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USE OF SEWAGE SLUDGE AS A FERTILIZER FOR INCREASING SOIL FERTILITY AND CROP PRODUCTION

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Abstract

The high nutrient and organic-matter contents of sewage sludge make it a useful soil amendment for farmers. In this study at four locations in Bavaria, the application of sewage sludge produced corn yields that were similar to or better than those produced by an equal application (in terms of N) of chemical fertilizer. High rates of sludge (800 m^3/ha) further improved crop yields, although such are impractical for farmers' fields. Residual beneficial effects of sewage-sludge application were seen also in terms of subsequent yields of barley. Application of sludge also improved biological and physical properties of the soils. More long-term studies are needed to better understand how sewage sludge contributes to the improvement of soil fertility and crop yields.

1. INTRODUCTION

The treatment of domestic and industrial wastes in sewage plants produces large amounts of sludge. Containing organic matter, and macro- and micro-nutrients, this product has been long used in agriculture and horticulture to improve soil fertility. Sewage sludges of disparate origins, e.g. household and industrial, may differ greatly in composition, making it necessary to check for harmful substances. In Germany, a 1992 ordinance dictates acceptable levels of heavy metals and organic chemicals in sewage sludge as well as in soil to which it is applied [1]. About 40% of sewage sludge is applied to agricultural land, and there are limitations to the amounts that can be used; for example, it can no longer be applied in water-shed areas, public land or parks [2].

2. FIELD-TRIAL METHODS AND SEWAGE-SLUDGE APPLICATION

The fertility of a soil depends on several factors, of which biological, chemical and physical influences interact. Therefore the effects of sewage sludge on plant growth must be studied under diverse climatic and soil conditions.

Plant yields in sludge-treated plots were compared against chemical-fertilizer controls, on four soil types in Bavaria. The amounts of sewage sludge applied varied during a 3-year rotation period, from 130 m^3/ha every year, 400 m^3/ha once in the rotation, to 800 m^3/ha once as an overdose. This high rate was for experimental purposes only to provide sludge in excess, and would not be practical for farmers' fields. All applications were made in the autumn.

To determine if γ-radiation changes the properties of sewage sludge, and influences the availability of nutrients to plants it was radiated with a dosage of 3 kGy. Because the sludge K-content was low, K fertilizer was applied at the recommended rate. The crop rotation consisted of corn, wheat and spring barley. The characteristics of the soils and the sewage sludge are shown in Tables I and II.

The activities of soil enzymes, dehydrogenase, alkaline phosphatase, protease, and catalase, were determine using standard techniques [5, 6].

3. RESULTS OF THE SEWAGE-SLUDGE FIELD TRIALS

The yields of corn differed with soil type and location (Table III). At Strassfeld, Neuriss and Baumannshof, the 130 m^3/ha treatment produced grain yields similar or superior[1] to those obtained with NPK fertilizer. The 400 m^3/ha treatment produced grain yields higher than with chemical fertilizer at Strassfeld, Neuriss and Neuhof. The trends in straw yields were similar to those of the grain, although the yield differences among the treatments were higher for straw than for grain. Radiation of the sludge resulted in slight reductions in grain yields at Strassfeld, Neuriss, and Neuhof. The 800 m^3/ha rate increased total yields at Strassfeld, Neuriss, and Baumannshof (Table III, Fig. 1).

In the second year of the crop rotation, grain yields of wheat with 130 m^3/ha did not reach those with the chemical-fertilizer treatment (Table IV). Also, the residual effects of 400 m^3/ha produced inferior yields, as did 800 m^3/ha with the exception of Strassfeld. The trends in wheat straw yield were different from those in grain yield [3].

Spring barley was planted in the third year of the rotation. Higher grain yields were observed with the sewage-sludge application rate of 130 m^3/ha at all four locations compared to the fertilizer treatment (Table V). In contrast, the 400 m^3/ha treatment failed to equal the fertilizer-control yield at any location; this applied also with 800 m^3/ha at Neuriss and Baumannshof. The effects of sludge on the barley straw were similar to those on the grain, and yields of grain and straw were generally comparable [4].

4. EFFECT OF SEWAGE SLUDGE ON SOIL FERTILITY

Sewage-sludge application increased the activity of soil microorganisms, as measured by enzyme assay (Table VI; the Baumannshof data showed inconsistensies, and are not included for comparison). Phosphatase, protease and catalase activities increased with sewage-sludge rate, whereas there was no trend in dehydrogenase activity. Differences in the enzyme activities occurred among the soil types. Tests at the end of the 3-year rotation showed microbial activity still increasing. The 800 m^3/ha treatment produced the highest activities, except for dehydrogenase. Irradiaton of the sewage sludge had no effect on the enzyme activites (data not shown) [5].

Changes in physical properties resulted from sewage-sludge application, but in several cases the trends were not consistent from soil to soil (Table VII); for example, field capacity was increased by 41% at Neuriss but decreased by 9% at Strassfeld. Clearly, soil type is important when studying the effects of sewage sludge, therefore field trials should be done across sites in order to find the most suitable rates for different soils [6].

5. CONCLUSIONS

As a source of nutrients and organic matter, sewage sludge is becoming increasingly important to farmers [2]. In this work at four locations in Bavaria, sewage sludge application gave corn yields similar to those obtained with the equivalent N-rate applied as chemical fertilizer. A rate of 130 m^3/ha was sufficient for this purpose, and 800 m^3/ha produced even higher yields [7]. Residual beneficial

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[1]Editor's note: The results are described as trends, not in terms of statistical significance.

effects of sewage-sludge were seen in the third year of the crop rotation (but not in the second year), and they varied depending on the location and the amount applied. Sludge improved biological as well as physical properties of the soil.

More long-term experiments are needed to improve our understanding of the effects of sewage sludge on soil fertility and crop yields, to contribute to the development of sustainable agricultural practices.

TABLE I. CHARACTERISTICS OF THE EXPERIMENTAL SOILS

	Strassfeld	Neuhof	Baumannshof	Neuriss
Soil type	Brown Earth	Humic Loam	Humic Sand	Sandy Loam
pH	6.4	6.7	5.1	7.1
Total N (ppm)	1,410	1,500	2,550	2,420
Cadmium	0.33	0.41	0.49	0.45
Copper	67	56	130	54
Zinc	220	27	200	350
Lead	9.9	9.6	3.6	14.2
Rainfall (mm/year)	850	764	764	905

TABLE II. CHEMICAL ANALYSIS OF SEWAGE SLUDGE FROM THE GEISELBULLACH PLANT (GERMANY)

	Geiselbullach sewage sludge		
	(%)		(mg/kg dry matter)
(pH 7.3)		Copper	382
Dry matter	3.0	Zinc	3,241
Organic matter	56.5	Manganese	228
Total nitrogen	7.7	Cobalt	5.9
NH_4 amount	4.3	Iron	7,150
Phosphorus	3.2	Lead	163
Potassium	0.48	Cadmium	12.5
Calcium	6.6	Chromium	63
Magnesium	0.94	Nickel	128

TABLE III. CORN YIELDS WITH VARIOUS APPLICATIONS OF SEWAGE SLUDGE (FIRST YEAR)

	Strassfeld	Neuriss	Neuhof	Baumannshof
	(t/ha)			
Grain				
NPK[a]	4.09	5.61	3.14	4.28
130 (m^3/ha)	4.43	4.28	2.84	4.75
400	5.29	6.45	3.95	4.26
800	5.74	6.69	3.29	5.11
Untreated sludge average	5.15	5.80	3.36	4.71
Irradiated sludge average	4.85	5.42	3.29	4.91
Straw				
NPK	6.84	5.32	6.59	4.00
130 (m^3/ha)	4.23	2.86	5.32	5.04
400	7.08	5.81	6.37	4.52
800	7.90	7.41	6.07	5.89
Untreated sludge average	6.40	5.36	5.92	5.15
Irradiated sludge average	5.48	5.18	5.61	5.13
Relative total yield	(Total yield with NPK = 100)			
130 (m^3/ha)	79.2	65.3	83.7	118
400	113	112	106	106
800	125	129	96.2	133
Untreated sludge average	116	117	95.3	119
Irradiated sludge average	103	106	91.4	121

[a]Applied as 160-160-240.

TABLE IV. WHEAT YIELDS WITH VARIOUS APPLICATIONS OF SEWAGE SLUDGE (SECOND YEAR)

	Strassfeld	Neuriss	Neuhof	Baumannshof
	(t/ha)			
Wheat grain				
NPK[a]	3.35	3.42	3.85	3.23
130 (m^3/ha)	3.19	2.40	3.05	2.96
400	2.77	2.47	2.48	2.22
800	3.56	2.84	3.47	2.79
Untreated sludge average	3.17	2.57	3.02	2.66
Irradiated sludge average	2.97	2.61	3.14	2.86
Wheat straw				
NPK	2.09	2.80	3.45	4.97
130 (m^3/ha)	2.14	2.98	2.50	5.16
400	1.74	2.04	2.30	3.57
800	2.11	2.19	3.08	4.13
Untreated sludge average	2.00	2.40	2.63	4.29
Irradiated sludge average	2.03	2.53	2.77	4.49
Relative total yield	(Total yield with NPK = 100)			
130 (m^3/ha)	97.9	86.3	96.0	98.3
400	83.0	72.4	65.4	70.0
800	104	80.7	89.6	83.8
Untreated sludge average	95.0	79.8	77.0	84.0
Irradiated sludge average	91.8	82.6	80.9	88.8

[a]Applied as 100-120-180.

TABLE V. BARLEY YIELDS WITH VARIOUS APPLICATIONS OF SEWAGE SLUDGE (THIRD YEAR)

	Strassfeld	Neuriss	Neuhof	Baumannshof
	(t/ha)			
Grain				
NPK[a]	5.50	2.43	3.80	2.40
130 (m^3/ha)	6.02	2.51	4.65	3.08
400	5.18	2.28	3.33	2.05
800	6.28	2.17	4.02	2.34
Untreated sludge average	5.83	2.32	3.40	2.49
Irradiated sludge average	5.94	2.37	3.96	2.47
Straw				
NPK	5.04	3.53	3.89	3.70
130 (m^3/ha)	5.68	3.59	4.67	4.99
400	4.61	2.89	3.40	2.44
800	5.68	2.73	4.04	3.32
Untreated sludge average	5.32	3.07	4.04	3.59
Irradiated sludge average	5.39	3.12	3.94	3.31
Relative total yield	(Total yield with NPK = 100)			
130 (m^3/ha)	117	61.0	93.1	80.8
400	97.8	51.6	67.3	44.9
800	120	49.0	80.6	56.6
Untreated sludge average	106	90.4	104	99.6
Irradiated sludge average	108	92.1	103	94.8

[a]Applied as 40-100-150

TABLE VI. RELATIVE EFFECTS OF SEWAGE-SLUDGE APPLICATION ON SOIL-ENZYME ACTIVITIES

Enzyme and sludge rate	Strassfeld	Neuriss	Neuhof	Average irradiated
	(Relative activity with NPK = 100)			
Dehydrogenase				
130 (m^3/ha)	123[a]	106	117	110
400	115	115	116	115
800	112	104	105	113
Alkaline phosphatase				
130 (m^3/ha)	131	107	110	114
400	138	140	117	122
800	170	139	119	142
Protease				
130 (m^3/ha)	163	125	125	135
400	175	154	146	159
800	233	175	170	190
Catalase				
130 (m^3/ha)	99	108	115	107
400	135	148	136	144
800	237	208	201	190

[a]Average values for spring and autumn.

TABLE VII. RELATIVE EFFECTS OF 800 m^3/ha SEWAGE SLUDGE ON SOIL PHYSICAL PROPERTIES.

	Strassfeld	Neuriss	Neuhof	Baumannshof
	(Relative to NPK = 100)			
Total pore volume (%)	90.4	91.4	104	97.7
Air pores (%)	57.0	64.0	57.0	85.0
Field moisture (%)	104	102	113	111
Effective field capacity (%)	91.1	141	126	106
Aggregate stability 6-2 mm (%)	108	111	119	154
Cation exchange capacity (mequiv/100g soil)	114	110	97.0	167
Ca (mequiv/100g soil)	117	103	148	260
Mg (mequiv/100g soil)	175	125	106	408

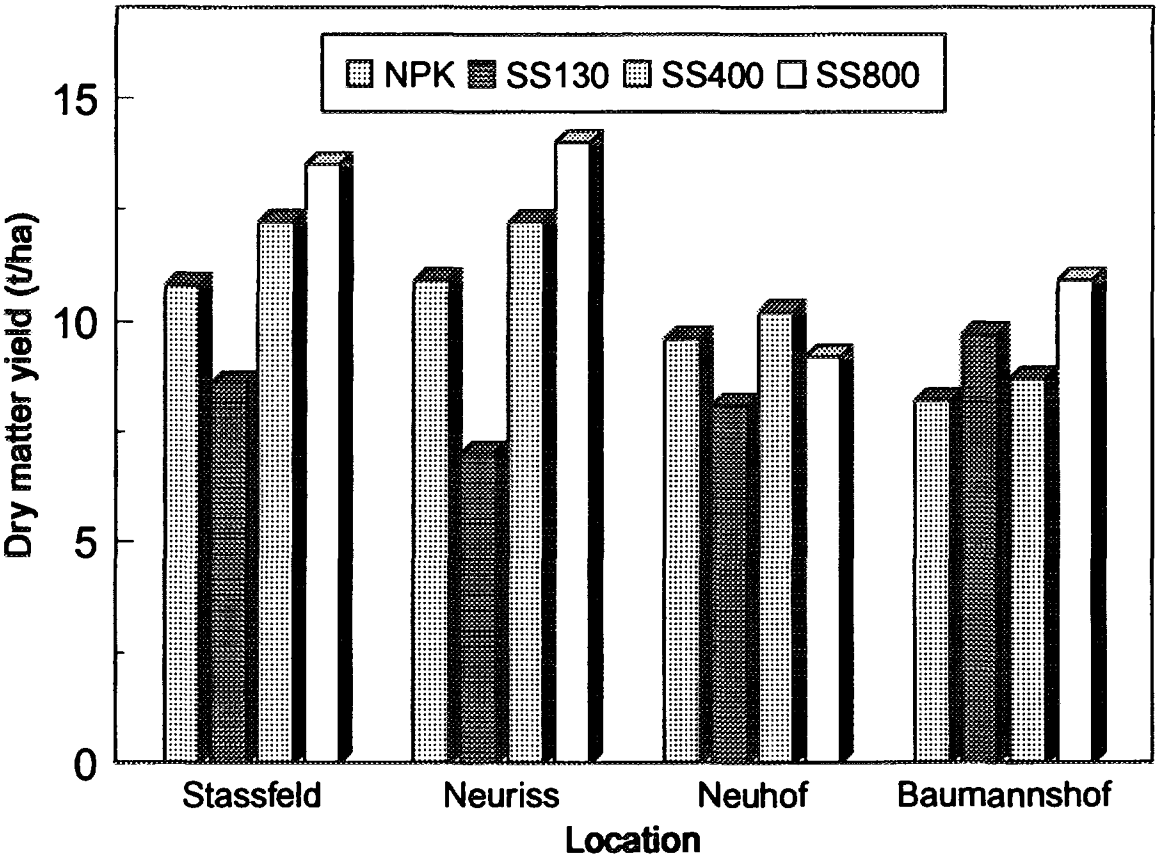

FIG. 1. Total dry matter yields of corn with various applications of sewage sludge (see Table III for details of NPK and sewage-sludge (SS) treatments).

REFERENCES

[1] BUNDESREPUBLICK DEUTSCHLAND KLÄRSCHLAMMVERORDNUNG (AbfKärV), vom 15April, Bundesgesetztblatt 1992, Teil I (1992) 912-934.

[2] BAYERISCHE LANDESANSTALT FÜRBODENKULTUR UND PFLANZENBAU, Freising Was der Landwirt bei der Ausbringung von Klärschlamm beachten mußl. Auflage Januar (1993).

[3] SÜSS, A., BECK, T., BORCHART, H., ROSOPULO, A., SCHURMANN, G., SOMMER, G., Ergebnisse 3jähriger Feldversuche mit bestrahltem, pasteurisiertem und Gamma-bestrahltem Klärschlamm Bayerisches Landwirtschaftliches Jahrbuch **55** (1978) 481-505.

[4] SÜSS, A., SCHURMANN, G., BECK, T., ROSOPULO, A., HAISCH, H., Hygienisierung von Klärschlamm durch Gammabestrahlung und Pasteurisierung:Wirkung von hygienisiertem Klärschlamm auf Boden und Pflanze Forschungsbericht T 81-218 Bundesministerium für Forschung und Technologie (BMFT-FB 81-218) (1981).

[5] BECK, T., SÜSS, A., Auswirkungen der Gamma-Bestrahlung und Pasteurisierung von Klärschlamm auf seine mikrobiellen Eigenschaften und die Mineralisierung im Boden, Z. Pflanzenernährung und Bodenkunde **140** (1977) 657-668.

[6] BECK, T., SÜSS, A., Der EInfluß von Klärschlamm auf die mikriobielle Tätigkeit im Boden, Z. Pflanzenernährung und Bodenkunde **142** (1979) 299-309.

[7] DIETZ, T., KRAUSS, M., Schwermetallaufnahme durch Gemüsepflanzen bei extremer Bodenbelastung, Bayerisches Landwirtschaftliches Jahrbuch **67** (1990) 549-559.