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Sartor, Laércio Ricardo; Assmann, Alceu Luiz; Assmann, Tangriani Simioni; Bigolin, Paulo Egidio; Miyazawa, Mário; de Faccio Carvalho, Paulo Cesar
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# EFFECT OF SWINE RESIDUE RATES ON CORN, COMMON BEAN, SOYBEAN AND WHEAT YIELD[1]

**Laércio Ricardo Sartor[2], Alceu Luiz Assmann[3], Tangriani Simioni Assmann[4], Paulo Egidio Bigolin[5], Mário Miyazawa[3] & Paulo Cesar de Faccio Carvalho[6]**


## SUMMARY

**Swine residue (SR) applied as nutrient source of crops such as corn, bean, soybean and wheat, besides representing an environmental-friendly way of disposing of organic waste resulting from swine production, may significantly increase grain yields, replacing mineral fertilizer. The objective was to evaluate the effect of SR rates on corn, common bean, soybean and wheat yields from 2002 to 2007, in comparison with mineral fertilizer. The experiment was carried out at the Instituto Agronômico do Paraná – IAPAR, Pato Branco, PR and consisted of increasing SR rates (0, 15, 30, 45, and 60 $m^3$ $ha^{-1}$) and one treatment with mineral fertilizer (NPK 4-30-10), using 250 kg $ha^{-1}$ for bean and 300 kg $ha^{-1}$ for corn, soybean and wheat. Also, in the treatment with mineral fertilizer, 60, 120 and 90 kg $ha^{-1}$ N was applied as topdressing to bean, corn and wheat, respectively. There were significant increases of grain yield in all evaluated years and crops with increasing SR rates, especially in the grass species under study. Also, with increasing SR rates applied every six months, K, P, Ca and Mg were accumulated in the soil and the pH increased. The application of 60 $m^3$ $ha^{-1}$ SR increased yields and exceeded the yield obtained with the recommended mineral fertilizer, indicating this amount as adequate for these crops.**


**Index terms: fertilizer, micronutrient, foliar nitrogen, organic residues, foliar phosphorous.**

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(2) Professor da Universidade Tecnológica Federal do Paraná, Campus de Dois Vizinhos, Estrada para Boa Esperança, km 04, Caixa Postal 157, CEP 85660 000 Dois Vizinhos (PR). E-mail: laerciosartor@hotmail.com

(3) Pesquisador do Instituto Agronômico do Paraná. BR 158, km 497, Bairro Bom Retiro, CEP 85505 970 Pato Branco (PR). E-mails: assmann@iapar.br; miyazawa@iapar.br

(4) Professora da Universidade Tecnológica Federal do Paraná, Campus de Pato Branco. Via do Conhecimento, km 1, CEP 85503-390 Pato Branco (PR). E-mail: tangrisimioni@yahoo.com.br

(5) Graduação em agronomia pela Universidade Tecnológica Federal do Paraná. E-mail: pagrbigolin@yahoo.com.br

(6) Professor da Universidade Federal do Rio Grande do Sul – UFRGS. Av. Bento Gonçalves 7712, Bairro Agronomia, CEP 90160-180 Porto Alegre (RS). E-mail: paulocfc@ufrgs.br

**RESUMO**: *PRODUTIVIDADE DE MILHO, FEIJÃO, SOJA E TRIGO EM RESPOSTA À APLICAÇÃO DE DEJETOS LÍQUIDOS DE SUÍNOS*

*A utilização de dejeto líquido de suínos (DLS) como fonte de nutrientes no cultivo de grãos como milho, feijão, soja e trigo, além de ser uma forma de descarte dos dejetos orgânicos resultantes da atividade suinícola, pode contribuir para aumento significativo no rendimento de grãos, substituindo assim o fertilizante mineral. Este trabalho teve o objetivo de avaliar o efeito da utilização de DLS no rendimento de grãos de milho, feijão, soja e trigo no período de 2002 a 2007, contrastando com a fertilização mineral. O experimento foi conduzido no Instituto Agronômico do Paraná (IAPAR), Estação Experimental de Pato Branco, PR, sobre um Latossolo Vermelho distroférrico, com a aplicação das doses de DLS de 0, 15, 30, 45 e 60 $m^3$ $ha^{-1}$ e um tratamento com adubação mineral. Como adubação de cobertura, no tratamento com adubação mineral, utilizaram-se 60, 120 e 90 kg $ha^{-1}$ de N para feijão, milho e trigo, respectivamente. Em todos os anos e para todas as culturas, foram observados aumentos significativos da produção de grãos em função das crescentes doses de DLS aplicadas, especialmente para as gramíneas. Também, com crescentes doses de DLS, aplicadas semestralmente, ocorre acúmulo de K, P, Ca e Mg no solo, com aumento do pH. O uso de 60 $m^3$ $ha^{-1}$ de DLS favorece a obtenção dos maiores rendimentos de grãos e supera o obtido com a adubação mineral recomendada, o que sugere ser essa a quantidade adequada a ser usada para essas culturas.*

*Termos de indexação: fertilizantes, fósforo foliar, micronutrientes, nitrogênio foliar, resíduos orgânicos.*

## INTRODUCTION

The swine residues (SR) as a function of their chemical characteristics have a high fertilizing potential, which may replace, in part or totally, mineral fertilizer to increase crop productivity and reduce the production costs of farms, especially in major swine producers. In addition, the application of SR in the soil has been advocated as an alternative to reduce its polluting effects to the environment, with benefits both technical and economic (Queiroz, 2004), enabling to develop an integrated livestock and agriculture, thus diversifying the source of income and promoting economic stability in the property (Konzen, 1997).

The South Region of Brazil accounts for approximately 60 % of technified swine production, generating approximately 450.5 million tons of waste per year (Konzen, 2003). In 2010, the pork production was estimated at 3.19 million tons, i.e., an increase of almost 20 %, of which 57 % was concentrated in the states of Paraná, Rio Grande do Sul and Santa Catarina, the latter with the largest share (Abipecs, 2010), which would generate 540 million tons of waste; this fact alone calls for the study of ways of using SR.

The recommendation of reference doses of SR is somewhat difficult due to the variability in nutrient concentrations among swine farms. Also, the response of grass and legume crops may differ, considering the biological N fixation by the legume crop. Scherer et al. (1986) recommended the application of 40 $m^3$ $ha^{-1}$ SR as reference for corn production, whereas Ceretta et al. (2005) observed a greater corn grain yield at 85 $m^3$ $ha^{-1}$ SR. Results of corn response to SR fertilization were reported elsewhere (Almeida, 2000; Franchi, 2001), but there is little information about the response to SR application in soybean, common bean, wheat and corn grain yield in the same area in consecutive years using this organic fertilizer.

This work aimed to evaluate the potential of SR as fertilizer on maize, common bean, wheat and soybean yields by increasing doses of manure and comparisons with the use of mineral fertilizer.

## MATERIALS AND METHODS

The experiment was initiated in November 2002 in an area of the Instituto Agronômico do Paraná (IAPAR) in Pato Branco, state of Paraná, in the physiographic region called the Third Paraná Plateau (latitude 26º 07' S, longitude 52º 41' W; 700 m asl). The rainfall in the last 10 years was on average 2000 mm per year. The regional climate was classified as Cfb (humid subtropical), according to Köppen (Maak, 1968) and the soil as Oxisol (Embrapa, 2006). The soil chemical properties were determined before the implementation of the experiment and in 2006 (Tables 1 and 4).

The crop succession used in the six years of evaluation consisted of corn, bean or soybean in the

**Table 1. Soil chemical properties prior to the experiment**

| Depth | pH $_{CaCl_2}$ | OM | $Al^{3+}$ | $Ca^{2+}$ | $Mg^{2+}$ | $K^+$ | P | V |
|---|---|---|---|---|---|---|---|---|
| cm | | g $dm^{-3}$ | cmol$_c$ $dm^{-3}$ | | | | mg $dm^{-3}$ | % |
| 0.0– 5.0 | 4.5 | 43 | 0.6 | 4.2 | 2.6 | 0.3 | 10 | 42 |
| 5.0–10.0 | 4.6 | 37 | 0.4 | 4.1 | 4.2 | 0.2 | 5 | 44 |
| 10.0–20.0 | 4.6 | 34 | 0.6 | 3.5 | 0.6 | 0.1 | 3 | 40 |

OM: organic matter, V: base saturation.

summer crop and wheat or oats in winter (Table 2). The grain yield of these crops, except for the oats, is presented in this paper.

The experiment was arranged in a randomized complete block design with four replications. The treatment consisted of the application of SR doses of 0, 15, 30, 45, and 60 $m^3$ $ha^{-1}$ and a treatment with mineral fertilization of 250 kg $ha^{-1}$ for common bean and 300 kg $ha^{-1}$ NPK 4-30-10, for corn, soybean and wheat, plus 60, 120 and 90 kg $ha^{-1}$ N as side dressing for common bean, corn and wheat, respectively, in 2002, 2003, 2004, 2005, 2006 and 2007. Fertilization with N alone was applied in the mineral fertilizer treatment to corn, wheat and common bean.

In the plot with mineral fertilization no SR was applied. The mineral fertilizer was applied in the rows of the respective crop (base fertilization), while N in these plots was applied as sidedressing when the plants had 4-6 true leaves (stage V4 to V6).

**Table 2. Crop rotation from 2002 to 2008 in the experimental area**

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| Summer | Corn | | Corn | | Corn | | |
| | | Bean | | Soybean | | Bean | |
| Winter | Oat | Wheat | Oat | Wheat | Oat | Wheat | -- |

SR rates were applied one week before each sowing date of respective crops, in other words, approximately every six months, resulting in a total of 10 SR applications to each plot over the six study years. The chemical characterization of SR (Table 3) was based on the averages of the organic fertilizer analysis in the six years of evaluation, with no significant differences among the years at a significance level of 5 %. The SR dry matter was determined (4.6 ± 0.5 % DM) after oven-drying the manure at 65 °C to constant weight. The pH and total N content of the manure was determined by methods used by Almeida (2000). The P and K levels were analyzed as described by Tedesco et al. (1995). The pH of the slurry was 7.5 ± 0.3.

Corn, soybean, common bean and wheat were sown in the no-tillage system. Each corn plot consisted of five rows spaced 0.90 m apart with approximately 5.5 plants $m^{-1}$. The corn hybrid Pioneer 30F53 was planted at a density of approximately 60,000 plants $ha^{-1}$. Three central rows of each plot were harvested to evaluate the maize grain yield, eliminating 1m from each end, resulting in a total assessed area of 21.6 $m^2$.

Each wheat plot consisted of 26 rows in which cultivar IPR 136 was sown, in a row spacing of 0.17 m and a plant density of approximately 350 seeds $m^{-2}$. The wheat grain yield of an estimated area of 31.5 $m^2$ in the plot was harvested and assessed.

For common bean each plot consisted of 10 rows spaced 0.45 m apart and 16 seeds of cultivar IAPAR

**Table 3. Nitrogen, phosphorus and potassium contents and amounts in the swine slurry applied to corn, wheat, soybean and common bean**

| Nutrient | kg $m^{-3}$ | Rate applied ($m^3$ $ha^{-1}$) | | | |
|---|---|---|---|---|---|
| | | 15 | 30 | 45 | 60 |
| | | kg $ha^{-1}$ | | | |
| N | 2.70 ± 0.22[1] | 40.5 | 81.0 | 121.5 | 162.0 |
| P | 2.03 ± 0.19 | 30.4 | 60.9 | 91.3 | 121.8 |
| K | 1.40 ± 0.31 | 21.0 | 42.0 | 63.0 | 84.0 |

(1) Average content of the six application; calculation on a wet basis.

Graúna were sown per meter in the growing season 2003/2004 and IPR Tiziu in 2007/2008. The grain yield was calculated from harvesting an area of 10.8 $m^2$ of the plot, corresponding to the three central rows, disregarding 1m at the row ends.

A semeadura da soja foi realizada no espaçamento 0,45 m. Soybean cultivar CODETC 205 was planted in rows spaced 0.45 m apart, on the wheat residues, at a density of 300,000 seeds $ha^{-1}$. The soybean grain yield was evaluated from a harvested area of 7.2 $m^2$.

For the grain yield of all crops, the mass was corrected to 13 % moisture and converted to kg $ha^{-1}$, and the crop-specific cultural treatments were applied when necessary with constant monitoring.

The sampling for foliar analysis in maize was performed only in the 2006/2007 growing season, in the flowering stage, when more than 50 % of the plants were in full flowering, and the first leaf opposite the first ear was collected. The leaves were dried in a forced air oven at 60 °C and then ground and sent to the laboratory for the foliar analysis of N, P and K by the Kjeldahl method, as described by Tedesco et al. (1995).

The results of the evaluations were submitted to analysis of variance. The homogeneous variables in the treatments were assessed by the F test. When the results were significant at 5 %, polynomial regressions were fitted to the SR rates and grain yield, seeking the model with the highest degree of significance. The maximum technical efficiency (MTE) was obtained from the maximum point of a quadratic equation. The statistical program used was STATGRAPHICS® (Manugistics, 1997).

## RESULTS AND DISCUSSION

### Corn

Maize production increased linearly with the application of SR doses in all seasons (Figure 1a). The greatest response was observed in the corn crop of 2006/2007 growing season, where each cubic meter of SR applied corresponded to an increase of 59.9 kg $ha^{-1}$ corn grain. In 2002/2003 and 2004/2005, the increases were 25.7 and 54.1 kg $ha^{-1}$ grain per cubic meter of applied SR, respectively.

The differences between the harvests were mainly due to the gradual yield increase over the years, which may be coupled to an improvement in soil fertility (Table 4) due to the SR application (Ceretta et al., 2003; Berwanger et al., 2008), and an increase in the water retention capacity, reducing erosion, improving aeration and creating a better environment for the development of soil microbial flora by the addition of organic matter to the soil, especially in no-tillage systems (Alves et al., 2008).

When adding the grain yield of three corn crops after the consecutive SR applications, it was observed that the rate of 60 $m^3$ $ha^{-1}$ SR resulted in a higher yield than mineral fertilization based on soil analysis (Figure 1b). The grain yield increased by 55 % at 60 $m^3$ $ha^{-1}$ SR over the unfertilized control, while the mineral fertilizer increased the yield by 51 % over the control. In the 2006/2007 growing season there was also an increase in N and P contents (Figure 2) in corn leaves, confirming the contribution of organic fertilizer to the availability of nutrients required by the maize crop. The response in maize N content to the application of increasing SR doses had a quadratic behavior, where the dose of 39.43 $m^3$ $ha^{-1}$ SR resulted in a higher accumulation of leaf N, with 20.6 g $kg^{-1}$ (Figure 2a). The decrease of N content at higher SR rates can be explained by the model of dilution of N proposed by Lemaire et al. (1997).

According to Malavolta (1981), the value indicated as the critical level in the maize leaf is approximately 30 g $kg^{-1}$ N, although this value can sink to a level of 10.1 g $kg^{-1}$ when analyzing the whole plant. The

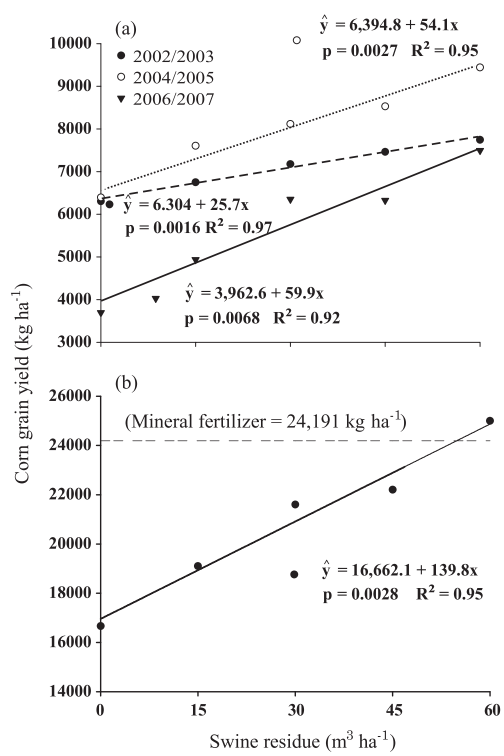


**Figure 1. Corn grain yield (kg $ha^{-1}$) as related to the application of swine residue rates of 0, 15, 30, 45, and 60 $m^3$ $ha^{-1}$ in the growing seasons 2002/2003, 2004/2005 and 2006/2007 (a) and cumulative corn yield of three harvests, comparing to the use of mineral fertilizer and swine slurry (b).**

same results were found by Trani et al. (1983), who proposed the concentration of 30.0 g $kg^{-1}$ N as the critical level for the crop. The N leaf concentration at a SR dose that reached the maximum technical efficiency (39.4 $m^3$ $ha^{-1}$ SR) was greater than that found in the mineral fertilizer treatment with base fertilization plus N as sidedressing, which resulted in a content of 19.2 g $kg^{-1}$ N in leaves.

The P accumulated in corn leaves was quadratically related to increasing SR doses, and the MTE was reached with 42.8 $m^3$ $ha^{-1}$ SR, which resulted in the content of 3.06 g $kg^{-1}$ (Figure 2b). This is higher than the critical value for corn of 2.2 g $kg^{-1}$ (Trani et al., 1983). Barcellos (1991) noted that with the application of 40 $m^3$ $ha^{-1}$ SR, the P uptake increased

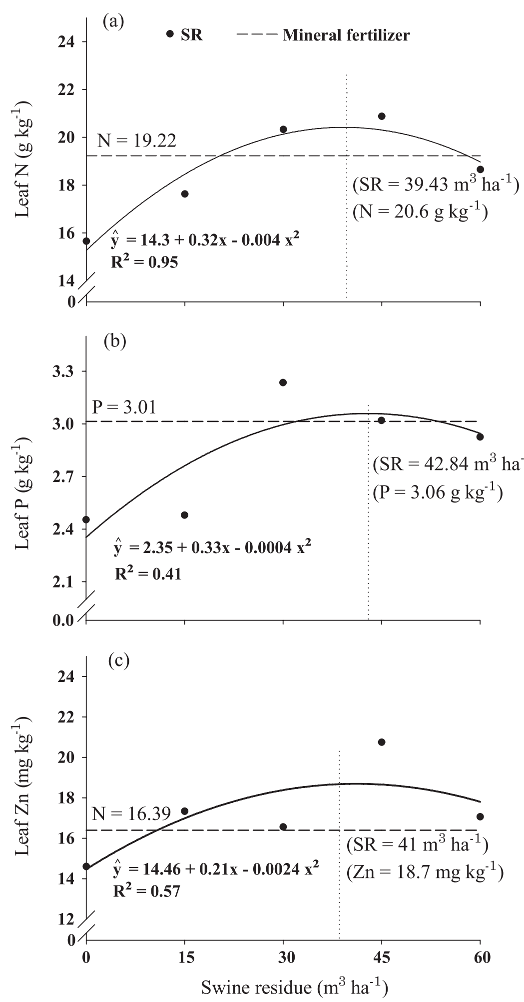


**Figure 2. Concentration of N (a), P (b) and Zn (c) in maize leaves as affected by SR rates and mineral fertilizer in the growing season 2006/2007. Values in correspond parentheses to the rate of SR for maximun content of the respective nutrient.**

by 38 % in corn shoots. In this paper, the application of 30 $m^3$ $ha^{-1}$ SR resulted in an increase of 32 % in P uptake compared to the control treatment. The P leaf concentrations in the mineral fertilizer treatment were lower than the SR rate that reached MTE, however did not differ, but were characterized as sufficient for crop development.

The Zn contents in the leaves had a quadratic relation to the accumulation of the nutrient, and MTE was achieved at 41 $m^3$ $ha^{-1}$ SR, leading to a content of 18.7 mg $kg^{-1}$ (Figure 2c). The observed value was below the critical level mentioned by Trani et al. (1983) of 20 mg $kg^{-1}$ Zn in corn leaves.

According to Pereira et al. (2007), the critical level for Zn deficiency is in the range of 15–20 mg $kg^{-1}$. In the mineral fertilizer treatment, the nutrient concentration was low, which can be related to the fact that this nutrient is present in the applied fertilizer mixture. The Zn is among the minerals with the greatest impact, in view of the low plant demand and its excessive concentration in swine manure, owing to the high doses used in animal feed and low assimilation by animals.

The other nutrients K, Ca, Mg, Cu, and Mn determined in the corn leaf were not affected by increasing SR doses with an average of 24.3 g $kg^{-1}$, 4.3 g $kg^{-1}$, 2.8 g $kg^{-1}$, 17.3 mg $kg^{-1}$ and 53.4 mg $kg^{-1}$, respectively, and did not differ from mineral fertilization with leaf concentrations of 26.2 g $kg^{-1}$, 4.0 g $kg^{-1}$, 2.6 g $kg^{-1}$, 12.1 mg $kg^{-1}$, and 52.9 mg $kg^{-1}$ for K, Ca, mg, Mn, and Cu, respectively. All other nutrient values were above the levels considered critical for the crop, with the exception of Ca.

## Wheat

Wheat production increased linearly with SR application (Figure 3). There was an increase of 27.3, 15.0 and 19.6 kg $ha^{-1}$ of wheat grain in the harvests of 2003, 2005 and 2007, respectively, per ton of SR applied. This difference was mainly due to climatic factors, since there was less rainfall in the harvest of 2005 than in 2003 (Figure 3a).

In the sum of the wheat grain yield of three years, the result of applying over 30 $m^3$ $ha^{-1}$ SR exceeds the yields with mineral fertilization. Ceretta et al. (2005) assessed SR doses in winter crops and observed a linear increase in dry matter production and grain yield, confirming the results obtained with wheat production in the experiment. Aita et al. (2006) observed an increase in oat dry matter production of 109 % over the control at 80 $m^3$ $ha^{-1}$ SR. In a study performed by Assmann et al. (2007) with a mixture of forage oat + ryegrass, the greatest response in forage yield was observed at 80 $m^3$ $ha^{-1}$ SR, providing an increase of 34 % over the control treatment without SR.

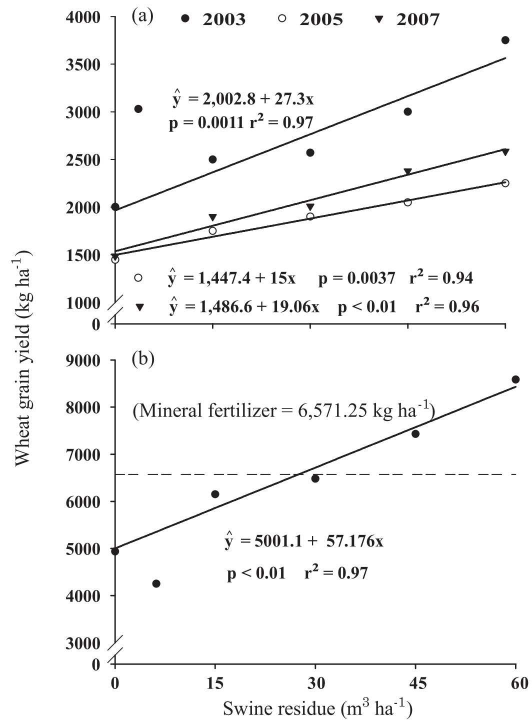


**Figure 3. Wheat grain yield (kg ha$^{-1}$) as related to the application of 0, 15, 30, 45, and 60 m$^3$ ha$^{-1}$ of swine residue for the growing seasons of 2003, 2005 and 2007 (a) and wheat yield accumulated in the three harvests compared to the use of swine residue and the mineral fertilizer as recommended for wheat (b).**

This yield increase can also be due to the increase in N caused by the application of SR because, N is a major component of SR of which about 50 % is in the mineral form (Ceretta et al., 2003). When N is applied, it has an immediate effect on plant growth and this may explain the higher yield achieved in the SR treatments compared to the treatment in which mineral fertilizer is used (Figure 3b).

## Common bean

In the 2003/2004 growing season, the maximum response in bean grain yield was achieved with 60 m$^3$ ha$^{-1}$ SR, with an increase of 97 % in grain yield over the control without fertilizer. The bean grain yield with mineral fertilizer was 2,683 kg ha$^{-1}$, equivalent to the production achieved with the application of approximately 50 m$^3$ ha$^{-1}$ SR (Figure 4a).

The common bean yield in the 2007/2008 growing season increased linearly with increasing SR application rates (Figure 4b). A 50 % yield increase was observed with the application of 60 m$^3$ ha$^{-1}$ SR over the control.

When the yield obtained with SR is compared to the use of mineral fertilizer, the effect for the use of SR was higher in all growing seasons, in the case of common bean for quantities above 45 m$^3$ ha$^{-1}$ SR. In a study of Shen & Shen (2001) with SR application to common bean the increased dry mass yield was confirmed and attributed to the higher P, K and Ca concentrations in the plant leaves that received SR, considering the symbiotic nitrogen fixation capacity of this legume.

Scherer (1986) evaluated grain production in maize/bean and bean/maize systems in two soils (Oxisol and Inceptisol) using manure and mineral N; the response in grain yield in common bean was achieved with the application of 80 and 40 kg ha$^{-1}$ N on both soils, with grain yield increases of 37 and 33 % compared to the control, respectively. The responses with manure were achieved with 80 m$^3$ ha$^{-1}$ for both soils with a 42 % increase, compared to the control.

## Soybean

The soybean yield was 2,902 kg ha$^{-1}$ with the application of 60 m$^3$ ha$^{-1}$ SR, an average increase

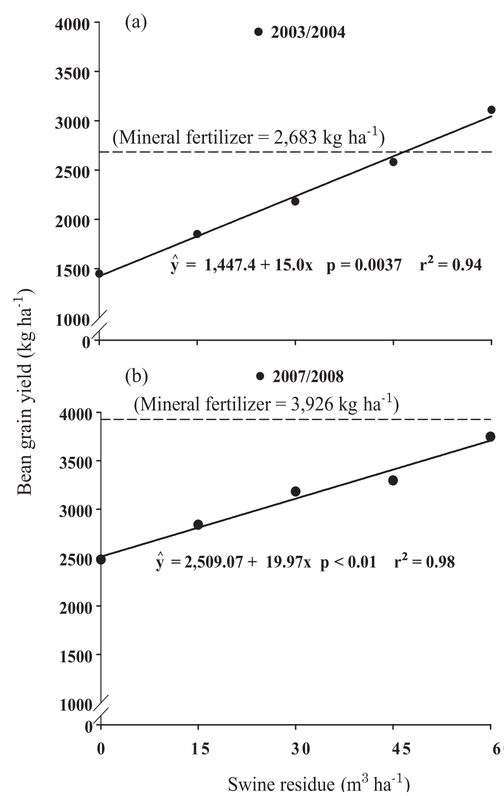


**Figure 4. Common bean grain yield (kg ha$^{-1}$) as affected by the application of 0, 15, 30, 45, and 60 m$^3$ ha$^{-1}$ swine residue in the growing seasons 2003/2004 and 2007/2008 (a) and compared to mineral fertilizer (b).**

of 25 % compared to the control without SR (Figure 5). The average production in the mineral fertilizer treatment was 2,405 kg $ha^{-1}$, equivalent to the application of 50 $m^3$ $ha^{-1}$ SR. Techio et al. (2009) observed grain yields of 1,657 kg $ha^{-1}$, in the control plot to 2,352 kg $ha^{-1}$ with the application of up to 88 $m^3$ $ha^{-1}$ SR, unlike in our study, since it was the third year of SR application.

With use of up to 45 $m^3$ $ha^{-1}$ SR, soybean yield did not change (Figure 5). This difference in response of soybean compared to corn, wheat and common bean is primarily because soybean has a good capacity for symbiotic N fixation. The response of soybean can be attributed to N, but also to the amounts of other nutrients applied via SR, which can possibly supply the crop with the use of 60 $m^3$ $ha^{-1}$ SR.

The responses of the four crops were basically a result of soil fertility improvement due to SR application (Basso et al., 2005; Assmann et al., 2007; Berwanger et al., 2008), which is observed in table 4. From 2002 to 2006, the soil pH increased as result of SR and mineral fertilizer applications. We also observed an increase in the concentration of OM and mineral N at higher SR rates. In addition, K, P, Ca and Mg accumulated in the soil by the successive applications and increasing SR doses, as reported by Sherer et al. (2010). These conditions were reflected in the crop response in grain yield and leaf nutrient content.

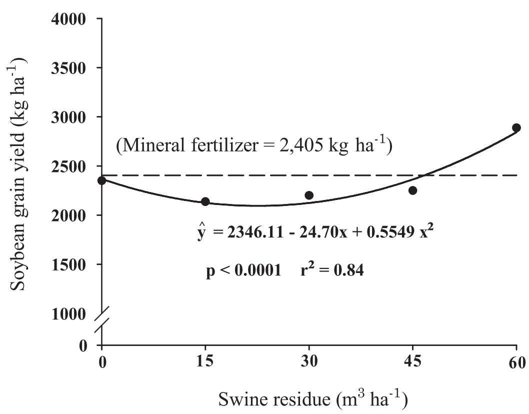


**Figure 5. Soybean grain yield (kg $ha^{-1}$) at rates of 0, 15, 30, 45, and 60 $m^3$ $ha^{-1}$ swine residue in the growing seasons 2005/2006 and with mineral fertilizer as recommended for soybean.**

Applying rates of 0–80 $m^3$ $ha^{-1}$, Assmann et al. (2007) observed increased K content (0.37 to 1.35 $cmol_c$ $dm^{-3}$) in the 0–5 cm layer. These same authors also noticed $Al^{3+}$ reduction and pH increase, which was attributed to the formation of soluble organic complexes with the organic acids (citric, tartaric, malonic, oxalic) present in the organic material, which were leached to deeper soil layers, and by the formation of insoluble complexes with organic substances of high molecular weight, adsorbed on the surface of soil particles (Miyazawa et al., 1993).

Some authors show that soil P content of 50 and 120 mg $dm^{-3}$ or higher, are considered high and critical (Sharpley & Halvorson, 1994). However, the maximum found in this study was 28 mg $dm^{-3}$ P. Mineral N as well, when excessive in the soil, can result in contamination problems. However, in the same soil class, Assmann et al. (2007) found no leaching of mineral N for applications up to of 80 $m^3$ $ha^{-1}$ SR, with values above 92 mg $dm^{-3}$ N of soil in the 0–5 cm layer, above the value found in 2006 in this study (Table 4).

The OM content in the soil did not change with increasing SR doses. Scherer et al. (2010) found no increase either in soil organic matter with SR application, and attributed this to the low OM

**Table 4. Soil chemical properties in 2002 and 2006, in the 0–20 cm layers, as affected by swine residue rates**

| SR | Year | pH $_{CaCl_2}$ | OM | $Al^{3+}$ | $Ca^{2+}$ | $Mg^{2+}$ | $K^+$ | P | V | N-min |
|---|---|---|---|---|---|---|---|---|---|---|
| $m^3$ $ha^{-1}$ | | | g $dm^{-3}$ | | $cmol_c$ $dm^{-3}$ | | | mg $dm^{-3}$ | % | mg $dm^{-3}$ |
| 0 | 2002 | 4.6 | 38 | 0.5 | 3.9 | 2.5 | 0.2 | 6.0 | 42 | |
| | 2006 | 5.7 | 39 | 0.0 | 7.5 | 4.1 | 0.5 | 6.5 | 67 | 40.7 |
| 15 | 2002 | 4.6 | 38 | 0.5 | 3.9 | 2.5 | 0.2 | 6.0 | 42 | |
| | 2006 | 5.5 | 40 | 0.0 | 7.0 | 4.0 | 0.4 | 9.9 | 67 | 45.0 |
| 30 | 2002 | 4.6 | 38 | 0.5 | 3.9 | 2.5 | 0.2 | 6.0 | 42 | |
| | 2006 | 5.6 | 42 | 0.0 | 8.1 | 4.1 | 0.7 | 23.0 | 70 | 53.1 |
| 45 | 2002 | 4.6 | 38 | 0.5 | 3.9 | 2.5 | 0.2 | 6.0 | 42 | |
| | 2006 | 6.0 | 40 | 0.0 | 8.6 | 4.4 | 0.7 | 23.1 | 77 | 49.5 |
| 60 | 2002 | 4.6 | 38 | 0.5 | 3.9 | 2.5 | 0.2 | 6.0 | 42 | |
| | 2006 | 5.7 | 40 | 0.0 | 7.9 | 4.1 | 0.7 | 28.0 | 73 | 52.0 |
| MF | 2002 | 4.6 | 38 | 0.5 | 3.9 | 2.5 | 0.2 | 6.0 | 42 | |
| | 2006 | 5.8 | 41 | 0.0 | 8.0 | 4.3 | 0.5 | 8.1 | 73 | 46.3 |

OM: organic matter; V: base saturation; N-min: N mineral ($N\text{-}NO^{3-}$ + $N\text{-}NH^{4+}$); MF: Mineral fertilizer.

contents of the SR, for which in the present study 4.6 % DM was found. This effect may have resulted in little variation in the mineral N concentrations at different SR rates. In addition, the considerable nutrient extraction with the grain yields of corn, soybean, common bean, and wheat must also be taken into account.

## CONCLUSIONS

1. The application of swine residue to maize, bean, soybean and wheat crops increases the grain yield and can replace the use of mineral fertilizer by the application of SR rates of 45-60 $m^3$ $ha^{-1}$.

2. The semiannual applications within six years of study contribute to the improvement of crop yields, increasing the K, P, Ca and Mg content in the soil.

3. The N, P and K concentrations in maize leaf increased with increasing SR applications, indicating that SR could be used as a nutrient source with specific dosage.

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