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Cultivation of soybean with swine wastewater

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This study evaluates the cultivation of soybean under the use of swine wastewater (SWW). The SWW used was diluted in water at 0, 25, 50 and 75%. At 15, 30 and 45 days after sowing, plant height, fresh weight, dry weight, leaf area, concentrations of NPK on leaf and productivity were determined. The results show that plant height was not affected by SWW concentrations, being higher for T1 (water only). Dilutions of SWW showed the highest values of fresh and dry weight at 25 and 75%. T2 treatment, with 25% of dilution, responded better to the leaf area parameter. The average values for the levels of NPK in the leaves of soybean with application of SWW diluted in concentrations of 25, 50 and 75% were below those recommended. Treatments T4 and T3 showed higher productivity; an increase of 16% compared to control.

Key words: Wastewater, reuse, productivity.

INTRODUCTION

The swine culture is practiced in all regions of Brazil, especially in the Midwest, Southeast and South, although the highest percentage is concentrated in the South, where approximately 20 million head are allocated, of which 25.3% are in the state of Paraná, 32.6% in Rio Grande do Sul and 42.2% in Santa Catarina (ABIPECS, 2008).

This activity generates high amount of waste liquids and solids, which could result in serious problems for the environment if discharged especially into water bodies in the region in large quantities. Shigaki et al. (2006) describe the increase in the potential for environmental impacts associated to confined swine intensive system developed in Brazil - the resulting swine manure has a high nutrient (phosphorus and nitrogen, mainly) and organic matter content, that contribute to eutrophication of freshwater.

However, the swine wastewater can also be a source of nutrients to agricultural crops, according to researchers developing studies on this subject: Meneghetti (2010); Doblinski et al. (2010); Smanhotto et al. (2010); Sampaio et al. (2010a); Sampaio et al. (2010b); Caovilla et al. (2010); Pelissari et al. (2009); Prior (2008); Anami et al. (2008); Dal Bosco et al. (2008); Anami et al. (2007); Saraiva et al (2007); Baumgarnter et al. (2007); Sampaio et al. (2007); Frigo et al. (2006); Caovilla et al. (2005) Suszek at al. (2005).

According to Gomes-Filho et al. (2001), the swine wastewater can provide nutrients in sufficient quantities to be enjoyed by fertigation of agricultural cultures,

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Table 1. Chemical analysis of soil.

Parameter	Value
pH	5.20
Al^{3+} ($cmol_c\ dm^{-3}$)	0.00
$H^+ + Al^{3+}$ ($cmol_c\ dm^{-3}$)	5.76
Carbon (C)(g dm^{-3})	19.01
Phosphorus (P)(mg dm^{-3})	9.50
Potassium (K^+)($cmol_c\ dm^{-3}$)	0.22
Calcium (Ca^{2+})($cmol_c\ dm^{-3}$)	5.02
Magnesium (Mg^{2+})($cmol_c\ dm^{-3}$)	2.61
Cu (mg dm^{-3})	8.87
Zn (mg dm^{-3})	4.77
Fe (mg dm^{-3})	72.00
Mn (mg dm^{-3})	78.00

Table 2. Physical-chemical analysis of non-diluted SWW.

Parameter	Value
pH (to 22ºC)	6.39
Alkalinity (g $CaCO_3$ L^{-1})	3.73
Turbidity (NTU)	2500.00
Total solids (g L^{-1})	7.86
Volatile solids (g L^{-1})	4.54
Phosphor content (mg L^{-1})	946.57
Ammoniacal nitrogen (mg L^{-1})	1540.00
Nitrate (mg L^{-1})	700.00
Total nitrogen (mg L^{-1})	3220.00
Potassium (mg L^{-1})	1350.00

leading to increased production, with approximately 2/3 of N, 1/3 of P, and 100% of K, found in wastewater as minerals, that is readily assimilated by the crops. Nevertheless, it is important to find an amount of SWW that can be applied to each crop to meet the best crop results without risks to the environment.

This study thus, aimed at evaluating the effects of applying swine wastewater (SWW) in plant height, leaf area, fresh weight, dry weight, and NPK in leaf and soybean productivity.

MATERIALS AND METHODS

The experiment was conducted inside a greenhouse built in the Experimental Center of Agricultural Engineering - NEEA, belonging to the State University of Western Paraná, Campus Cascavel, whose geographical coordinates are 24° 53' S latitude, 53° 23' W longitude and average elevation of 682 m. The experimental area is classified as typic dystroferric Red Latosol of clay texture (EMBRAPA, 1999), composed of 68% clay, 13% silt and 19% sand. The chemical characteristics of soil are shown in Table 1.

The experimental area was dried out ten days before the deployment of the treatments, using the Roundup (glyphosate), with dose of 2 L ha^{-1} and fertilization according to the interpretation of data obtained from soil analysis (Table 1), not being necessary liming, but only fertilization at sowing, following the methodology of EMBRAPA (1999). The chemical fertilizer NPK was used in 04-20-20 formulation on all plots at a dose of 250 kg ha^{-1}.

The crop deployed in the experiment was soybean (Glycine max L. Merrill) cultivate CD 216 of Central Agricultural Cooperative of and Economic Technology Development Ltda, (COODETEC) with vegetative cycle around 50 days and cycle total of 105 to 110 days. Seeds were treated with Derozal Plus fungicide (Carbendazin 200 ml 100 kg^{-1}) and plated at a spacing of 0.30 inches between rows and 5 cm between plants, with an average depth of 3 to 4 cm and about 16 to 20 seeds per linear meter, making a total of 5100 plants in the area of 96 m^2. After emergence of the culture (15 days), insecticide was used (imidacloprid) at a dosage of 500 ml ha^{-1}.

The application of SWW was conducted by dripping (drip tape) with drip type poritex, distributed along lines, composed of control panels, four water tanks with a capacity of 1000 L, four pumps (Schnneider) 0.5 hp, four sand filters and four filter screen. Irrigation was performed according to the water requirement of the crop and determined from four tensiometers installed along the greenhouse for the control of soil moisture. Where soil moisture reached 80% of field capacity, culture was irrigated.

The values of matric potential soil water were obtained from the readings of the columns measured in mercury manometer twice a week and the characteristic curve of soil moisture, obtained in laboratory were finally used in determining the irrigation. The swine wastewater (SWW) came from Agroindustry of Organic Fertilizer Pelleting Pegoraro. The SWW composition was characterized, as follow: pH, alkalinity, acidity, turbidity, volatile solids, total solids and phosphorus (P) were determined at the Laboratory of Environmental Sanitation UNIOESTE, and potassium (K), total nitrogen, ammonia and nitrate were determined in the Laboratory Solanálises Cascavel, Paraná. The data obtained are shown in Table 2.

The SWW experiment was conducted, filed in 1000 L tanks and diluted in well water in the following proportions: 0, 25, 50 and 75%, being T1, T2, T3 and T4 (T1 = water, T2 = SWW diluted to 25%, T3 = AR diluted to 50% and T4 = AR diluted to 75%), respectively. Dilution permitted different nutrients contents in the fertigation water. After dilution, chemical analyzes were performed, whose results are shown in Table 3, as the same parameters mentioned above (Table 2), following the methodology of EMBRAPA (1999) for each treatment. It should be highlighted that T1 represents irrigation with well water without SWW mix. With the use of pumps and after passing through filter systems, each fertigation waters were conducted by drip until the crop.

The experiment was conducted in a completely randomized design (CRD) with four treatments and five repetitions for each, making a total of 20 plots. The size of each plot was 1.20 × 3.00 m, with spacing of 0.30 m plots. Analysis of variance and F test was used at 5% probability. The treatment means were compared by Tukey test and all data on the coefficient of variation exceeding 30%, was performed in its transformation and $\alpha = 0.05$. Data were collected at 15, 30 and 45 days after crop emergence; a total of ten plants per replication, in all treatments and parameters were determined: plant height, green mass, dry mass and area of leaf and at the flowering stage, the content of NPK in the sheet was determined.

Collections were carried out at 15, 30 and 45 DAE (days after emergence) in ten random plants per parcel, totaling 50 plants per treatment, while the height of each plant (distance between the soil surface and the apex of the main stem plant) was determined according to the methodology described by Hamada (1993), in which the results were expressed in cm. Again, samples were taken at 15, 30 and 45 days after emergence (DAE), but two random plants per parcel, totaling ten plants per treatment, weighed on precision scales (0.001 g) and was determined in fresh grass, according to the methodology described by Hamada (1993).

Table 3. Physical-chemical analysis of water and diluted SW and quantity of nourishment applied.

Parameter/treatment	T1	T2	T3	T4
pH (to 22ºC)	7.69	6.78	6.96	6.81
Alkalinity (g $CaCO_3$ L^{-1})	0.09	1.38	2.20	3.28
Turbidity (NTU)	0.86	500.00	670.00	1135.00
Total solids (g L^{-1})	-	1.96	4.26	5.14
Volatile solids (g L^{-1})	-	1.76	2.04	3.40
Phosphor content (mg L^{-1})	81.07	431.06	944.54	1009.40
Ammoniacal nitrogen (mg L^{-1})	-	520.00	710.00	900.00
Nitrate (mg L^{-1})	-	70.00	28.00	42.00
Total nitrogen (mg L^{-1})	-	530.00	790.00	1150.00
Potassium (mg L^{-1})	-	143.00	190.00	220.00
Electrical conductivity (µS cm^{-1}** or mS cm^{1})*	107.30**	5.44*	8.39*	10.82*
Quantity of nourishment applied (kg ha^{-1})				
Total solids (kg ha^{-1})	-	5037.2	10948.2	13209.8
Phosphor content (kg ha^{-1})	-	1107.82	2427.47	2594.16
Ammoniacal nitrogen (kg ha^{-1})	-	1336.40	1824.70	2313.00
Nitrate (kg ha^{-1})	-	179.90	71.96	107.94
Total nitrogen (kg ha^{-1})	-	1362.10	2030.30	2955.50
Potassium (kg ha^{-1})	-	367.51	488.30	565.40

* mS cm^{-1}, ** µS cm^{-1}.

New collections were taken at 15, 30 and 45 DAE (days after emergence) of two random plants per parcel, totaling ten plants per treatment and weighed on precision scales (0.001 g). After weighing, the plants were cut and packaged in paper bags, properly labeled and put to dry to constant weight in a greenhouse of forced air at 65°C. The dry weight was determined according to the methodology described by Hamada (1993).

Besides the previous collections, others came also at 15, 30 and 45 DAE (days after emergence) of two random plants per parcel, totaling ten plants per treatment. After collection, the plants were cut, separating them from the remaining leaves. With the use of graph paper, the leaf area was determined (HAMADA, 1993). Two plants of the centerline of each plot were collected totaling ten plants per treatment and the analysis of NPK on leaf was performed, whose methodology was described in EMBRAPA (1999). The collection at 115 DAE (days after emergence) of five random plants per parcel, totaling 25 plants per treatment was done, after which the plants were threshed, separating them from the rest of the grains, weighed and packed in paper bags properly labeled.

RESULTS AND DISCUSSION

Plant height

The data obtained in the experiment for plant height (cm) of soybean are shown in Figure 1. No statistically significant differences were found between treatments in the periods evaluated (15, 30 and 45 DAE); fact identical with KALIL also occurred (1992).

Junchen (2000) found no differences in plant height of lettuce when irrigated with wastewater and drinking water, however, Chateaubriand (1988), applying SWW in furrow irrigation in corn, had an increase in plant height by 19%, compared with the witness only irrigated with water supply. Gomes (1995), applying organic fertilizer in corn, Hill and Sousa (1992) and Vasquez-Montiel et al. (1996), using facultative lagoon wastewater in corn and sorghum, and Freitas et al. (2004), using SWW diluted to 50% irrigating corn, observed slight increase in the values of plant height.

The blades used SWW did not influence the average plant height, as shown in Figure 1. HAMADA (1993) noted that the vertical development of the plant is not uniform, even without application of wastewater. T1 Treatment (water) showed the greatest heights of plants in all periods, and the maximum height reached by the plant was 73.40 cm, 45 days after emergence (DAE). The values found for T2, T3 and T4 were smaller, possibly due to increased concentration of SWW; the nutrient supplied at high concentrations may have caused physiological disorders in plants, making it difficult to extract water.

Baumgartner et al. (2005), working with fertigated lettuce with SWW pond aquaculture, AR stabilization pond of pig manure and SWW pond algae production fueled with waste digester, found that excess nutrients such as K and Na may hinder the extraction of water and other nutrients, and thus preventing growth.

Fresh weight

Figure 1 also shows the average value for the level of

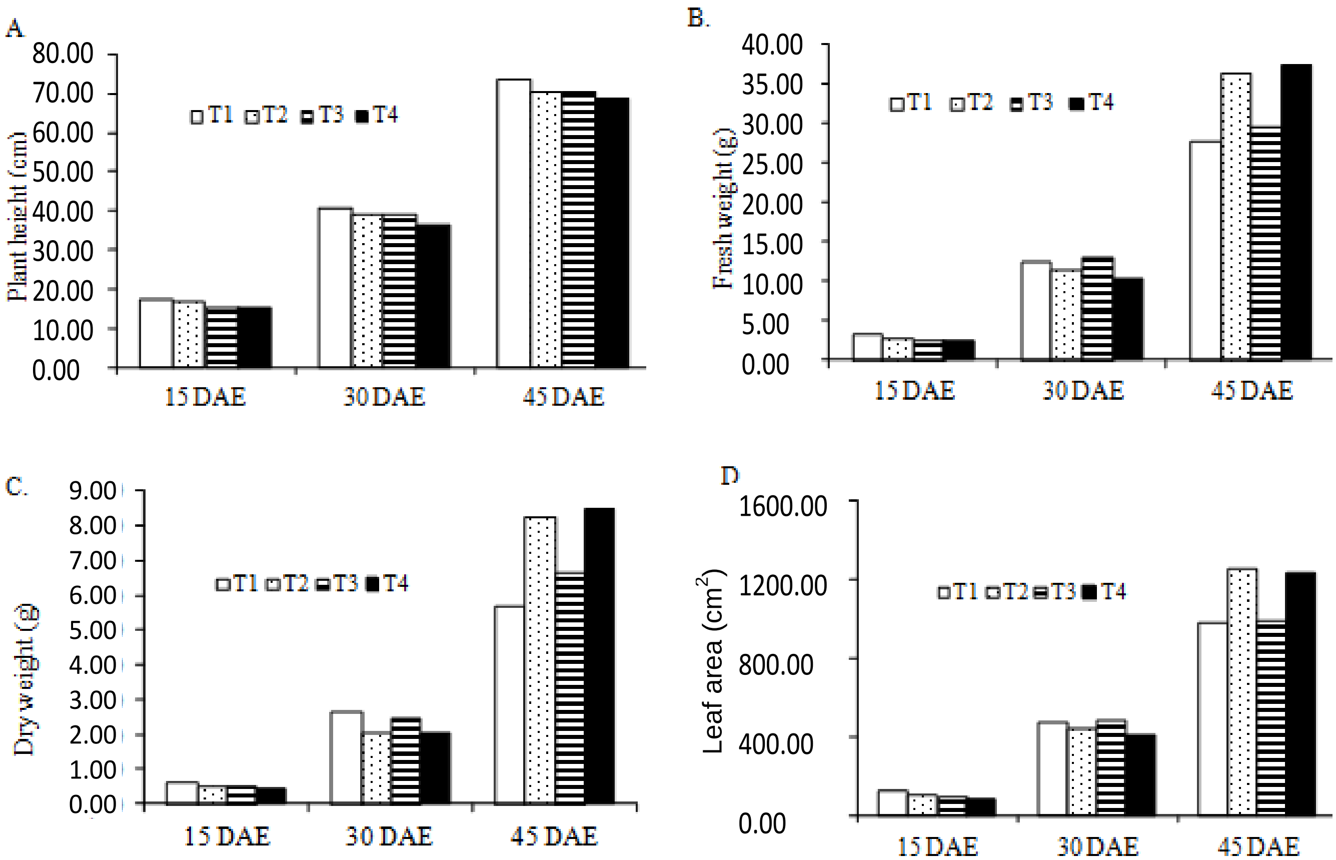

Figure 1. Plant height (A), fresh weight (B), dry weight (C) and leaf area (D) for the treatments. T1 = water; T2 = SWW diluted to 25%; T3 = SWW diluted to 50%; T4 = SWW diluted to 75%.

weight obtained in the experiment for the three readings (15, 30 and 45 DAE), and can be observed that there were no statistically significant differences ($p \geq 0{,}05$) among treatments in moments. Comparing the results of weight with plant height, it is seen that the treatments were similar, at 15, 30 and 45 DAE. Despite the mean test indicate no significant difference, the results show that fresh weight treatments T4 and T2 presented numerically, the best results followed by treatments T3 and T1, after 45 days of emergence.

Chateaubriand (1988), applying SWW in furrow irrigation for the corn crop, obtained a 40% increase in fresh weight compared with the control irrigated with water only. Gomes Filho et al. (2001), obtained using SWW in forage oat, 5% increase in fresh weight in relation to treatment irrigated with water only.

Mount and Sousa (1992) and Vazquez-Montiel et al. (1996) observed, through facultative lagoon wastewater for the corn crop and sorghum, small increase in fresh weight. Freitas et al. (2004), using SWW diluted to 50% in irrigation of corn, showed an increase of 50% in fresh weight in relation to treatment irrigated only with water supply.

Junchen (2000) and Baumgartner et al. (2005) found significant differences in the fresh weight, unlike the authors mentioned before when values decreased in fresh weight fertirrigated relative to the treatments irrigated with water only. Yet according to the authors, different wastewaters have different characteristics and, therefore, express different results. The results found by the authors cited above also may have differed from those found in this work, due to the culture they worked with. Most authors who have worked with grasses showed different absorption of nutrients from legumes, such as used in this work.

The average result for T4 treatment is justified by the plant's blooming period (45 DAE), since most nutrient uptake occurs at this stage of development and also may be related to the level of phosphorus (P) and nitrogen (N) found in leaf analysis data verified as follows (NPK) although these values are below those recommended by EMBRAPA (1999) that determine minimum and maximum values for the concentrations of these elements from 2.5 to 5.0 for phosphorus and 40 - 54 g kg^{-1} to nitrogen.

Dry mass

Figure 1 shows the dry weight (g) on the basis of rates of application from SWW and water. The readings were collected 15, 30 and 45 days after emergence. This also shows the values of leaf area (cm^2) for the four treatments. The values of the F statistic for the parameter were not significant (p> 0.05) for the three doses of SWW readings with water applied on soybean. The analysis of variance applied to the dry mass (g) showed no significant difference (p> 0.05) for 15, 30 and 45 days after emergence. The highest average values for dry mass (g) were found in treatments T4 and T2, followed by T3 and T1. The same behavior was observed for the fresh weight 45 DAE. Chateaubriand (1988), applying SWW in furrow irrigation on corn, Gomes Filho et al. (2001) using SWW oat forage, Mount and Sousa (1992), Vazquez-Montiel et al. (1996) using facultative lagoon wastewater in corn and sorghum; and Freitas et al. (2004), with SWW diluted to 50% irrigating corn and obtained higher values of dry matter in relation to the treatments irrigated with water only.

Junchen (2000) and Baumgartner et al. (2005) showed highly significant differences in dry mass, unlike the other authors mentioned above, there is a reduction in dry mass values in Fertigation, compared to irrigation with water only, a parameter which is directly connected and is proportional to the fresh weight, that is, increase or decrease in fresh mass also causes an increase or decrease in dry matter values indicating that the treatments T4 and T2 provided the largest plant dry mass, because the availability was higher than in T1, T3 in the accumulation was smaller than in T2 and T4, but higher in T1, although without statistical differences between them.

Leaf area

The parameters (Figure 1) studied indicates that at 15 days after emergence (DAE), T1 (water) was numerically better than other treatments for all parameters. This may have occurred because of the response time for the doses of SWW acted on culture. For plant height (cm), T1 (water) showed the greatest results, both for 15, and for 30 and 45 days after emergence (DAE). However, after 30 days of emergency, this was not observed for the parameters fresh weight (g), dry mass (g) and leaf area (cm^2).

T3 (50% of SWW and 50% water) showed the best results, followed by treatment T1 (water). At 45 DAE, the treatments T2 and T4 showed the best results for fresh weight (g) and dry mass (g) than the other treatments. The same was not observed for plant height (cm). The T1 and T2 were numerically larger than the others, respectively. For leaf area (cm^2), 45 DAE, the T2 and T4 were those with the highest values, as had been observed in fresh weight and dry weight.

Chateaubriand (1988), fertigated corn crop with SWW, Gomes Filho et al. (2001), used SWW oat forage, Mount and Sousa (1992) and Vasquez-Montiel et al. (1996), used facultative lagoon wastewater in corn and sorghum and Freitas et al. (2004) used SWW diluted to 50% irrigating corn and observed significant increase in leaf area, probably because of the various SWW, whether concentrated or diluted. Their cultures used mostly grasses and responded differently to SWW, compared to soybeans used in this study (legume).

Leaf analysis

The analysis of variance applied to nitrogen, phosphorus and potassium, after 45 days from emergence (45 DAE), showed no significant difference (p> 0.05) for the match, however, for nitrogen and potassium analysis, showed a significance by Tukey test at 5% probability. Cerezo et al. (1995) found no significant differences on the content of foliar NPK, compared to the control, when they worked with young orange trees irrigated with effluent urban crude for three years.

For all treatments, the average values of phosphorus (P) were below the values determined by EMBRAPA (1999) (Table 4), corroborating the studies of Saraiva (2004) in fertigation of corn with manipuera and also found values of P lower than recommended for the corn crop, generated possibly by the low mobility of the element and competition with other nutrients exist in SWW, which may have caused the inhibition of its removal by culture and may also have been influenced by the pH because, when observing values above 6.5, there may be unavailable to the plant elements; this fact was not observed for the treatments T1 and T2 to the leaf nitrogen and potassium, respectively.

The highest value was found for potassium in the treatment T1, decreasing to the other treatments, which may have occurred due to the high content of calcium and magnesium in the soil, as they compete in the same place for absorption hence impede the extraction of water and other nutrients such as, for example, potassium, one of which is responsible, along with nitrogen for the growth of the plant, agreeing with the results of Lopez (1988), in his work with chili, which verified that the absence of these element causes an imbalance of the part area with respect to root portion, abortion of flowers and greater sensitivity to diseases.

Productivity

The treatments T4 (75% of wastewater) and T3 (50% of wastewater) showed higher yield (4800 kg ha^{-1}), respectively, followed by T2 (25% of wastewater), T1 (water only) (3840 and 4020 kg ha^{-1}), respectively, so that treatments that received SWW obtained in higher concentration higher productivity; about 16% higher than T1 irrigated with water alone. Chateaubriand (1988), fertirri-

Table 4. Average values for NPK content on the leaf after 45 days of emergency (DAE) of soy.

Treatment	Phosphorus (g kg^{-1})	Nitrogen (g kg^{-1})	Potassium (g kg^{-1})
T1	1.42^{a}	28.44^{b}	18.10^{a}
T2	2.00^{a}	43.52^{a}	15.70^{ab}
T3	1.13^{a}	32.36^{ab}	11.90^{bc}
T4	1.42^{a}	34.01^{ab}	11.40^{c}
General average	1.50	34.58	14.27
CV (%)	41.37	21.51	15.61
DP	0.62	7.44	2.23
Interpretation (g kg^{-1})*	2.5 - 5.0	40 - 54	17 - 25

Equal capital letters on the column indicate that there is no statistic difference amongst them by Tukey test; 5% of probability. T1 = water; T2 = 25% wastewater and 75% water; T3 = 50% wastewater and 50% water; T4 = 75% wastewater and 25% water. *= Values determined by EMBRAPA (1999).

gated corn crop with SWW, and obtained an increase in productivity of about 40% compared to the control. Gomes-Filho et al. (2001) using SWW oat forage achieved 5% higher productivity compared to the control with water supply.

Conclusions

Under the conditions of this study, it is concluded that: there was no significant difference between treatments T1, T2, T3 and T4, at 5%, for the parameters: plant height, fresh weight, dry weight and leaf area; the leaf analysis of phosphorus showed no significant differences between treatments; the application of swine wastewater induced higher nitrogen absorption and lower absorption of potassium in soybean; the treatments T3 and T4 had higher productivity, that is about 16% higher than the T1.

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