NO_2^-), respectively.

Ingrid et al. (1997) found that doses of 60, 120 and 180 m^3 ha^{-1} of SW resulted in significant accumulation of nitrate in the root zone with loss of nitrogen. However, the authors showed that nitrogen losses by runoff can reach up to 93.341 kg ha^{-1} under irrigation and also that the repeated application of the recommended dose may cause contamination of soil and water.

One may observe in Table 6 that the behavior of the parameters related to soil acidity after applications of SW did not suffer influence of swine manure applications. Sampaio et al. (2009) working with the application of SW under simulated rain condition observed that was not affected by the doses of 0, 100 and 200 m^3 ha^{-1}. Dal Bosco (2007) also working with SW doses (0, 50, 100 and 150 m^3 ha^{-1}) on a soybean crop did not verify statistical differences in soil pH.

Copper is a micronutrient observed in certain deficiency in soils with high organic matter, but this work was influenced in the first and second application with linear adjustment and high homogeneity of the data (Pimentel Gomes, 2000). Both Fe and Cu were influenced by the doses of SW in the third application, showing increases according to the doses. Prior (2010) found values from 3.73 to 5.31 mg L^{-1} for Cu contents in the soil under application of SW, verifying that increasing doses of SW did not cause increases in copper concentrations in the soil, which was not observed in this study, for there was no copper accumulation in the soil. A similar situation was observed by Meneghetti (2010), who found accumulation of manganese, copper and zinc in the soil after increasing doses over a period of SW.

Smanhotto et al. (2010) analyzed copper and zinc in the soil with the application of SW in soil cultivated with soybeans and observed that copper in the soil showed no significant differences with the application of SW and

Table 5. Mean values of NH_4^+, NO_3^-/NO_2^-, P, K+, Mg^{2+} and Ca^{2+} in the soil according to the doses of SW.

1st Application	NH_4^+	NO_3^-/NO_2^-	P	K^+	Mg^{2+}	Ca^{2+}
(m^3 ha^{-1})	mg dm^{-3}			mmol$_c$ dm^{-3}		
0	19.25^{a}	29.17^{a}	28.14^{a}	4.17^{a}	19.05^{a}	50.30^{a}
40	19.25^{a}	38.50^{a}	28.69^{a}	3.73^{a}	23.14^{a}	49.03^{a}
80	25.67^{a}	44.33^{a}	22.34^{a}	3.10^{a}	18.63^{a}	47.77^{a}
120	22.17^{a}	35.00^{a}	26.25^{a}	3.63^{a}	18.45^{a}	46.00^{a}
160	20.42^{a}	56.00^{a}	32.58^{a}	3.50^{a}	25.73^{a}	54.23^{a}
200	19.83^{a}	51.33^{a}	37.53^{a}	3.91^{a}	23.11^{a}	54.43^{a}
L.R.	0.0152$^{n.s.}$	2.2718$^{n.s.}$	1.8240$^{n.s.}$	0.0310$^{n.s.}$	0.6079$^{n.s.}$	0.5409$^{n.s.}$
Q.R.	1.8797$^{n.s.}$	0.0070$^{n.s.}$	1.8240$^{n.s.}$	0.4752$^{n.s.}$	0.1211$^{n.s.}$	0.7783$^{n.s.}$
C.V (%)	23.25	49.90	32.73	46.39	34.69	19.31
2nd Application						
0	15.80^{a}	22.17^{a}	7.10^{a}	3.30^{a}	14.00^{a}	40.67^{a}
40	14.63^{a}	19.83^{a}	24.67^{a}	5.23^{a}	15.67^{a}	37.67^{a}
80	16.97^{a}	16.33^{a}	9.23^{a}	2.83^{a}	14.33^{a}	38.33^{a}
120	13.47^{a}	17.50^{a}	8.00^{a}	4.57^{a}	15.33^{a}	47.00^{a}
160	13.47^{a}	19.83^{a}	9.20^{a}	3.67^{a}	14.00^{a}	42.33^{a}
200	13.47^{a}	17.50^{a}	13.13^{a}	4.40^{a}	19.00^{a}	43.67^{a}
L.R.	2.4381$^{n.s.}$	1.3692$^{n.s.}$	0.1906$^{n.s.}$	0.1332$^{n.s.}$	1.7627$^{n.s.}$	1.7117$^{n.s.}$
Q.R.	0.0714$^{n.s.}$	1.2642$^{n.s.}$	0.0014$^{n.s.}$	0.0000$^{*(1)}$	0.9252$^{n.s.}$	0.0001$^{*(2)}$
C.V (%)	16.91	20.79	69.66	35.92	21.28	14.32
3rd Application						
0	16.97^{a}	20.47^{a}	27.83^{a}	3.93^{a}	20.33^{a}	44.00^{a}
40	11.13^{ab}	19.30^{a}	24.40^{a}	3.40^{a}	14.67^{a}	42.67^{a}
80	11.13^{ab}	21.63^{a}	27.70^{a}	2.60^{a}	19.67^{a}	48.33^{a}
120	11.13^{ab}	20.47^{a}	20.10^{a}	2.93^{a}	16.33^{a}	39.33^{a}
160	9.97^{b}	22.80^{a}	18.83^{a}	2.87^{a}	17.00^{a}	40.00^{a}
200	9.97^{b}	21.63^{a}	22.00^{a}	3.47^{a}	17.33^{a}	38.67^{a}
L.R.	10.3714$^{*(3)}$	0.9657$^{n.s.}$	1.2687$^{n.s.}$	0.4799$^{n.s.}$	0.1464$^{n.s.}$	1.8729$^{n.s.}$
Q.R	3.5000 $^{n.s.}$	0.0000 $^{*(4)}$	0.1019$^{n.s.}$	2.2823$^{n.s.}$	0.1524$^{n.s.}$	0.3274$^{n.s.}$
C.V (%)	21.12	15.18	41.64	33.62	34.92	15.67

Means with different small letters in the columns are statistically different at 5% of probability (*), or non-significant ($^{n.s.}$) by Tukey's test. (L. R.) Linear regression; (Q.R.) Quadratic regression. (*) = significant at 5% probability; ($^{n.s.}$) = non-significant. (1) $\hat{y}$= 4E-19 x^2 + 0.0018x + 3.8171 r² = 0.023; (2) $\hat{y}$ =-2E-05x^2 + 0.0041x + 0.5012 r² = 0.57; (3) = $\hat{y}$ -0.0275x + 14.462 r² = 0.61; (4) $\hat{y}$= -1E-07x^2 + 0.0109x+19.962 r² = 0.43.

fertilization, whereas zinc concentrations in the soil were influenced by the rates applied. Meneghetti (2010) found similar results analyzing soil acidity by applying swine wastewater treated in a stabilization lagoon in the culture of baby corn, and the pH of the aqueous extract of the soil did not vary with treatment doses of SW, there was only significant change in pH in response to fertilization. Ceretta et al. (2003) stated that the possibility of change in the pH of the aqueous extract of the soil with the application of SW is minimal and observed that the pH practically did not change with the application of different rates of SW (20 and 40 m^3 ha^{-1}) in pasture soil.When studying a dystroferric red latosol in western Paraná, Dal Bosco et al. (2008) found chemical changes in the soil due to the application of SW for eight consecutive years at a rate of 99 t ha^{-1}/year. The results showed that the application led to an increase in calcium concentration from 3.2 to 6.2 cmol$_c$ dm^{-3} in the layer at 0 to 30 cm, while the magnesium concentration increased from 2.0 to 3 cmol$_c$ dm^{-3}, 7 cmol$_c$ dm^{-3}, also in the 0 to30 cm layer. The concentration of phosphorus before the application of SW was 33.7 mg dm^{-3} in the 0-30 cm layer and 3.8 mg dm^{-3} in the 30-60 cm layer, and increased to 51.1 mg dm^{-3} (0-30 cm) and 5.4 mg dm^{-3} (30-60 cm) after the application. The concentrations of sodium, potassium and organic matter, mainly in the 0 to 30 cm layer, also had their values increased.

Table 6. Mean values of pH, MO, Al, H+Al, Mn, Cu, Fe and Zn in the soil according to the doses of SW.

1st Application (m^3 ha^{-1})	pH Água	MO g dm^3	Al mmol$_c$ dm^{-3}	H+Al mmol$_c$ dm^{-3}	Mn mg dm^{-3}	Cu mg dm^{-3}	Fe mg dm^{-3}	Zn mg dm^{-3}
0	5.71^a	27.5^a	0.83^a	49.81^a	156.70^a	7.87^a	22.33^a	5.00^a
40	5.90^a	25.76^a	0.69^a	43.13^a	172.56^a	8.17^a	25.50^a	4.99^a
80	5.75^a	26.07^a	0.69^a	45.90^a	153.85^a	8.10^a	26.67^a	5.63^a
120	5.78^a	23.86^a	1.11^a	46.20^a	159.24^a	7.92^a	24.67^a	4.93^a
160	5.88^a	23.56^a	0.83^a	42.48^a	164.40^a	8.25^a	23.83^a	5.09^a
200	5.70^a	24.78^a	0.56^a	44.64^a	157.52^a	8.42^a	27.83^a	5.72^a
L.R.	0.001$^{n.s.}$	3.021$^{n.s}$	0.237$^{n.s.}$	0.169$^{n.s}$	0.076$^{n.s}$	0.856$^{n.s}$	1.307$^{n.s.}$	1.252$^{n.s.}$
Q.R.	0.066$^{n.s.}$	0.763$^{n.s}$	2.246$^{n.s.}$	0.062$^{n.s}$	0.095$^{n.s}$	0.073$^{n.s}$	0.038$^{n.s.}$	0.168$^{n.s.}$
C.V (%)	9.97	10.61	29.07	30.46	6.97	7.83	14.76	11.29
2nd Application								
0	5.40^a	15.33^a	2.93^a	48.00^a	119.67^a	21.20^a	22.67^a	5.37^a
40	5.32^a	16.00^a	2.73^a	52.33^a	134.00^a	23.80^a	25.67^a	6.23^a
80	5.45^a	13.67^a	2.10^a	41.33^a	108.67^a	21.77^a	24.67^a	6.50^a
120	5.53^a	14.00^a	1.70^a	42.00^a	119.00^a	23.20^a	27.00^a	6.10^a
160	5.24^a	16.00^a	2.93^a	50.33^a	123.33^a	22.37^a	23.67^a	6.13^a
200	5.57^a	15.33^a	1.70^a	43.00^a	115.67^a	21.77^a	27.00^a	6.00^a
L.R	0.530$^{n.s.}$	0.002$^{n.s}$	1.659$^{n.s.}$	1.044$^{n.s}$	0.312$^{n.s}$	0.00$^{*(1)}$	0.868$^{n.s.}$	0.130$^{n.s.}$
Q.R.	0.146$^{n.s.}$	2.114$^{n.s.}$	0.205$^{n.s.}$	0.341$^{n.s}$	0.011$^{n.s.}$	0.791$^{n.s}$	0.131$^{n.s.}$	0.627$^{n.s.}$
C.V (%)	3.38	9.21	40.81	13.31	12.85	10.64	15.92	23.38
3rd Application								
0	6.03^a	26.00^a	0.63^a	43.33^a	114.67^a	26.67^a	20.93^a	7.80^a
40	5.63^a	28.00^a	2.33^a	50.00^a	111.00^a	25.33^a	21.80^a	7.10^a
80	5.83^a	28.00^a	1.67^a	41.00^a	119.33^a	27.00^a	20.37^a	8.63^a
120	5.50^a	23.33^a	4.00^a	52.33^a	109.33^a	28.33^a	22.63^a	6.77^a
160	5.67^a	22.00^a	1.67^a	32.33^a	99.65^a	37.00^a	23.50^a	5.77^a
200	5.52^a	23.00^a	2.50^a	47.33^a	114.33^a	32.33^a	24.56^a	7.63^a
L.R.	2.347$^{n.s.}$	4.855$^{n.s}$	4.106$^{n.s.}$	0.209$^{n.s}$	0.367$^{n.s}$	10.674$^{*(2)}$	12.670$^{*(3)}$	0.406$^{n.s.}$
Q.R.	0.325$^{n.s.}$	0.304$^{n.s}$	4.436$^{n.s.}$	0.002$^{n.s}$	0.056$^{n.s}$	0.273$^{n.s}$	1.750$^{n.s.}$	0.055$^{n.s.}$
C.V (%)	6.57	14.12	46.39	22.07	14.00	13.92	6.74	29.86

Means with different small letters in the columns are statistically different at 5% of probability (*), or non-significant ($^{n.s.}$) by Tukey's test. (L.R.) Linear regression; (Q.R.) Quadratic regression. (*)= significant at 5% of probability; ($^{n.s.}$) = non-significant. (1) $\hat{y}$ = -6E-05x + 22.352 r² = 2E-05; (2) $\hat{y}$ = 0.0462x + 24,821 r² = 0.6; (3) $\hat{y}$ =0.0185x + 20.46 r² = 0.74.

They also found that in the layer of 30 to 60 cm there was no change with regard to potassium.

Conclusion

Soil attributes related to the acidity did not suffer influence of successive applications of SW. In the first application, none of the evaluated parameters was influenced by variations in SW doses. K and Ca macronutrients presented quadratic behavior in the second application. Micronutrient Cu suffered an increase due to the application of SW in the second and third application, while Fe showed an increase only in the third application of SW.

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