Indicators for Use of Sewage Sludge in Rice Culture in Sandy Latosol

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Abstract

The upland rice cultivation requires a large supply of nutrients, which are supplied, usually for mineral fertilizers. This need fertilization can be replaced by organic fertilizers, such as sewage sludge. This study aimed to verify the effect of sewage sludge doses on the development of rice grown in sandy soil of low fertility in order to obtain indicative to determine proper dosage use of it. An experiment in pots using a sandy clay loam soil of sandy texture, in which we used a randomized blocks with five replications was conducted. The treatments were constituted by conventional mineral fertilizer and the addition of sewage sludge corresponding to a dosage of 0, 5, 10, 20 and 40 t ha^{-1} supplemented with nutrients to achieve the recommended levels, a total of six treatments. It evaluated the fresh weight of shoots and roots, dry weight of shoots and roots, plant height and number of tillers. It was found that the addition of sewage sludge increased the production of fresh and dry weight of shoots and roots, as well as height and number of tillers of rice plants.

Keywords: Oryza sativa, Organic Fertilizer, Sewage Sludge (Biosolids)

1. Introduction

Rice (*Oryza sativa* L.) is one of major cereals that are the basis of food (Fageria et al, 2011), Accounting for about half the energy and protein intake of individuals (Young and Pellet, 2006). It is estimated that it is responsible for about 20% of world energy consumption and 15% of protein intake (Kennedy and Burlingame, 2006). In the 2012/2013 harvest, Brazil produced 11,924,200 tons of rice and according to forecasts, the grain must expand its production area as well as the importance on the national scene, particularly in dryland cropping system (Conab, 2013). Currently, national breeding programs have developed upland rice cultivars with great grain characteristics, size and resistance to lodging suited to mechanization and disease resistant, making rainfed agriculture more competitive in terms of market (Tragnago et al., 2013). To maintain the productivity of commercial crops, it is necessary to apply lime and fertilizer (Raij et al., 2007). Crops require the application of appropriate amounts of inputs, so that the economic criteria are met and at the same time, there is the maintenance of soil fertility conservation to maintain or increase productivity. According Agrianual (2013), spending on fertilizers and corresponds to 38% of total production cost.

In Brazil, the upland rice has been grown predominantly in low fertility soils, so it is necessary the supply of nutrients, usually supplied by the application of mineral fertilizers. However, organic fertilizers has also been used which are less expensive and reduce volatilization problems related to (C), leaching (C and K) and specific binding (P). Nascimento et al. (2004), claim that the residue can replace, even partially, mineral fertilizers. This substitution results in greater economy since the sewage sludge is provided at low cost in almost all Brazilian states. Andreoli and Pegorini (1999) and Kummer (2013) emphasize that the use of sewage sludge in agriculture is a viable alternative. These are materials rich in organic matter, macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Cu, Mn and Zn) - (Kummer, 2013), and is therefore considered as fertilizer for crops (Bettiol and Camargo, 2006), also providing savings of natural resources by reducing the mineral fertilization. Fertilization with sewage sludge presents advantages over conventional mineral, depending on the slow release of nutrients in the soil after application. Grutzmacher et al. (2013) found that, in the long term, the sewage sludge resulted in benefits to the farming system, with an emphasis on stocks of C and N. In work with sunflower cultivation, using different doses of sewage sludge alkaline, Deschamps and Favaretto (1997) found the possibility of replacing 100% the amount of nitrogen recommended without yield losses when compared to treatments with mineral fertilizer. However, to obtain such advantages, the determination of the appropriate dose is required to meet the needs of each culture as well as reducing environmental liabilities by a more proper disposal of the residue.
This study aimed to verify the effect of the application of sewage sludge in the development of rain-fed rice cultivation, to obtain criteria for the use.

2. Materials and Methods

The experiment took place from October to December 2012, at the experimental station of the State University of Maringa, Campus Umuarama-PR, Parana, Brazil, located at 23°47'31"S latitude and 53°15'25 "W longitude and average altitude of 375 m, conducted in the open in plastic pots of 15 liter filled with soil classified as Oxisol sandy typical (Embrapa, 2006) (Table 1) The climate is classified as Cfa, according to Koppen, with average annual rainfall of 1500 mm, average annual temperature of 22°C, relative humidity annual average of 70% with an average of two frosts per year (Iapar, 1994). The experimental design was randomized blocks, with six treatments with five repetitions. Initially, the soil to be packaged in the pots has been fixed with limestone, in order to raise the base saturation of 60% (Sbcs, 2004). As a result, it was determined that the treatments were constituted the addition of sewage sludge and complementation with mineral fertilizer: 1) absolute control (without chemical fertilizers and without application of sewage sludge); 2) conventional mineral fertilizers; 3) 5 t ha^{-1} of sewage sludge + supplementation with mineral fertilizer; 4) 10 t ha^{-1} of sewage sludge + supplementation with mineral fertilizer; 5) 20 t ha^{-1} of sewage sludge + supplementation with mineral fertilizer; 6) 40 t ha^{-1} of sewage sludge + supplementation with mineral fertilizer. This was necessary to complement treatment with sewage sludge, because of the low phosphorus and potassium contents found in the sludge produced by the wastewater treatment plant Umuarama-ETE, Parana State, Brazil (Table 2), so as to equalize the amount applied to the treatment fertilization mineral.

In the treatment used where conventional mineral fertilizer was applied corresponding to 10 kg ha^{-1} of N at seeding, along with 60 kg ha^{-1} P_2O_5 (superphosphate) and 50 kg ha^{-1} of K_2O (potassium chloride) and 40 kg ha^{-1} N (ammonium sulfate) at 40 days after emergence, applied in coverage. The applications were made on the basis of soil analysis (Table 1) and following the recommendations of the Sbcs (2004) for upland rice crop in the first year crops. Sowing was held on October 26, 2012, with the upland rice cultivar IPR 117, early maturing material Agronomic Institute of Paraná (Iapar) recommended for the northwestern region of Paraná, following the agroclimatic zoning of culture. Ten seeds were sown per pot and then held thinned to five plants per pot (plot). The experiment was conducted outdoors in order to simulate field conditions. Throughout the conduct of the field work, the soil of the pots was kept moist by natural rainfall or by irrigation in dry seasons. At the start of flowering to 54 days after sowing, evaluated the plant height and tillering. Then the plants were sectioned at the time of the soil surface and the roots were separated from the soil, resulting in the fresh weight of shoots and roots. The shoots and roots were dried in a forced circulation oven at 65°C for 72 hours. Statistical analysis was performed following the model of analysis of variance through the Sisvar program v. 5.3 (Silva, 2007) Once compiled, the data set was subjected to the test Lilliefors homogeneity of variances. Answered the model assumptions, we used the Tukey test to compare means in the 5% level of significance. To determine the optimal doses of sewage sludge for each evaluated feature, we used the first derivative of the regression equation.

3. Results and Discution

Rice plants respond positively and significantly to the application of sewage sludge added as a source of organic fertilizer (Table 3). It is observed also that the application of doses above 10 t ha^{-1} showed higher mass accumulation of shoot and higher plant height than the mineral fertilizer, which demonstrates the residue of potential fertilize the soil and provide better capacity development of plants with the application of sewage sludge. This could be because, according to Kummer (2013) provides the sludge S, Ca and Mg as well as micronutrients such as Cu, Zn and Mn, which may have contributed to the better development of rice plants (Table 4). The sludge agricultural use has been recommended by many researchers, for providing agronomic benefits such as increased soil pH (Bettiol and Camargo, 2006; Oliveira et al, 2002;. Tsutiya, 2001), reducing the potential acidity, increase in organic matter content (Tsutiya, 2001), increased ability to exchange cations (Oliveira et al, 2002) and increase in the availability of nutrients (Da Ros et al., 1993; Tsutiya, 2001; Lima et al., 2012) in various cultures. Replacement indication purposes of traditional mineral fertilizer by organic fertilization with sewage sludge, the dose of 10 t ha^{-1} had to be sufficient to match the values obtained with mineral fertilizer, save only for the variable fresh weight of roots, where equality occurred at a dose of 20 t ha^{-1}.

It was observed that the application of increasing doses of sewage sludge resulted in increased growth of rice plants. Figure 1 shows the trend lines showed a high setting and a maximum point, which allows to conclude that the maximum value in plant growth was obtained. Thus, it established the first derivative of the regression equations obtained from the graphs in Figure 1. It was observed that the best development of rice plants was obtained with dose ranging between 34.79 and 42.58 t ha^{-1} , which demonstrates that the average value set as the maximum technical efficiency was 37.89 t ha^{-1} (Table 5). The maximum value may have occurred because the plant reaches its maximum absorption and utilization of nutrients, or by possible excess of any component, causing toxicity (Figure 1). The morphological characteristics evaluated serve as parameters that can be extrapolated to estimate the yield, since they are related to increased plant capacity, wherein it is apparent that the higher the values of such the greater the productivity achieved (Fageria, 2006).

These differences in the treatments containing sewage sludge are closely linked with the issue of nitrogen fertilization. This macronutrient is highly required by the rice crop and is aplenty associated with organic matter in the sewage sludge. On the other hand, for other nutrients, such as P and K, the dose was relatively the same in all treatments. Held supplementation with mineral fertilizer when sewage sludge did not have sufficient quantities to meet the need for P and K by culture. And this occurred in all treatments due to the low presence of these macronutrients in the mud. Junio et al. (2012) confirm that even after a year of its implementation on the ground and two consecutive harvests of corn, sewage sludge also provides these nutrients to plants. According Fageria (1984), the rice plant needs nitrogen during the vegetative phase, this phase extending from germination to the tillering phase, and this chlorophyll the plant nutrient component. It stimulates the growth of the rice root system and therefore favors tillering, increases the number of spikelets per panicle and the grain protein percentage (Buzetti et al., 2000). Nitrogen (N) is one of the nutrients most limiting rice productivity, accounting for the increase in leaf area of the plant. Thus, increases, the efficiency of interception of solar radiation and the photosynthetic rate, reflecting positively in rice productivity. For as in the mud, the N is released gradually becoming available to plants throughout the cycle, you have not lost rapidly as in mineral fertilizer.

Another factor to consider, as cited Nascimento et al. (2004), and Hue (1995), is that although the sludge is a phosphor poor source, it acts positively decreasing the adsorption of the element in the soil. This fact is due to the high content of organic matter, which can provide organic ions that compete with the phosphate adsorption sites by increasing the availability of the element. Phosphorus (P) exerts various effects on the rice crop, the most important being the increased productivity of the components, in particular the number of panicles and root formation, is very important in biochemical reactions energy production and metabolism of the plant (Fageria, 1994). Hue (1995), found in his work the event of high potassium retention in cycles of annual crops in soils treated with sewage sludge. This is also due to increased organic matter in the soil, coming from sludge application. They create new binding sites in which the K^+ ion can bind, not losing is so easily leaching case was free in the soil solution. Potassium (K) is an essential nutrient for several important physiological and biochemical processes occurring in the plant being accumulated in greater amounts in modern rice cultivars, when compared with other essential nutrients (Fageria, 1994). Another factor that may explain the better performance of treatments sludge is in relation to micronutrients in their composition, even at low doses required by the plant, play important roles in it (Fageria, 1994).

Nascimento et al. (2004) and Kummer (2013), found growing behavior of cation exchange capacity with the application of sewage sludge doses, which is reflected in the improvement of soil fertility, with consequent income gain of cultures. In this way, they justify the results obtained in this test. A very questioned factor on the use of sewage sludge in agriculture is in relation to its potential for possible toxicity to plants and soil. This is why some heavy metals are found in the sludge composition, such as zinc, cadmium, lead, copper, manganese and iron, in varying proportions, depending on the origin of the waters treated sewage. On the other hand, consulting work on the subject, Oliveira et. al (2005) found that in rice cultivation, there were no signs of toxicity or translocation to plant shoots and grains, when subjected to high doses of these metals. In another study, Oliveira (1998), investigated the levels of these metals in soils treated with high doses of sludge enriched with these elements. The author found that the results indicated levels below the maximum allowed limit, according to the results obtained by Nascimento et al. (2004), which provides indications that it is safe to use sewage sludge.

However, there is potential contamination of groundwater by leaching of nitrates when the sludge is applied too much and unsuitable areas (shallow soils near streams and springs, steep slope sites on shallow aquifers or wetlands). Therefore, its use never eliminates the assistance and guidance of a skilled professional and the use of science-based criteria. Overall, this study provides indications that, for rainfed rice cultivation, the optimal dose for use of this waste as an alternative fertilizer, is around 38 t ha^{-1}. Consequently the sludge application, the producer gets improvements in productivity, the chemical and physical soil conditions and use with cost savings that alternative organic fertilizer, while also helping to solve the environmental problem of disposal of this waste.

4. Conclusions

1. The alternative use of sewage sludge as organic fertilizer is effective for upland rice cultivation.
2. The sewage sludge doses increased the production of fresh and dry weight of shoots and roots, as well as height and number of tillers of rice plants.
3. The dose of 38 t ha^{-1} of sewage sludge, showed the best development in the middle of rice. 4. The dose of 10 t ha^{-1} + complement introduced himself enough to match the values obtained with conventional mineral fertilizers.

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Table 1: Chemical and Particle Size Characterization of 0-20 cm of Haplortox Typically Used in the Test

pH	M.O.	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	CTC
(CaCl2)	g dm^{-3}	mg dm^{-3}	$cmol_c dm^3$						
4.97	6.05	7.20	0.15	1.38	1.00	0.00	3.97	2.53	6.50
V	Fe	Cu	Mn	Zn	B	S	Areia	Silte	Argila
%	mg dm^{-3}						%		
38.91	121.1	5.37	85.72	3.2	0.45	11.25	87.4	2.95	9.65

Extractors: (Ca^2 +, + Mg^2, Al^3 +) - KCl 1 mol L-1 -; (P, K +) - Mehlich - 1. M.O. = Organic matter - Walkley & Black

Table 2: Chemical analysis of sewage sludge produced by ETE of Umuarama/PR, Brazil

Determinations	Analytical Results
Total Solids (ST)	67.32%
Humidity	32.68%
Organic Carbon	26.20% (ST)
Total Sulfur	0.95% (ST)
pH in H_2O (1:10)	6.7
Kjeldahl Nitrogen	3.63% (ST)
Ammonia Nitrogen	0.23% (ST)
Nitrate Nitrogen	0.14% (ST)
Nitrogênio Nitrito	0.13% (ST)
Total Phosphorus (P_2O_5)	0.17% (ST)
Total Potassium (K_2O)	0.10% (ST)
Total Sodium	0.08% (ST)
Total Calcium	15.93% (ST)
Total Magnesium	1.32% (ST)

Table 3: ANOVA Summary for: fresh weight of shoots (FWS), dry weight of shoots (DWS), fresh root weight (FRW), dry root weight (DRW), total height (TH) and number of tillers (TIL) in the treatments

Source of Variations	GL	Quadrado médio FWS (g)	DWS (g)	FRW (g)	DRW (g)	TH (cm)	TIL
Treatment	5	1509.91*	120.36*	112.35*	29.86*	515.59*	13.57*
Blocks	4	18.12	1.48	1.90	0.85	7.12	0.38
Residue	20	8.68	1.60	1.38	0.44	4.06	0.32
CV(%)	-	7.94	12.24	10.27	14.00	6.61	9.92

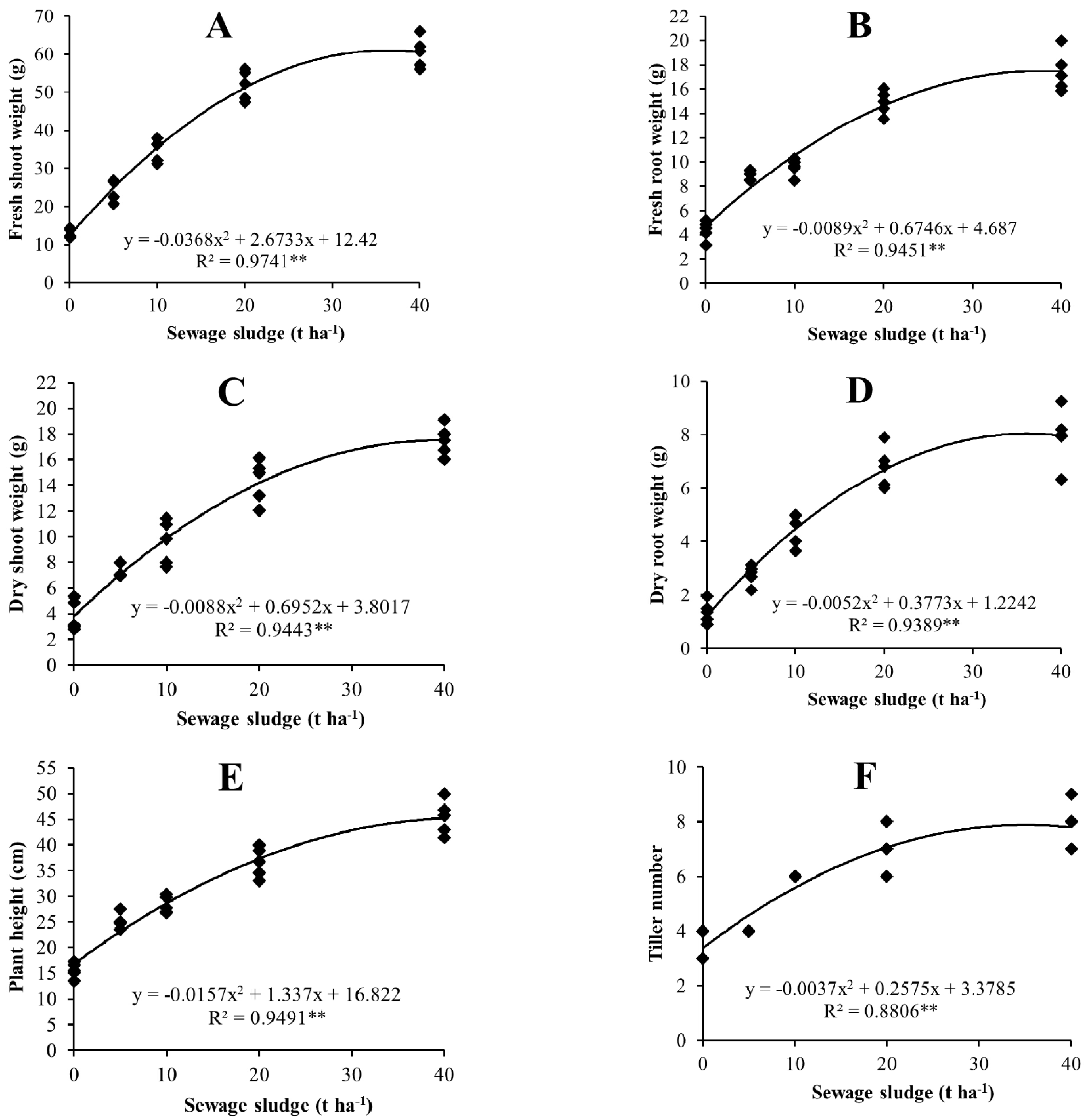
Table 4: Fresh and dry Weight of Shoots and roots, Height and Number of Tillers of Rice Plants to Sewage Sludge Doses

Treatments	54th day after blooming FWS (g)	DWS (g)	FRW (g)	DRW (g)	TH (cm)	TIL
Absolute Testimonial	12.85 e	3.82 e	4.38 d	1.36 d	15.62 e	3.6 c
Mineral Fertilizer	38.06 c	9.73 c	13.57 b	5.06 b	31.90 c	6.0 b
5 t ha^{-1} of sludge	24.62 d	7.19 d	8.86 c	2.77 c	25.12 d	4.0 c
10 t ha^{-1} of sludge	34.76 c	9.59 cd	9.58 c	4.47 b	28.32 cd	6.0 b
20 t ha^{-1} of sludge	51.83 b	14.34 b	14.90 b	6.77 a	36.64 b	7.0 ab
40 t ha^{-1} of sludge	60.40 a	17.48 a	17.43 a	7.94 a	45.36 a	7.8 a

FWS= Fresh weight of shoots; DWS= Dry weight of shoots; FRW= Fresh root weight; DWS= Fresh root weight; TH= Plant height; TIL= number of tillers

Values followed by the same letters in each column do not differ statistically by the Tukey test 5% probability

Figure 1: Fresh weight of shoot (A), fresh root weight (B), dry weight of shoots (C), dry weight of roots (D), height of the plants (E), number of tillers (F) analyzed plant rice exposed to increasing doses of sewage sludge



** significant at 1% probability

Table 5: Values derived from the regression equation for fresh weight of shoots and roots, dry weight of shoots and roots, plant height and number of tillers

Characteristics evaluated	Value of maximum technical efficiency of sewage sludge (t ha-1)
Fresh weight of shoot	x'=36.32
Fresh weight of the roots	x'=37.89
Dry weight of shoot	x'=39.50
Dry weight of roots	x'=36.27
Plant height	x'=42.58
Number of tillers	x'=34.79
Mean	x'=37.89