LONG-TERM EXCESSIVE ORGANIC WASTE USE ON ENVIRONMENTAL IMPACT AND SUSTAINABILITY

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ABSTRACT

The effect of high amounts of sewage sludge and pig slurry (2 and 5 tons of organic matter respectively) applied in a 25 year field experiment were investigated. The change of selected soil properties, in crop yields and contents during the last five years were measured and discussed. The pH-value of the soil decreased in unfertilised plots or when high quantities of pig slurry was applied. Phosphate content increased considerably with high application of organic fertilisers.

Large amounts of nitrogen in pig slurry together with a decrease of pH-value decreased the yield of the several crops, especially red roots and celery considerably. Both, sewage sludge and pig slurry, in general are very valuable organic fertilisers. Nevertheless in consequences of hygienic reasons and risks of organic pollutants and heavy metals the agricultural use of sewage sludge will be forbidden from 2006 in Switzerland. On unfertilised acid soils the yield of various crops was very low and some crops were in addition enriched with heavy metals. Best guarantee for an equable crop contents in ecologically friendly and sustainable plant production is a well-balanced fertilisation adjusted to the plants nutrient uptake.
Keywords: *long term field experiment, fertilisation, pig slurry, sewage sludge, crop yields, heavy metals.*

INTRODUCTION

In a long term field experiment applying large amounts of treated sewage sludge and pig slurry the trial aimed to clarify the middle and long term effects with reference to the physical, chemical and biological properties the soil as to determine the plant yield in crop rotation.

The quantitative limit f liquid organic fertiliser like as pig slurry and sewage sludge per unit area as well as the consequences of an over fertilisation where estimated (Siegenthaler et al., 2000).

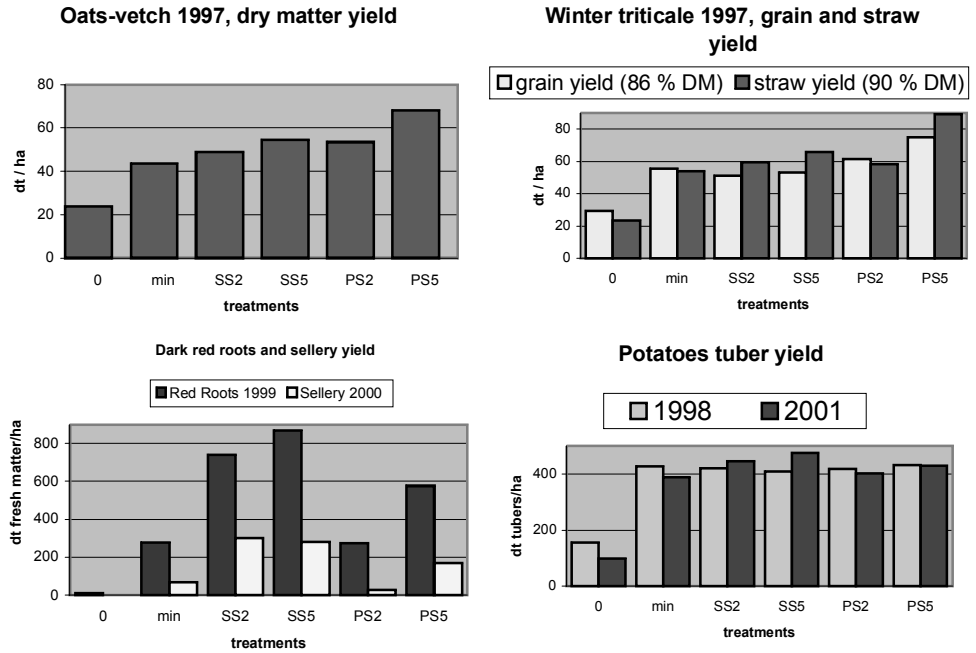
MATERIAL AND METHODS

The experimental field at Liebefeld's Research Station near Berne (565 m above sea level, 1100 mm average precipitation, 9.7 ^{0}C average temperature) where 104m long and 12 m large, divided into 6 parts, 4 repetitions and six treatments with zero, 2 and 5 tons of organic matter per hectare and year of sewage sludge and pig slurry respectively. As a control a standard mineral fertilisation (N, P, K, Mg) were applied. The applied quantities of organic fertilisers correspond approximately ~ 2 to 3 livestock unit (LU) and 4 to 6 LU for the high doses of sewage sludge and pig slurry respectively (Walther et al., 1994).

5	1	3
6	4	2
3	5	6
2	1	4
6	4	2
5	3	1
4	6	5
1	2	3

- 1 0 = no fertiliser, control
- 2 min = mineral standard fertilising (N,P,K,Mg)
- 3 SS2 = sewage sludge 2 tons OM ha^{-1}, y^{-1}
- 4 SS5 = sewage sludge 5 tons OM ha^{-1}, y^{-1}
- 5 PS2 = pig slurry 2 tons OM ha^{-1}, y^{-1}
- 6 PS5 = pig slurry 5 tons OM ha^{-1}, y^{-1}

RESULTS AND DISCUSSION



At the beginning of the trial in 1976 the pH-values in the top soil were between 6.0 and 6.4. Not surprisingly, the soil pH-value changed considerably during the trial time. The pH-values of the soil reduced in the treatments where no fertiliser or high quantities of pig slurry were applied. In some cases (e.g. red roots and celery) too large amounts of nitrogen in pig slurry significantly decreased the yield. In case of high doses of sewage sludge and pig slurry, the levels of copper, zinc and cadmium in the soil increased remarkably in soil and plants during the trial period of more than twenty years.

Levels of zinc and cadmium reached or even exceeded actual limits of Swiss legislation. We observed that the essential elements for plants (copper and zinc) are mainly concentrated in the generative parts (grain), whereas cadmium is mainly found in the vegetative parts (straw, leaves) of the plant. The cadmium content in red roots where ten time higher in comparison to triticale and fodder crops. Like Unwin (1996) we found on the other hand no strict correlation bet-

ween the applied quantity of heavy metals by organic fertiliser and the crop metal content could be observed.

Table 1. *Amounts of nutrients as well as total heavy metals applied by fertilisers during the 20 first years experimental period, (kg/ha; fallout unconsidered)*

Treatment	OM	P	K	Cu	Zn	Cd
	kg ha^{-1} y^{-1}			kg ha^{-1} /20y^{-1}		
0	0	0	0	-	-	-
Min.	0	45	220	[1]	[1]	-
SS2	2000[2]	130	125	32.3	131.1	0.26
SS5	5000[2]	350	250	79.8	353.4	0.74
PS2	2000[2]	95	240	11.4	52.3	0.09
PS5	5000[2]	260	430	34.2	150.11	0.11

Table 2. *Resulting average values for each treatment in the soil (0-20cm)*

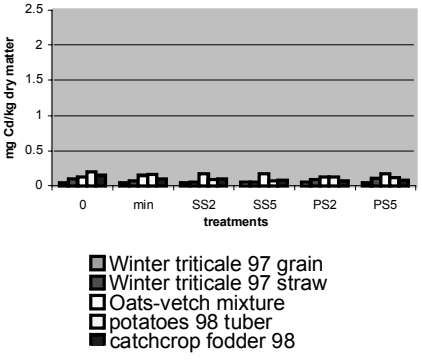
	pH	C org	P-Test [3]	K-Test [4]	Cu		Zn		Cd	
	(H_2O)	%			ppm	ppb	ppm	ppb	ppm	ppb
1994 Treatment					Total[5]	Soluble[6]	Total[5]	Solubl[6]	Total[4]	Soluble[6]
0	5.3	1.31	6.2	0.7	24.2	76	51.0	928	0.258	11.6
Min.	5.6	1.43	19.9	3.7	23.5	85	53.0	505	0.220	5.3
SS2	6.1	1.71	11.7	5.2	35.1	100	91.9	200	0.476	<2.6
SS5	6.8	2.10	12.8	2.7	54.1	109	152.4	88	0.841	<2.6
PS2	5.1	1.48	30.7	2.8	27.0	121	57.0	1715	0.234	10.6
PS5	4.9	1.56	64.4	3.5	30.4	181	66.8	2268	0.216	9.2

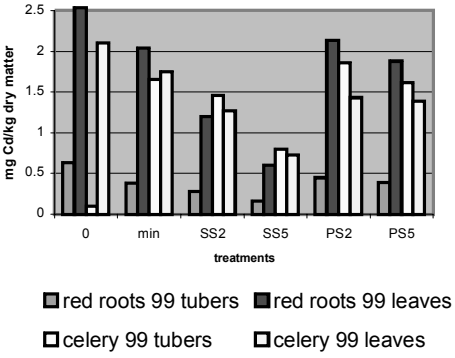
0 = without fertilising; min = mineral standard fertilisation, SS = sewage sludge; PS = pig slurry
1) not determined; 2) estimated value; 3) P-Test value (Method: CO_2-saturated water, 1:2.5): 8 - 16 sufficient, 16.1 - 32 storage, >32 enriched; 4) K-Test value (Method: CO_2-saturated water, 1:2.5): 2 - 4 sufficient, 4.1-8 storage, >8 enriched ; 5) Total content: Extracted by nitric acid (2 M HNO_3), 1 : 10; 6) Soluble content Extracted by sodium nitrate (0.1 M $NaNO_3$), 1:2.5; underlined values exceed Swiss guidelines values.

Table 3. *Guide values Swiss Federal Ordinance Relating to Soil Contaminations 1998. (Swiss Federal Council, 1998)*

Cu		Zn		Cd	
ppm[5] total	ppb[6] soluble	ppm[5] total	ppb[6] soluble	ppm[6] total	ppb[6] soluble
40	700	150	500	0.8	20

A lowering of the soil pH-value increased the solubility of the heavy metals in the soil so that in some cases plant uptake increased. The heavy metal of crops grown on unfertilised soils were increased because of increased soil pH values. In the view of the nutrient demand of plants and of the





heavy metal accumulation in crops and soil an upper limit of three livestock units (LU = one 600 kg dairy cow producing 6000 kg of milk per year or ~ 2.3 pig-places, eq. 315 kg Total-N and 45 Total-P per hectare) per hectare.

CONCLUSIONS

In case of high doses of pig slurry and sewage sludge the yields of some cultures decreased significantly and the heavy metal contents in soil and plants increased. Therefore the livestock unit (LU) per hectare (cattle, pig as well as poultry) have to be strongly limited. The LU should be restricted to a maximum of tree per hectare. For mountain area the corresponding values in Swiss legislation are regressively gradated to 1.1 LU/ha depending on the altitude.

In particular cadmium - a not essential element for plants – toxic for animals and humans – which is mainly found in vegetative parts of plants, without damaging these considerably it applies to consider for a sustainable agriculture. In condition that further generations can count on proper soil, it is absolutely necessary to limit and to decrease heavy metals in soil and in concerned fertilisers. Special attention should be given to the pH-values of soil (to correct by lime fertiliser where necessary) because crops grown on acid soil, also unfertilised ones, generally are enriched with heavy metals.

The challenges for a sustainable and environmental plant production are a well balanced fertilisation adjusted to the plant uptake, adaptation of the livestock units to available agricultural surface and an appropriate adaption of heavy metal limits in soil and in wastes within the corresponding legislation.

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