Effect of sewage sludge on the incidence of corn stalk rot caused by *Fusarium*

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ABSTRACT

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The final disposition of sewage sludge generated at Sewage Treatment Stations (STS) for agricultural purposes is a technique under expansion, because sludge is rich in macro and micronutrients, and in organic matter. The effect of incorporation of sludge from sewage generated in STSs at Franca and Barueri, SP, on the incidence of corn stalk rot caused by *Fusarium* spp. was studied in a randomized block trial with three replicates, in 200 m^2 plots in a Red Distroferric Latosol (clayey texture). Sludges were incorporated into to the soil at concentrations of 0; 1; 2; 4; and 8 times the recommended rate based on their nitrogen content, in three consecutive corn cultivations: the 1999 minicrop or "safrinha" ('CATI AL 30') and the 1999/2000 ('AG1043') and 2000/2001 ('Savana 133S') crops. The sludge rates were compared to the recommended mineral fertilization for the corn crop. This paper presents data obtained in the second and third sludge application cycles, since the disease did not occur during the first cycle. For the 1999/2000 and 2000/2001 crops, the percentage of diseased plants was positively correlated with the concentration of sludges incorporated into to the soil. The coefficients of determination for the second corn cultivation were R^2=0.90 and R^2=0.84, while for the third cultivation they were R^2=0.77 and R^2=0.45, for sludges from Franca and Barueri, respectively. The sludge concentrations also showed positive correlation with the *Fusarium* population in the soil and with the electric conductivity (EC); on the other hand, they were negatively correlated with the pH. The correlation studies between the percentage of diseased plants and the soil's chemical attributes were significant and positive, for the two sludges and the two last cultivations, at the 5% level, for phosphorus content, CEC, N_{total}, $N_{nitrate}$, and EC; on the other hand, it was negatively correlated with the pH. For the second cultivation, the percentage of diseased plants was positively correlated with all micronutrients (Fe, B, Cu, and Zn), except for Mn. These results demonstrate that if sewage sludge is to be utilized in agriculture in a safe manner, there is a need for long-term interdisciplinary studies performed under the ecological conditions of cultivation.

Additional Keywords: biossolid, *Zea mays,* soilborne pathogen, organic matter.

RESUMO

Bettiol, W. Efeito do lodo de esgoto na incidência da podridão do colmo do milho causada por *Fusarium*. ***Summa Phytopathologica***, v.30, p.16-22, 2004.

A disposição final do lodo de esgoto, gerado nas Estações de Tratamento de Esgoto (ETE), na agricultura, é uma técnica em expansão, pois o lodo é rico em macro e micronutrientes e matéria orgânica. Num ensaio casualizado em blocos, com três repetições, em parcelas de 200 m^2, em um latossolo vermelho distroférrico textura argilosa, foi estudado o efeito da incorporação dos lodos de esgotos originários das ETEs de Franca e de Barueri, SP, sobre a incidência da podridão do colmo do milho causada por *Fusarium.* Os lodos foram incorporados ao solo nas concentrações de 0, 1, 2, 4 e 8 vezes a dose recomendada com base no teor de nitrogênio, em três cultivos sucessivos de milho: safrinha 1999 ('CATI AL 30') e safras de 1999/2000 ('AG1043') e 2000/2001 ('Savana 133S'). As doses de lodo foram comparadas com a adubação mineral recomendada para a cultura do milho. Nesse trabalho são apresentados os dados obtidos no segundo e no terceiro ciclo de aplicação do lodo, pois no primeiro não ocorreu a doença. Para as safras 1999/2000 e 2000/2001, as análises de regressão mostraram que a porcentagem de plantas doentes foi positivamente correlacionada com a concentração dos lodos incorporados ao solo. Os coeficientes de determinação para o segundo cultivo do milho foram de R^2=0,90 e R^2=0,84, enquanto que para o terceiro cultivo foram de R^2=0,77 e R^2=0,45, para os lodos de Franca e de Barueri, respectivamente. As concentrações de lodos também apresentaram correlação positiva com a população de *Fusarium* do solo e com a condutividade elétrica (CE), por outro lado foram negativamente correlacionadas com o pH. As correlações entre a porcentagem de plantas doentes e os atributos químicos do solo foram significativas e positivas, para os dois lodos ao nível de 5%, para o teor de fósforo, a CTC, N_{total}, $N_{nitrato}$ e CE; por outro lado, foi negativamente correlacionado com o pH. Para o segundo cultivo, a porcentagem de plantas doentes apresentou correlação positiva com todos os micronutrientes (Fe, B, Cu e Zn), exceto para o Mn. Os resultados evidenciam que para a utilização segura do lodo de esgoto na agricultura, há necessidade de estudos interdisciplinares a longo prazo e nas condições ecológicas de cultivo.

Palavras-chave adicionais: biossólido, *Zea mays,* fitopatógeno habitante do solo, matéria orgânica.

During the last decades, sewage started to be treated in order to revert the pollution of rivers, resulting in the production of a sludge rich in organic matter and nutrients, called sewage sludge, which needs proper final disposition. Among the several available alternatives for disposing of sewage sludge, one of the most convenient is using it in agriculture. Since the sludge is rich in nutrients and has a high organic matter content, its application as a soil conditioner and/or fertilizer is widely recommended. However, using sewage sludge as a fertilizer causes alterations in the physical, chemical and biological properties of the soils. Therefore, each and every study about the use of sewage sludge in agriculture must provide a knowledge concerning what takes place with respect to these characteristics, since each of them plays a fundamental role in soil life and in the way the agroecosystem functions. The lack of knowledge about the effects sewage sludge might have on the community of organisms, on the contents of heavy metals and on the physical and chemical properties of tropical soils is one of the problems that relate to its use in agriculture. Since we know that sewage sludge application causes these alterations, it is necessary to understand them and verify what the involved consequences are.

The plant pathogens that inhabit the soil are highly influenced by the way the soil is managed; thus, sewage sludge may interfere with the occurrence of diseases caused by these organisms. The first references involving the effect sewage sludge has on plant pathogens are by Cook et al. (1964) and Markland (1969), quoted by Liu (14), which verified that dollar spot disease on turf was reduced with the application of sewage sludge. Incorporation of sewage sludge to the soils reduced the incidence or the severity of Sclerotinia drop on lettuce, caused by *Sclerotinia minor* (Lib.) de Bary (16, 18); root rot on sorghum and sugarcane roots, caused by *Pythium arrhenomanes* (2, 7); root rot on peppers, caused by *Phytophthora capsici* Leonian (15); Fusarium wilt on cucumber and basil, caused by *Fusarium oxysporum* Schlecht (9, 15); damping-off caused by *Rhizoctonia solani* Kühn and *Pythium ultimum* Trow on peas and cotton (13); dollar spot on Creeping Bentgrass and Annual Bluegrass Turf, caused by *Sclerotinia homoeocarpa* F.T. Bennett (20); root rot caused by *Pythium graminicola* Subram on Creeping Bentgrass (6); root rot on beans, cotton and radish, caused by *R. solani* (15); bacterial wilt on tomato, caused by *Pseudomonas solanacearum* (22); *Meloidogyne incognita* on tomato (3); damping-off on cucumber seedlings, caused by *Pythium aphanidermatum* (Edson) Fitzp. (25); and damping-off and rot in the collar of bean plants, caused by *Sclerotium rolfsii* Sacc. (24). On the other hand, McIlveen & Cole Jr (17) and Chellemi et al. (5) reported that sewage sludge did not interfere with the incidence of bacterial wilt in corn and tomato, respectively. However, there are reports also of increased diseases as a consequence of sewage sludge incorporation, as, for example, *Gibberella* rot on corn (17), root rots caused by *P. ultimum* and *Thielaviopsis basicola* (Berk & Broome) Ferraris in beans, peas, and cotton (18), and corn stalk rot caused by *Fusarium* (1).

Thus, since we are dealing with a residue with potential for use in large scale in the Brazilian agriculture, it is necessary to identify what impacts its use might have on the occurrence of plant diseases. In this work, we evaluated its effect on corn stalk rot, caused by *Fusarium* spp.

MATERIAL AND METHODS

The experiment was conducted at the Embrapa Meio Ambiente Experimental Field, located in Jaguariúna (SP), at latitude 22° 41' S, longitude 47° W. Gr., and altitude 570 m., on a Red Distroferric Latosol (clayey texture), whose physical and chemical characteristics in the layer from 0-20 cm, before the onset of the study, were the following: pH in water=5.8; OM%=2.55; P=3.5 mg dm^{-3}; K=1.51; Ca=27.5; Mg=8.5; Al=1; H=35; CEC=73.5 mmol dm^{-3}; V%=50.8; and clay=450 g kg^{-1}.

The sewage sludges were obtained from the Sewage Treatment Stations (STS) in Barueri, SP, which treats home and industrial sewage (Barueri Sludge – BS) and in Franca, SP, which essentially treats home sewage (Franca Sludge – FS). The most important characteristics of these sludges are presented in Table 1. The sewage treatment process is identical for both STSs, consisting of aerobic and anaerobic digestion.

The studied treatments, for each sludge, were: control; mineral fertilization (NPK) recommended for the crop (23); sewage sludge based on the nitrogen concentration that provides the same amount of N as in the mineral fertilization; and two, four, and eight times the recommended sewage sludge dosage (Table 2). Calculations of sludge rates were performed as a function of the nitrogen available for the plants, considering the nitrogen mineralization rate as 30%. For treatments involving sewage sludge, supplementary potassium was applied when necessary. The need for supplemental potassium depended on the potassium content in the sludge and on the total amount applied in each treatment.

The study was carried out during three years; in the first year the corn variety cultivated was CATI AL 30, and sowing was done on Apr/05/1999 (minicrop); in the second year the hybrid AG1043 was cultivated, and sowing was on Dec/13/1999; in the third year the hybrid Savana 133S was used, sown on Oct/30/2000. For the third cultivation, the pH was corrected individually in each plot to pH 5.7 one month before sludge application, based on a soil-neutralizing curve. The cultural practices adopted were those traditionally utilized for the crop, without irrigation. The stubble was removed from the plots before sludge application. Table 2 displays the amounts of sludge and fertilizers applied in each treatment, during the three corn cropping seasons. The sludges were toss-distributed in the total area of the experimental plots, and incorporated at a depth of 20 cm with a rotary harrow, three to four days before sowing.

The experimental design was set up as randomized blocks with three replicates. Each plot measured 10 x 20m, with 12 rows per plot. The plots were separated by hedgerows with at least 5 m on each side, planted with *Bracchiaria* grass kept at a short height.

Incidence of stalk rot

The total number of plants on the central rows of the plots and the number of plants showing symptoms of corn stalk rot caused by *Fusarium* spp. were evaluated approximately 100 days after each sowing operation. These data were used to calculate the incidence of the disease per plot.

Fusarium population

The *Fusarium* population in the soil was determined through the serial-dilution method, followed by plating in culture medium. The NSF medium (19) was utilized. Aliquots (0.1 mL) of the dilutions (10^{-2} and 10^{-3}) for each soil sample were transferred to each culture medium in Petri dishes, with three replicates. Assessments were performed by counting the number of colonies per Petri dish and expressed as colony-forming units g^{-1} of dry soil (CFU g^{-1} dry soil).

Table 1. Chemical characteristics of sewage sludges from Sewage Treatment Stations in Franca (FS) and Barueri (BS), located in the State of São Paulo, utilized in three corn plantings.

Characteristic		First cultivation		Second cultivation		Third cultivation	
	Unit(1)	BS	FS	BS	FS	BS	FS
P	g/kg	15.9	16.0	31.2	21.3	26.9	12.9
K	g/kg	1.0	1.0	1.97	0.99	1.0	1.0
Na	g/kg	0.5	0.5	0.6	0.6	0.5	0.9
Ar	mg/kg	<1	<1	<1	<1	<1	<1
Cd	mg/kg	12.8	3.32	9.5	2.0	9.4	2.05
Pb	mg/kg	364.4	199.6	233	118	348.9	140.5
Cu	mg/kg	1058	239.8	1046	359	953.0	240.9
Cr	mg/kg	823.8	633.8	1071	1325	1297.2	1230.3
Hg	mg/kg	<0.01	<0.01	<1	<1	<0.01	<0.01
Mo	mg/kg	<0.01	<0.01	<1	<1	<0.01	<0.01
Ni	mg/kg	518.4	54.7	483	74	605.8	72.4
Se	mg/kg	<0.01	<0.01	<1	<1	<0.01	<1
Zn	mg/kg	2821	1230	3335	1590	3372	1198
B	mg/kg	36.2	40.7	11.2	7.1	29.3	19.7
C	g/kg	248.2	305.1	271	374	292.9	382.4
pH		6.6	6.3	6.4	6.4	6.4	5.4
Humidit	%	3.5	6.0	53.3	52.1	32.8	2.8
N Kjeldahl	g/kg	26.0	47.0	26.4	50.8	38.5	55.2
N-ammoniacal	mg/kg (2)	1566.9	4803.2	156	119	2401.6	2094.1
N-Nitrate-Nitrite	mg/kg (2)	106.2	22.0	106	54.8	51.3	43.9
S	g/kg	13.4	16.3	10.8	13.3	17.1	15.7
Mn	mg/kg	429.5	349.3	335	267	418.9	232.5
Fe	mg/kg	54181	33793	32500	31706	37990	24176
Mg	g/kg	3.0	2.2	3.7	2.5	4.5	2.2
Al	mg/kg	28781	32564	25300	33550	23283	23317
Ca	g/kg	40.3	29.2	22.8	16.8	47.8	24.8

(1)Concentration values given are based on dry matter. (2)Concentration values for nitrogen in the ammoniacal and nitrate forms were determined in the sample under the original conditions.

Table 2. Franca Sewage sludge (FS), Barueri Sewage sludge (BS), and mineral fertilizer amounts applied in three corn cultivations.

Treatment	Sewage sludge (kg/ha – dry matter)			NPK (4.20.16) + Urea			KCl (kg/ha)		
	Cropping			Cropping			Cropping		
	1°	2°	3°	1°	2°	3°	1°	2°	3°
Control	-	-	-	-	-	-	-	-	-
Recommended mineral fertilization	-	-	-	400 + 77	450 + 160	450 + 182	-	-	-
FS that provides the N amount recommended	3014	3504	3766	-	-	-	47	55	95
FS that provides twice the N amount recommended	6028	7008	7533	-	-	-	41	49	75
FS that provides four times the N amount recommended	12057	14017	15065	-	-	-	28	39	30
FS that provides eight times the N amount recommended	24113	26033	30131	-	-	-	-	18	-
Control	-	-	-	-	-	-	-	-	-
Recommended mineral fertilization	-	-	-	400 + 77	450 + 160	450 + 182	-	-	-
BS that provides the N amount recommended	8095	3995	5315	-	-	-	5	47	65
BS that provides twice the N amount recommended	16190	7991	10631	-	-	-	-	32	15
BS that provides four times the N amount recommended	32381	15981	21262	-	-	-	-	6	-
BS that provides eight times the N amount recommended	64762	31962	42524	-	-	-	-	-	-

pH and electric conductivity (EC) of the soil

Soil samples were analyzed to determine pH and EC according to methodology described by Embrapa (8).

Chemical attributes of the soil

Soil fertility analyses (macro and micronutrients) were performed in soil samples collected on Jan/12/2000 and Mar/23/2001. These dates correspond to the middle of the second cropping season and to the final of the third.

RESULTS AND DISCUSSION

No plants showing symptoms of stalk rot were observed in the first corn cultivation cycle, i.e., during the 1999 minicrop. However, the incidence of the disease was high in the two subsequent cultivations (Figure 1). For the 1999/2000 and 2000/2001 crops, the regression analyses showed that the percentage of diseased plants was positively correlated with the concentration of sewage sludges incorporated to the soil

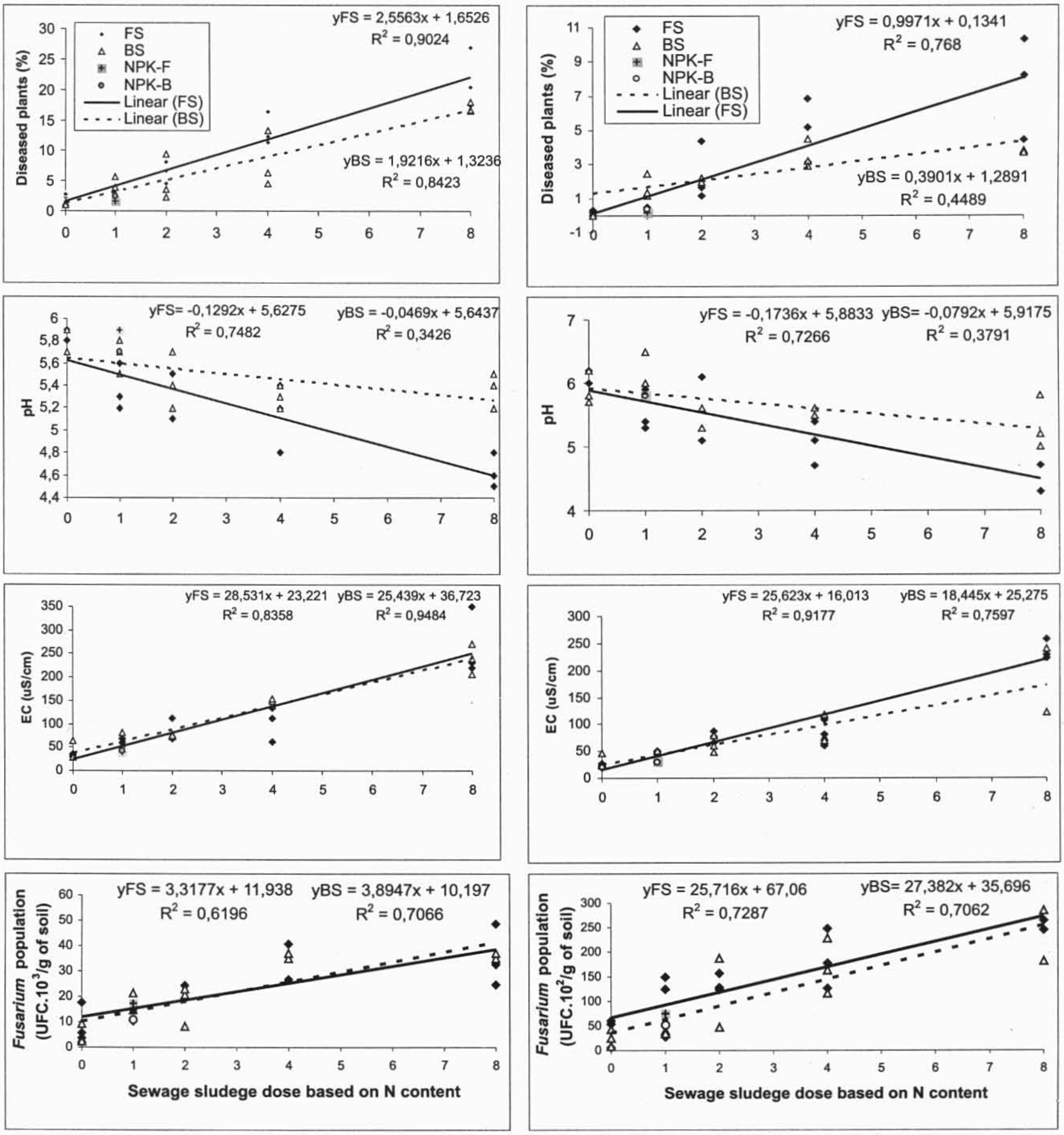

Figure 1. Effect of sewage sludge rates (FS=Franca sludge; BS= Barueri Sludge; NPK-F=recommended mineral fertilization - compares to Franca sludge; NPK-B=recommended mineral fertilization - compares to Barueri sludge) over the percentage of diseased plants, pH and electric conductivity of the soil, and *Fusarium* population in the soil. Left column contains data referring to second planting; right column refers to third planting.

(Figure 1). The coefficient of determination for the second corn cultivation were R^2=0.90 and R^2=0.84, for sludges from Franca and Barueri, respectively, while for the third cultivation they were R^2=0.77 and R^2=0.45. These data agree with those observed by McIlveen & Cole Jr (17), which verified an increase in *Gibberella* rot in corn with the application of sludge.

When the sludge was applied at the concentration recommended by CETESB's norm P4230, which establishes criteria for application of sludges from biological treatment systems in agricultural areas (4), that is, in a rate that provides a nitrogen amount similar to that supplied by the treatment with mineral fertilization, the occurrence of the disease was similar between the two treatments, demonstrating the importance of applying an adequate amount of sludge. When the sludge was applied at rates of 2, 4, and 8 times the recommended rate, the incidence of the disease was high. However, these rates cannot be utilized by farmers because, in spite of the increase in corn productivity, serious environmental impact problems could occur, such as nutritional unbalance and contamination of ground water by nitrates. On the other hand, this result demonstrates it is necessary to monitor the occurrence of the disease in areas where the residue is continually used, because the problems pointed out here could be observed in the short term.

The *Fusarium* population in the soil, determined through serial-dilution, was positively correlated with the concentration of sludges, with coefficients of determination R^2=0.62 and R^2=0.71, for the second corn cultivation, and R^2=0.73 and R^2=0.71 for the third, for sludges from Franca and Barueri, respectively. The *Fusarium* populations in the soil showed a variation between 10,000 for the control, and 40,000 for the highest sludge concentration (Figure 1).

Even though the acidity in the soil was corrected to pH 5.7 before the first and third sludge applications, a marked reduction in soil pH occurred, reaching pH values around 4.0 for the highest sludge concentrations. Soil acidification was more pronounced with sludge from Franca than with sludge from Barueri (Figure 1). Negative correlations between pH and sludge concentrations were observed, with values of R^2=0.75 and R^2=0.34 in the second cultivation, and R^2=0.73 and R^2=0.38 in the third cultivation, for sludges from Franca and Barueri, respectively. It was also observed that with the reduction in soil pH there was an increase in the incidence of the disease (Figure 1).

The electric conductivity (EC) in the soil was positively correlated with sewage sludge concentration, with coefficient of determination values of R^2=0.84 and R^2=0.95 in the second, and R^2=0.92 and R^2=0.76 in the third cultivation, for sludges from Franca and from Barueri, respectively.

Taking into account the two sludges, the correlation analysis performed between the variables in the second corn cultivation demonstrated that the percentage of diseased plants is negatively correlated with pH (r=-0.67**) and positively correlated with EC (r=0.84**) and with the *Fusarium* population in the soil (r=0.77**). In the third cultivation the incidence of disease was also negatively correlated with pH (r=-0.66**) and positively correlated with EC (r=0.78**) and with the *Fusarium* population in the soil (r=0.72**).

Pereira (21) and Shurtleff (26) recommend a balanced fertilization, especially by avoiding low potassium levels and high nitrogen levels, to control the disease. Since sewage sludge is an excellent source of nitrogen and there were three consecutive sludge applications, part of the organic nitrogen was possibly mineralized during this period, making available an excessive amount of this nutrient. The total nitrogen content in plots where sewage sludge from Barueri was applied reached values up to 194 $\mu g\ g^{-1}$ soil, in the third cultivation (unpublished). On the other hand, sewage sludge is low in potassium and supplementing with this nutrient might have been insufficient. One of the possible explanations for the increase in incidence of the disease was the nutrient unbalance caused by sewage sludge applications (Tables 3 and 4). This

Table 3. Soil chemical analysis performed in samples collected in the middle of the second cultivation of corn fertilized with sewage sludge.

Treatment	OM	pH	P	K	Ca	Mg	H+Al	S.B.	CEC	V%	B	Cu	Fe	Mn	Zn
	g/dm^3		mg/dm^3	mmolc/dm^3						%	mg/dm^3				
Franca sewage sludge															
CTRL	32.33	4.5	6.67	1.33	10.67	6.33	48.67	18.33	67.23	27.33	0.13	1.07	52.67	4.2	0.9
NPK	33.67	4.6	8.33	1.4	13	7.67	47	22.01	69.23	31.67	0.14	1.23	55.67	5.2	1.4
FS1N	33.67	4.3	19.33	2.33	9.33	4.67	56	16.33	72.4	22	0.23	1.37	71.67	6.1	3.43
FS2N	38	4.3	42.33	1.73	13.67	5	61	20.4	81.4	25.33	0.28	2.13	103.67	9.5	8.43
FS4N	39.33	4.3	33	1.47	15.33	5.67	61	22.47	83.47	27.33	0.31	1.87	86	7	6.8
FS8N	43.67	4.1	78.67	1.1	18.67	5	74.67	24.77	99	25.33	0.39	3.1	127.33	8.6	17.53
Barueri sewage sludge															
CTRL	35.5	5.02	7.5	1.32	25.25	18	43.75	44.57	88.5	42.75	0.14	1.22	49	6.57	1.2
NPK	35.33	4.47	47	1.37	15	5.67	54	20.03	76.17	28	0.2	3.73	78.67	5.43	10.4
BS1N	36	4.6	54	1.9	19	8	49.33	28.9	78.57	37	0.18	4.4	70.67	5.53	11.93
BS2N	37.33	4.53	66.67	1.7	20	6.67	51	28.37	79.6	35.33	0.19	5.1	82.67	6.37	14.17
BS4N	37.67	4.5	73.33	1.43	20.33	6.33	60.67	28.1	88.7	31.33	0.23	7	96.33	6.1	20.8
BS8N	44.67	4.8	175.67	0.9	36.33	5.67	49	42.9	92	46.67	0.34	15.7	128	8.1	49.57

CTRL=control; NPK=recommended mineral fertilization for corn cropping; FS1N=Franca sewage sludge that provides the amount of nitrogen recommended for the crop; FS2N, FS4N and FS8N= two, four and eight times the concentration of FS1N, respectively; BS1N=Barueri sewage sludge that provides the amount of nitrogen recommended for the crop; BS2N, BS4N and BS8N= two, four and eight times the concentration of BS1N, respectively.

disequilibrium occurs since the sludge is not nutritionally balanced.

It can be observed from Tables 3 and 4 that the level of P increased with sludge applications. The correlation studies between levels of P and percentage of diseased plants demonstrated the existence of positive correlations between these two characteristics, with r=0.73 and r=0.92 for Franca sludge; and r=0.65 and r=0.57 for Barueri sludge, in the second and third cultivations, respectively (Table 5). In a review on *Fusarium* wilt management in garden vegetables with macro and micronutrients, Jones et al. (12) discuss that high levels of phosphorus foster the incidence of the disease, while increased amounts of K and Ca reduce its severity.

Besides the N_{total} content, the form of N in the soil is important towards increasing the severity of diseases caused by *Fusarium* spp. According to Huber (10), in addition to the content, the available form of N interferes with the occurrence of diseases caused by soil pathogens. Using information about the contents of N in the soils (unpublished) where Barueri sewage sludge was applied, correlation studies were carried out showing that the amounts of N_{total} and $N_{nitrate}$ are positively correlated with the percentage of diseased plants, and that there is no correlation with $N_{ammoniacal}$. In the second cultivation the r values were 0.83*, 0.84* and 0.09, and in the third cultivation these values were r=0.53*, r=0.52* and r=0.35, for N_{total}, $N_{nitrate}$, and $N_{ammoniacal}$, respectively. These data demonstrate the importance of N availability in the soil for diseases to occur (11).

In the second cultivation, it was observed that the micronutrients contents, with the exception of Mn, was positively correlated with the percentage of diseased plants. The following r values were obtained in the correlation studies: r=0.69* and r=0.88* for B; r=0.83* and r=0.73* for Cu; r=0.74* and r=0.75* for Fe; and r=0.84* and r=0.71* for Zn, with sludges from Franca and Barueri, respectively (Table 5).

The CEC values were positively correlated with the percent of diseased plants for the two sludges and the two cultivations, with r=0.83* and r=0.85* for Franca sludge; and r=0.52* and r=0.56* for Barueri sludge, in the second and third cultivations, respectively (Table 5). These data demonstrate the importance of nutrients in the occurrence of diseases caused by soil-borne pathogens.

These results clearly show the need for interdisciplinary

Table 4. Soil chemical analysis performed in samples collected at the end of the third cultivation of corn fertilized with sewage sludge.

Treatment	OMg/dm³	pH	P	K	Ca	Mg	H+Al	S.B.	CEC	V%
			mg/dm³	mmolc/dm³						
					Franca sewage sludge					
CTRL	23.67	5.37	4.33	0.53	19.33	9.33	30	29.2	59.17	49.33
NPK	25	5.27	12.67	1.23	23.67	9.33	34	34.23	38.53	50
FS1N	26.33	5.03	10.33	0.77	19.33	8	39.33	28.1	37.73	41.33
FS2N	29.67	5.3	21.67	0.73	30.33	10	35	41.07	76.2	52.33
FS4N	31	4.7	27.67	0.53	20	6.67	47	27.2	74.37	36.33
FS8N	34.33	4.43	62	0.47	19	5.33	60	24.8	84.93	29
					Barueri sewage sludge					
CTRL	28	5.17	4.67	0.6	18.33	10.67	35.67	29.6	65.27	45.33
NPK	25.33	5.1	8.33	1	19.33	7.67	36.67	28	64.97	43
BS1N	25.67	5.33	27.67	0.6	26	10.33	31.33	36.93	68.17	53.67
BS2N	29.33	5.03	44.33	0.63	25	8	40.67	33.63	74.53	44.67
BS4N	29.67	5.1	82	0.6	30.33	6.67	40.67	37.6	78.5	47.67
BS8N	34	4.97	178	0.53	40	6.67	45.33	47.2	92.8	51

CTRL=control; NPK=recommended mineral fertilization for corn cropping; FS1N=Franca sewage sludge that provides the amount of nitrogen recommended for the crop; FS2N, FS4N and FS8N= two, four and eight times the concentration of FS1N, respectively; BS1N=Barueri sewage sludge that provides the amount of nitrogen recommended for the crop; BS2N, BS4N and BS8N= two, four and eight times the concentration of BS1N, respectively.

Table 5. Correlation between chemical attributes of soil fertilized with sewage sludge from Sewage Treatment Stations in Franca (FS) and Barueri (BS) and percentage of corn plants with stalk rot, in the second and third corn cultivations.

	OM	pH	P	K	Ca	Mg	H+Al	S.B.	CEC	V%	B	Cu	Fe	Mn	Zn
							Franca sewage sludge – Second cultivation								
% of diseased plants	0,86*	0,54*	0,73*	-0,51	0,71*	-0,03	0,70*	0,55*	0,83*	0,08	0,69*	0,83*	0,74*	0,44	0,84*
							Barueri sewage sludge – Second cultivation								
	0,62*	0,25	0,65*	0,56*	0,61*	0,42	0,05	0,49	0,52*	0,34	0,88*	0,73*	0,75*	0,32	0,71*
							Franca sewage sludge – Third cultivation								
	0,86*	0,59*	0,92*	-0,44	-0,16	-0,41	0,72*	0,03	0,85*	-0,37	-	-	-	-	-
							Barueri sewage sludge – Third cultivation								
	0,22	0,44	0,57*	-0,41	-0,62*	0,50	0,50	0,35	0,56*	-0,03	-	-	-	-	-

research studies involving the utilization of urban-industrial residues in agriculture to be carried out. Considering that sewage sludge amendments cary in their composition differents forms of polutants such as: heavy metals, organic chemical compounds and pathogens that may represent threat to human life, it is recommended rigorous control in their agricultural use.

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